Scira Menoni
Claudio Margottini
Editors

Inside risk: A Strategy for Sustainable Risk Mitigation

Springer

Inside Risk: A Strategy for Sustainable Risk Mitigation

Scira Menoni, Claudio Margottini (Eds.)

Inside Risk: A Strategy for Sustainable Risk Mitigation

Springer

Scira Menoni
Dept. of Architecture and Planning
Politecnico di Milano

Claudio Margottini
Dept. Geological Survey of Italy
ISPRA, Rome

Editorial Assistant: Funda Atun

This publication was entirely funded under FPVI (VI Framework Programme) of the EU Commission and developed within the Scenario project (Support on Common European Strategy for sustainable natural and induced technological hazards mitigation, CN 036979).

ISBN 978-88-470-1841-9 ISBN 978-88-470-1842-6 (eBook)
DOI 10.1007/978-88-470-1842-6

Springer Milan Dordrecht Heidelberg London New York

Library of Congress Control Number: 2010937689

9 8 7 6 5 4 3 2 1

Cover-Design: Beatrice ᗺ., Milan
Typesetting with LaTeX: PTP-Berlin, Protago-TeX-Production GmbH, Germany
(www.ptp-berlin.eu)
Printing and Binding: Grafiche Porpora, Segrate (Mi)

Springer-Verlag Italia srl – Via Decembrio 28 – 20137 Milano-I
Springer-Verlag is a part of Springer Science+Business Media (www.springer.com)

Contents

Foreword

Fatalities and economic losses due to natural catastrophic events have increased in recent decades and some communities around the world face natural hazards almost daily.

This is why disaster risk reduction is a world challenge. The UN International Decade for Natural Disaster Reduction (1990–2000) and the current Hyogo Framework for Action (2005–2015) are contributing to this consciousness raising and stimulation of action at various levels.

In Europe the 2009 communications, "A community approach on the prevention of natural and man-made disasters" and "EU strategy for supporting disaster risk reduction in developing countries" are strong contributions to this global effort.

Knowledge is a key partner for addressing risks and an integrated approach towards the disaster issue is a prerequisite.

In this context European research policy aims to strengthen the European research community to promote scientific excellence and innovation and advance knowledge and understanding, and to support the implementation of related European policies. The European Commission has been encouraging research on natural disasters since the early 1980s through successive Framework Programmes for Research and Technological Development. Research under the current Seventh Framework Programme aims to reduce and mitigate the environmental, social and economic effects of natural disasters through a holistic multidisciplinary approach in which aspects of hazard or multi-hazards, vulnerability and risk assessment are addressed in an integrated manner.

This book is timely. It contains results from the reflections, analyses and debates of many European scientists collaborating in the EC project "SCENARIO" and in several others in the field of natural hazards.

It presents an interesting perspective on sustainable ways to address and mitigate natural and technological hazards and risks.

It will certainly contribute to the strategic effort that is needed in the field of disaster reduction in introducing new research ideas, concepts and challenges.

By building bridges between science and policy, it reinforces resilience capacity, improves public awareness and contributes to education in the field of disaster reduction.

Bruxelles, January 2011

Denis Peter
Climate Change and
Natural Hazards – I.4
European Commission
Directorate-General
for Research & Innovation

Acknowledgements

The Editors would like to thank the following people for their valuable contributions:

- Denis Peter, Scientific Officer of the EU Commission, who supported our work in all its stages;
- Bjorn Vidar Vangelsten from the unit 'Climate change and environmental risks', who followed the entire development of the Scenario project;
- Miranda Dandoulaki, Bruna de Marchi, Paolo Gasparini, Patrick Pigeon and Fiona Tweed, who were members of the so-called Governance Body of the Scenario project and were the peer reviewers of the different chapters of the book. Their insight, suggestions and corrections were essential to the working group to improve and enrich the content of the book. We also would like to thank José Barredo and Andrea Camia for their help, and Katja Firus for the excellent organisation of our project work.

Milan, Rome, April 2011 *The Editors*

List of Contributors*

Scira Menoni
Politecnico di Milano

Claudio Margottini
Instituto Superiore per la Protezione e la Ricerca Ambientale
Roma

Funda Atun
Politecnico di Milano

José Barredo
Commission of the European Communities
Directorate-General
Joint Research Centre
Bruxelles

Andrea Ceudech
Università di Napoli, Federico II

Miranda Dandoulaki
Commission of the European Communities
Direcorate-General
Joint Research Centre
Ispra (Varese)

Ad De Roo
Commission of the European Communities
Direcorate-General
Joint Research Centre
Bruxelles

Hugh Deeming
Lancaster University

Giuseppe Delmonaco
Istituto Superiore per la Protezione e la Ricerca Ambientale
Roma

George Eftichidis
Algosystems
Athens

José Fernando Esteban
Atos Origin Sociedad
Anonima Española
Madrid

Floriana Ferrara
T6 Ecosystems srl
Roma

* The institutions named were the affiliations at the time of the SCENARIO project (2006–2008)

Adriana Galderisi
Università di Napoli, Federico II

Borya Izquierdo
Atos Origin Sociedad
Anonima Española
Madrid

Malaak Kallache
Potsdam Institute for Climate
Impact Research

Jürgen Kropp
Potsdam Institute for Climate
Impact Research

Seda Kundak
Istanbul Technical University

Jorge Lopez
Atos Origin Sociedad
Anonima Española
Madrid

Darren Lumbroso
HR Wallingford Ltd
Wallingford

Quejdane Mejri
Politecnico di Milano

Daniela Molinari
Politecnico di Milano

Pierluigi Plebani
Politecnico di Milano

Antonio Pugliano
Vigili del Fuoco Lombardia
Milano

Fiona Tweed
Staffordshire University

Steven Wade
HR Wallingford Ltd
Wallingford

Gordon Walker
University of Lancaster

1

Introduction to Sustainable Risk Mitigation for a More Resilient Europe

G. Walker, H. Deeming, C. Margottini, S. Menoni

1.1 Introduction

Over the past 15 years it has become increasingly accepted that there is a need to integrate the principles and practices of sustainability with the principles and practices of risk mitigation. Only by adopting a sustainable approach to risk mitigation, it is argued, can effective, equitable and long term approaches to mitigating risks and building resilience be developed. In this book we consider what the integration of sustainability and risk mitigation might mean, why it is needed to manage the likely future profiles of hazard, exposure, vulnerability and risk in Europe, and how it might be pursued specifically in a European context.

To-date there has been no comprehensive attempt to approach the topic of sustainable risk mitigation from a European perspective, considering the threats, opportunities and challenges involved and how the physical, social, political and cultural context of Europe is likely to evolve over coming decades. Thinking ahead is crucial as the future is one in which patterns of hazard, vulnerability and risk will change from what currently exists and what is currently planned for. Under climate change scenarios the distribution and severity of extreme events is expected to become increasingly uncertain and unpredictable. With political enlargement of the EU, greater population mobility, changing patterns of economic activity and eventually prosperity and increasing technological and social complexity, the systemic nature of the risks faced and the multiple forms of vulnerability involved are becoming ever more apparent. In this book we attempt to capture both the dynamics and the complexities involved and to chart out a "road map" towards a more sustainable and resilient Europe. In this respect we are particularly concerned with what future research priorities need to be to improve our understanding of both the challenges and possibilities of sustainable hazard and risk mitigation.

In this opening chapter we consider what the drivers towards the integration of sustainability and risk mitigation have been, what concepts have been

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

developed and applied, and outline what the key elements of a sustainable approach might consist of, both in the long and short term. Whilst discussing each of these in general terms, we also begin to highlight some of the specific European perspectives and contexts that are considered in subsequent chapters.

1.2 The Drivers for Integration

The literature on sustainability and hazard or risk mitigation is now extensive and includes academic, practitioner and governmental consideration of the need to adopt sustainable approaches to hazard and risk management. Across these documents a number of key drivers can be identified that have pushed towards the integration of ideas and principles between previously separate domains of policy (see Fig. 1.1).

1.2.1 The Inadequacies of Existing Approaches

Across much recent discussion of hazard and risk management a sense of the need to move beyond established approaches and practices emerges. Faced with rising trends of damage, loss and disaster in different parts of the world

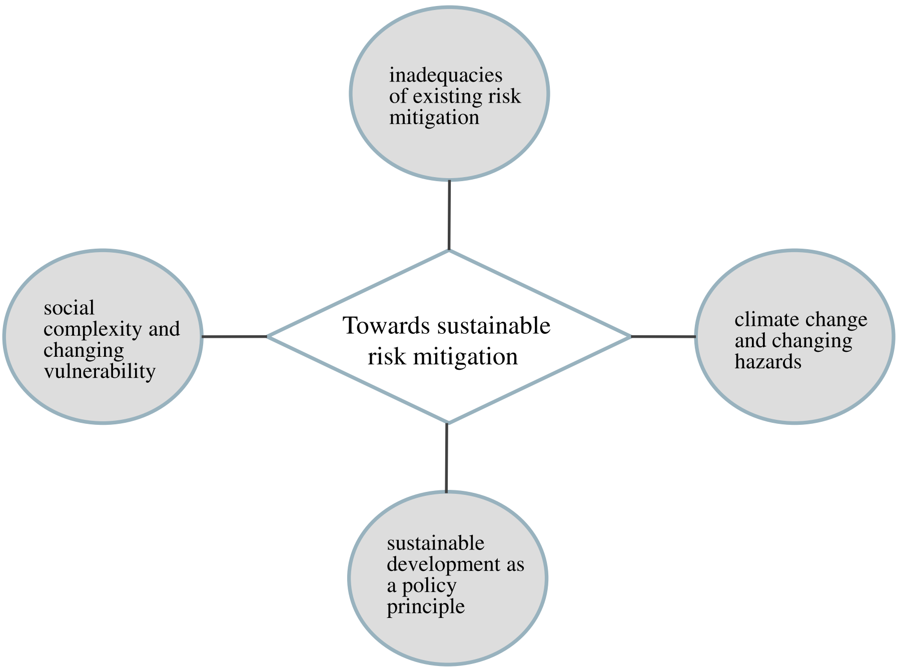


Fig. 1.1. Drivers for the integration of sustainability and risk mitigation

and continued difficulties in coping with both known and unknown patterns of hazard and risk, there has been a clear search for better ways of "living with risk". For example:

1. In the UN/ISDR strategy for disaster reduction (2005) the need for integration with sustainable development objectives is set in the context of "increasing losses and steep costs associated with reconstruction" and the inadequacy of haphazard "quick fix" solutions that pay insufficient attention to the many factors that contribute to vulnerability.
2. In an authoritative account arising from the reassessment of natural hazards in the US (Mileti, 1999) the rising losses associated with most forms of disaster over the previous 30 years in the US are traced, a rising trend which has been maintained despite the emergence of a multidisciplinary hazards community, the introduction of a wide range of hazard management measures and massive expenditures on technical and structural measures. The conclusion is reached that many mitigation measures are simply *postponing losses* that will inevitably be more catastrophic when they do occur and that many efforts at disaster mitigation are resulting in short term or cumulative environmental degradation and ecological imbalance.
3. In a comparative analysis of the management of hazards and risks in Australia, New Zealand and the US, May et al. (1996) identify many problems with reliance only on structural "hazard prevention" measures and with top-down approaches to managing land uses to mitigate hazards, associating these with inflexibility, continued loss, environmental harm and the undermining of local sustainability.

Each of these accounts, as many others, portray a past in which established approaches to hazard mitigation have proved inadequate and a future in which losses will only continue to rise unless more sustainable approaches are adopted. There are many parallels with the European experience here, which has similarly involved rising trends of damage and loss over past decades and clear deficiencies in current hazard, risk and disaster management practice.

1.2.2 The Importance of Sustainable Development

Since its formulation in the Brundtland report (1987) there has been widespread acceptance of the importance and purpose of pursuing sustainability as an objective of societal change across public, private and non-governmental bodies of many different forms. Whilst there are multiple interpretations and definitions of what sustainable development means and should constitute (Lele, 1991; Dobson, 1998; McNeill, 2000) and sometimes intense disagreements over the attachment of the term 'sustainable' to particular activities and practices (Porritt, 1993; Mitcham, 1995; Redclift, 1996; Holland, 2000) there is at least some consensus around the key dimensions of:

- *integration* of economic, social and environmental objectives
- *futurity* in thinking ahead to the long term interests of future as well as current generations
- *equity* in pursuing approaches that are fair and inclusive and promote social and environmental justice.

In being conceived as an overarching global objective it follows that the pursuit of sustainability should be integrated into all areas of society and across all areas of government – including those concerned with hazard and risk management. Hazards leading to disasters are from this perspective seen as a threat to sustainability, eroding the basis for a good quality of life and damaging both human and ecological value. Accordingly questions of hazard, risk and disaster were featured in both the Rio Declaration and Agenda 21, which emerged from the 1992 UN Rio Conference on Environment and Development, and in the plan of implementation agreed at the World Summit on Sustainable Development in 2002. Paragraph 37 of the Plan of Implementation states that "*an integrated, multi-hazard, inclusive approach to vulnerability, risk assessment and disaster management including prevention, mitigation, preparedness, response and recovery is an essential element of a safer world in the 21st Century*". In the book we consider the extent to which such statements have been translated into sustainable risk mitigation strategies.

1.2.3 Climate Change and Changing Patterns of Hazard

A third driver has been the acceptance of the realities of climate change as a growing influence on patterns of current and future natural hazards. The Fourth Assessment Report (AR4) published by the Intergovernmental Panel on Climate Change (IPCC, 2007b) has added empirical evidence of the observed impacts on the environment already caused by anthropogenic changes to the atmosphere, to the more theoretical projections in their three earlier reports. The warming trend of the climate system is now unequivocal and it is *very likely* ($>$ 90% confidence) that most of the *observed* increase in temperature is due to the *observed* increase in anthropogenic greenhouse gas emissions (GHG). Even if anthropogenic GHG emissions were to cease tomorrow, due to lags in the ocean / atmospheric system the effects of the GHGs already emitted would continue to increase through the next century. This short to medium term inevitability of impacts makes explicit that there is a requirement for adaptation measures to be undertaken as part of any development strategy. However, it also reinforces the need for significant action to be taken to reduce emissions substantially if large *additional* positive feedbacks to the warming are to be avoided. According to some, these significant reductions need to be underway within the next ten years (Hansen et al. 2007).

Predicted climate change related hazards include more frequent and severe droughts, floods and storms in addition to a large array of human health hazards and complex biological impacts on the productivity and stability of livelihoods that depend on natural resources (IPCC, 2007a). Aside from the atmospheric effects of rising temperatures the increasing heat is also projected to contribute to a rise in global sea-level of between 0.18m and 0.59m this century (IPCC, 2007b); however, extrapolation forward from the trend in rising global sea-level of the last decade has suggested that a rise of 1.4m could be possible (Rahmstorf et al., 2007).

In the light of this understanding of the likely and yet uncertain impacts of climate change, the need for sustainable approaches that look through the short and medium terms to the long term has become increasingly evident. That these approaches need to be flexible and adaptive to changing circumstances, in order that they can enable communities to be more resilient in the face of shifting threats, is also more apparent.

1.2.4 Complexity and Vulnerability

A fourth driver is the growing complexity of society and recognition of the systemic nature of the vulnerabilities and risks that are being faced. It has long been argued that disasters are not natural in origin, they are rather created by human actions and the way that society is structured and organised (White, 1945; Hewitt and Burton, 1971; Wisner et al. 2004). Losses are caused by the interaction between physical and socio-economic systems. As more property, infrastructure and people are exposed to potential hazards, and as physical, social, cultural and systemic forms of vulnerability are produced, hazardous events become more likely to turn into disasters that will inevitably harm those that are more rather than less vulnerable. It therefore becomes necessary to think about hazard mitigation in terms of the way in which economic, social and technological development takes place and how this can be shaped in ways which mitigate rather than exacerbate vulnerability and the potential for loss.

1.3 Sustainability and Risks in International and European Strategies and Policy

In Fig. 1.1, four drivers for an integrated approach to risk mitigation were identified. These four drivers have in various ways contributed to the development of strategies and policies at international levels which seek to bring together sustainability and risk management objectives. Key examples concerned with disaster risk are:

1. The 1994 Yokohama Strategy and Plan of Action for a Safer World which asserted that "*Disaster prevention, mitigation, preparedness and relief are four elements which contribute to and gain from the implementation of sustainable development policies. These elements, along with environmental protection and sustainable development, are closely interrelated*" (paragraph 2).

2. The 2005 Hyogo Framework for Action on Building the Resilience of Nations and Communities to Disasters, which calls for "*the more effective integration of disaster risk reduction considerations into sustainable development policies, planning and programming at all levels, with a special emphasis on disaster prevention, mitigation, preparedness and vulnerability reduction*" (paragraph 12).

Whilst individual European member states are signatories for these international actions plans, at a European level there has been little explicit attention given to the need to integrate sustainability into risk mitigation.

For the EU, issues of hazard and risk are addressed most directly by Civil Protection Action Programmes for improving coordination and cooperation between member states – developed from 1987 onwards with the first in place in 1997 (see http://ec.europa.eu/environment/civil/index.htm). There is also legislation relating to the mechanisms through which the Community provides financial and other assistance during disasters and funds research and operational coordination. However, reviewing the various EU civil protection documents that have been produced recently, the language and concepts of sustainability do not feature in the framing of the issues or approaches to addressing them – even though some of the aspects of a sustainable approach to hazard and risk mitigation (see later discussion) are included in the coordinating actions that are being pursued.

Similarly the EU sustainable development strategy (EU, 2006a) makes no direct mention of hazards and risks, or of the need to integrate disaster management into sustainable development policy. In paragraph 2 of the strategy, it does state that whilst maintaining a long-term perspective, there is urgency in the need to recognise that short term action is already required to mitigate current unsustainable trends in relation to a number of interrelated factors, including; *climate change, threats to public health* and the *management of natural resources*, but no more specific references to natural hazards can be found.

Some Member States have more explicitly recognised the importance of hazard and risk mitigation within their national sustainable development strategies. For example in the UK one stated objective within the strategy document "Securing our Future" is "*to reduce the risk of flooding to a greater proportion of vulnerable properties whilst making sure flood risk management policies across Government are forward looking, and contribute to sustainable development including biodiversity, water quality, urban drainage and regeneration.*" (HMG, 2005, p. 93).

The one piece of emerging European legislation that does more directly incorporate both sustainability and hazard and risk mitigation considerations is the "Floods Directive" 2007/60/EC. In the article related to hazard and risk maps it is explicitly stated that (see article 6.3): ***"****Flood risk management plans shall take into account relevant aspects such as costs and benefits, flood extent and flood conveyance routes and areas which have the potential to retain* *flood water, such as natural floodplains, the environmental objectives of Article 4 of Directive 2000/60/EC, soil and water management, spatial planning, land use, nature conservation, navigation and port infrastructure."*

The need for a more wide-ranging and explicit European view on sustainable hazard and risk mitigation links to a number of considerations. Crucially, hazards producing potentially very high losses – some of which will be trans-boundary, having impacts on multiple EU states either physically or through indirect consequences – are better treated in an agreed upon, integrated and coordinated way.

EU enlargement now means that the land area, population, built environment and critical infrastructure potentially to be implicated in disasters has increased in scale, as has the diversity of existing practices of risk and hazard management. In the case of natural hazards, it is necessary to view disasters as regional in scope, where threats and potential losses are shared with other partners in the EU. Developing a European perspective on sustainable risk mitigation will improve the situation not only for new accession states, but also for the existing member states, as there are still large discrepancies in the way risks are treated and managed and many unsustainable practices exist.

However, it is important to recognise that the goal for Europe cannot be complete harmonisation, as there are many political, cultural and contextual factors why this would not be either feasible or appropriate. For example, one result of the ARMONIA FP6 project was that given the great diversity of land use planning systems across the EU, achieving harmonisation in how these take account of hazards and risks is almost impossible (Fleischauer et al. 2006). However achieving greater consistency of *outcomes* (such as levels of risk reduction and ability to cope and recover) from risk mitigation across Europe is important in terms of both efficiency and equity considerations. Achieving sustainable mitigation through the principles and strategies that will be described in this book is an important European objective, even though each country will have to attain this within legislative, social, and cultural constraints.

Experience outside European borders also shows that a more cohesive framework is needed for how assistance is provided by the EU during disasters elsewhere in the world. The EU "Community Mechanism" programme, aimed at creating integration among European search and rescue teams that are sent on missions around the world, is a recognition of this need. Capacity building initiatives, funded by several of the EU member states, did feature in a number of programmes sustaining Southern East Asia after the tsunami. The goal in the future may be to ground such initiatives in a more cohesive European programme, similar too and supporting those of the United Nations.

1.4 Bringing Sustainability and Risk Mitigation Together: Key Principles

Whilst policy statements are important in setting out principles for action at an international level, these need to be underpinned by a deeper understanding of what bringing sustainable development, disaster reduction and hazard reduction together might mean. There have been a number of attempts in the literature to define what sustainability means in the context of natural hazards. Four examples are shown in Box 1.1.

These definitions share some common themes.

1. they see sustainability as a condition under which hazards and risks can be better lived with, not one in which all losses are somehow prevented
2. they focus on the ability of "communities" and "localities" to cope with and recover from, in particular, more frequent and smaller natural events. Resilience is therefore a crucial part of sustainability
3. they indicate a greater degree of self-reliance, a condition under which "communities", to some degree at least, are able to look after themselves rather than needing help from elsewhere. There is therefore a strong theme of "localisation" in these definitions.

Expanding on such definitions, Mileti (1999) provides the most thoughtful and thorough discussion of the wider principles that should underpin the process of working towards the goal of sustainability – or of building sustainable hazards mitigation. Six key principles are identified (Box 1.2).

Box 1.1
The Meaning of Sustainability in the Context of Natural Hazards

"*Sustainability with respect to natural hazards consists of outcomes where the risks of catastrophic loss are reduced, while community resilience to less dramatic natural events is increased*" (May et al. 1996, p. 174)

"*Sustainability means that a locality can tolerate – and overcome – damage, diminished productivity and reduced quality of life from an extreme event without significant outside assistance*" (Mileti, 1999, p. 4)

"*Sustainable and resilient communities are defined as societies which are structurally organized to minimize the effects of disasters, and, at the same time, have the ability to recover quickly by restoring the socio-economic vitality of the community*" (Tobin, 1999, p. 13)

"*Sustainable flood management provides the maximum possible social and economic resilience against hazards by protecting and working with the environment, in a way which is fair and affordable both now and in the future*" (Scottish Executive, 2004)

Box 1.2
Key Principles of Sustainable Hazard Mitigation (Mileti, 1999)

1. *Maintain and, if possible, improve environmental quality* – hazard and mitigation efforts should not lead to environmental degradation, but rather be coupled with actions that managed environmental resources in an effective and sustainable way.
2. *Maintain and, if possible, enhance people's quality of life* – a population's quality of life has many components and processes of community planning should determine locally the quality of life they want to achieve now and for future generations. Hazard mitigation efforts should be integrated with processes for achieving quality of life, taking account of externalities that are imposed on other communities and nations.
3. *Foster local resiliency to and responsibility for disasters* – localities need to take responsibility for recognizing its environmental resources and the environmental hazards to which it is prone and then choose a level of hazard that it thinks is appropriate to its circumstances. Resilience which enables the community to better cope with this level of hazard then needs to be developed using measures that are appropriate to the particular context.
4. *Recognize that sustainable, vital local economies are essential* – a sustainable economy is one that is diversified, less easily disrupted by disasters and does not simply shift its externalities elsewhere
5. *Identify and ensure inter- and intragenerational equity* – intergenerational equity means not passing on unnecessary hazards to future generations and allowing trends to continue which will make hazards, risks or vulnerability worse in the future. Intragenerational equity focuses attention on the fact that not all people or parts of society are equally at risk, or equally vulnerable. Principles of social and environmental justice therefore need to be built into a sustainable approach.
6. *Adopt a consensus building approach starting at the local level* – many decisions need to be taken to balance between different elements of a sustainable approach, to decide on courses of action and degrees of toleration. Participatory processes which are inclusive of different parts of society are necessary to both be equitable but also to foster a sense of community, achieve a sense of ownership and generate ideas and information. As already discussed focussing action and decision processes at a local level is a key part of a sustainable approach.

These six principles are reiterated to different degrees by other authors and in various reports concerned with sustainability and hazards. Tobin (1999) particularly emphasises resilience in casting the goal as to create "sustainable and resilient communities". Mileti and Gailus (2005) stress the two way nature of the relationship – "*disasters are more likely to occur in tandem with unsus-*

tainable development" and "*disasters hinder movement towards sustainability*" (p. 497). The Hyogo framework (2005) identifies "*good governance*" and "*international and regional cooperation*" as particularly important to support actions at local levels. Schneider (2002) stresses the need to integrate emergency management into processes of community planning and development and argues for the need to see disasters as "*community-based problems requiring community based solutions*" (p. 143). Pearce (2003) similarly stresses the importance of public participation within a framework of community planning that integrates closely with disaster management.

Whilst there are differences of emphasis and interpretation there is a broad consensus as to what the goals and principles of a sustainable approach to hazard mitigation should be. However, putting these principles into practice will be far from straightforward, involving many challenges and complex and difficult decisions. Tobin (1999) argues that "*truly sustainable and resilient communities are not possible in the current socio-political-economic environment*" (p. 23) and that far reaching changes in political awareness and motivation will be required. Mileti and Gailus (2005) refer to the need for "*a significant shift in the national culture*" (p. 493) and argue that "*extraordinary actions*" (p. 501) are required. O'Brien et al. (2006) point out that the implications in relation to climate change alone are so serious that "*national decision-making will require strong, sustainable and accepted institutional structures and a population and civil society educated in the issues and alternatives*" (p. 76).

Whilst many of these challenges and complexities are generic in nature, they take a particular form in a European context in which there is a multi-level structure of governance, a diversity of political and cultural traditions and very different environmental, economic and social conditions across its many regions and localities.

For example, it has been proposed that under a sustainable approach, prevention or safety from natural and technological disasters should be considered as a public good (Reddy, 2000) – as are health, security and quality of life under the welfare systems of countries in Europe (although with some differences in implementation). Considering environmental safety a public good links this to environmental goods such as water, air, historic heritage, etc. Each of these have the same kind of difficulties in reaching an equitable situation and avoiding the "free-riding" typically associated with goods that lie outside the market. However, achieving a level of tolerable risk, in the face of natural as well as technological hazards has some specific differences compared to other societal objectives.

First, in general the threatened community cannot be regarded as the whole country but just a part of it and to some degree there is choice involved in living near to or distant from sources of potential hazard (although this does not apply equally to all social groups and the taking of *informed* choices can in no way be presumed). While water quality preservation or clean air will benefit the whole nation, it is clear that any prevention strategy will imply a redistribution of national wealth, because some people are more endangered than others. This politically can make establishing safety as a public good a difficult step to take.

Second, while water and air pollution are “creeping events”, to which each citizen is contributing in some differential way, risks that are considered in this report relate to events occurring suddenly, though the exact time of occurrence as well as their magnitude can be hard to predict. This uncertainty leads to different attitudes towards prevention: the choice to be made is between “certain costs – both public and private – to be borne today” and “potential costs for tomorrow”, which will be paid largely by governments (Mechler, 2003). If the risk is perceived as imminent, then the need for action now is likely to be accepted; if the risk is seen as unlikely then spending on other social needs may be seen as more important.

Such underlying differences of perspective emphasises the politics involved and that making progress towards agreed and common positions is often difficult to achieve. However, this is true of much European policy and should not deter the development of frameworks that can identify common principles and desirable outcomes whilst enabling these to be implemented and achieved in ways that are appropriate and acceptable to local circumstances.

1.5 Bridging between Climate Change and Natural Hazards Studies

Investigating the relationship between climate change and natural disasters is a quite challenging issue since differences derive from intrinsic elements:

- different time of occurrence; climate is an ”average weather” where disasters are strictly depending from local extreme weather conditions (depending from disaster type), occurring suddenly in a very short time window
- different spatial domain; climate is global process while disasters, very often (depending from disaster type) involve quite local/district impact.

and from external factors due to scientific gaps:

- limitation of available data for clearly understanding the relationship between natural hazard and climate variability
- limitation of climate modeling in describing future occurrence and impact of natural hazards
- different school of thought; a shared language and shared concepts are still missing, even inside a given scientific community. Osmosis thorough the disaster science and climate science is still very week.

This dichotomy is also well debated in international literature which refers to two different approaches: disaster risk reduction (ISDR, 2004) and adaptation to climate change. In practice (IPCC, 2007a) there has been a disconnect between disaster risk reduction and adaptation to climate change, reflecting different institutional structures and lack of awareness of linkages. Disaster risk reduction, for example, is often the responsibility of civil defence agencies, while climate-change adaptation is often covered by environmental or energy departments. The first tends to focus on sudden and short-lived disasters, such as floods, storms, earthquakes and volcanic eruptions, and has tended to place less emphasis on 'creeping onset' disasters such as droughts. Furthermore, many natural hazards are not climate or weather related.

Nevertheless, there is an increasing recognition of the linkages between natural risk mitigation and adaptation to climate change, since climate change alters not only the physical hazard but also the potential impact.

A shared language and shared concepts between the two communities are still missing. Science of natural disaster risk have been endorsed since the Fifties, with unification of disaster related definitions in the Seventies (UNESCO, 1972; UNDRO, 1980); scientific basis for adaptation plans, e.g. initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects, has been ratified from IPCC (2001). The resulting situation is often perceived as the proverbial "Babelonian Confusion" also within the same community (Thywissen, 2006). The two scientific communities started to discuss together only recently (IPCC, 2009).

From the natural hazards point of view, formulations of the problem, well described in Cardona (2007) owe a lot to the original ideas of the so-called human ecology school of thought first proposed by geographers at the University of Chicago during the second decade of the 20th century and further developed by White (1942, 1964, 1973), Kates (1971, 1978) and Burton (1962), Burton and Kates (1964), as well as by Burton, Kates and White (1968, 1978) in their studies on hazards and disasters. On the other hand, the convolution of the frequency of extreme events with the severity of its feasible consequences has been the traditional approach for risk assessment from the techno-hazards point of view.

Prompted by these ideas, the Office of the United Nations Disaster Relief Coordinator (UNDRO) and UNESCO organized an expert meeting in July 1979, following the UNESCO meeting in 1972 (UNESCO, 1972), with the objective of proposing a unification of disaster related definitions. The report which came out of that meeting, Natural Disasters and Vulnerability Analysis (UNDRO 1980), included the definitions of natural Hazard, Vulnerability, elements at risk (Exposure), and Risk.

In the field of climate, the conceptualization of impacts, vulnerability and adaptation is coming from IPCC (2001). The report assesses advances in understanding vulnerability of major sectors, systems, and regions to climate change. Vulnerability is defined by IPCC (2001) as the extent to which a natural or social system is susceptible to sustaining damage from climate change. Vulnerability is a function of the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and the degree of exposure of the system to climatic hazards.

The semantic disconnect between disaster risk reduction and adaptation to climate change is evident: the meaning is quite similar but the terminology is completely different.

Several independent approaches have been developed to assess risk from natural hazards and vulnerability to climate change. Few comparisons of resulting methodologies are available. The general process comprises (Samuels, 2009): source (e.g. climate stimulus or extreme weather phenomena), pathway (e.g. climate change effects or hazard), receptor (e.g. house, people, environment), consequences (e.g. economic damage, loss of life, loss of habitat).

When a the above general process is adjusted to risk assessment in natural hazards studies or to vulnerability assessment in the climate change chain, similarities and differences become evident.

With respect to natural hazard, flood risk assessment can be taken as an example (Lumbroso, 2005):

- Hazard that is the probability of occurrence of a given natural phenomenon and its magnitude/intensity
- Exposed elements that are items affected by hazard
- Vulnerability that is the susceptibility of exposed elements to losses
- Risk that is the expected losses for exposed elements having a specified vulnerability and affected by a given hazard.

Figure 1.2 on the next page represents the state of the art in flood risk assessment (Lumbroso, 2005).

When dealing with climate change, the process is slightly different from above and comprises (Lissner et al., in print):

- Hazard that is the consequence of a climate stimulus
- Exposed elements that are items affected by a given hazard
- Sensitivity that is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change
- Vulnerability that is the expected consequence in a given period.

In Table 1.1 the two examples are compared, hereby considered as representative of natural hazards and climate change methodologies, showing similarities and discrepancies between the approaches. Obviously, not all the scientific studies can be fully referred to these but the milestones can be certainly ascribed to such general principles. Major differences are in the identification of potential damage to receptors and then the consequences. For instance, in natural hazards after the identification of receptor affected by the hazard, the following step is the analysis of damageability, that is traditionally defined as vulnerability. This implies a characterisation of different receptors (exposure), defining how prone they are to be damaged (vulnerability).

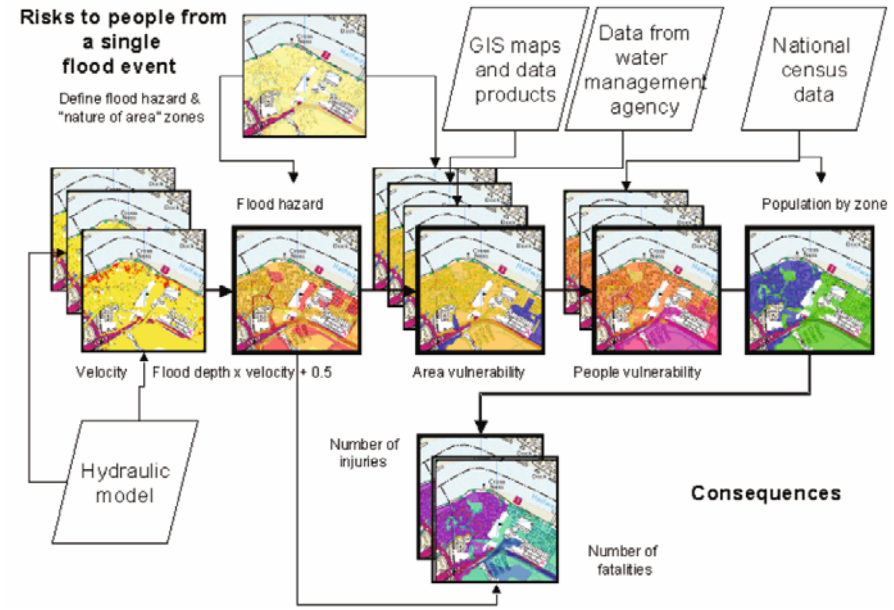


Fig. 1.2. Chain to assess flood risk according to Lumbroso (2005)

Table 1.1. Drivers for the integration of sustainability and risk mitigation

Samuels (2009)	*Lissner et al. (in press)* *CC*	*Lumbroso (2005)* *DRR*
Source (e.g. rainfall, waves, water level)	Climate stimulus	Rainfall
Pathway (e.g. floodplain inundation, overtopping of defences)	Number of heatwave days	Flood hazard
Receptor (e.g. houses, people, environment)	1. Urban High Intensity (sealed areas) 2. Population aged > 65 years 3. Sensitivity	1. Population by zone 2. People vulnerabiliy 3. Area vulnerability
Consequences (e.g. economic damages, loss of life, loss of habitat)	Vulnerability (degree of affected people)	Risk (number of injuries and fatalities)

A similar approach is proposed in Lissner et al. (in printing) for heat-waves, where population over 65 years living in urban areas is considered more susceptible to the climate stimulus. The integration of the two elements is generating a paramenter describing the sensitivity of exposed items, that is the indicator of potentially affected people (vulnerable in natural hazards studies).

The integration of sensitivity with number of heat waves is characterising the distribution and the concentration of vulnerable people (people at risk in the natural hazards approach). In risk analisis, the integration of hazard with vulnerable exposed items is characterising the items at risk (vulnerable in climate change).

In conclusion, from UNISDR (2009) "adaptation faces similar challenges to disaster risk reduction, in particular a governance framework that can allow risk in the development sectors to be addressed".

1.6 Core Concepts for Sustainable Risk Mitigation

In order to progress the discussion through the rest of the book it is necessary to outline and where possible define some of the key terms and concepts involved in sustainable hazard and risk mitigation. We have already discussed the meaning of sustainability in section 4 but there are other key terms and concepts that need to be addressed.

Hazard

In line with a range of international bodies we define a hazard as a physical event, phenomenon or human activity with the potential to result in harm.

This definition, when applied across Europe, encompasses a broad range of both natural phenomena and human activities which have the potential to cause damage and disruption, with member states being exposed to such hazards in an extremely heterogeneous fashion. Hazards can be of either slow (e.g. drought) or rapid (e.g. earthquake) onset and have the potential to have effects which can be felt across a range of scales. Many specific examples are provided in chapter 2 of this book.

In dealing with the scale of hazards in Europe it is important to appreciate, as already observed, that such hazards can have "transboundary effects". A good example of this would be flooding; this is a hazard which can naturally occur throughout a catchment, whereas, administrative boundaries can cut across the centre of a river. In such circumstances several countries or territories can be affected either consecutively or simultaneously by a flood event.

Different forms of "natural" hazard can interact through domino reactions and can be triggered by the same environmental event e.g. landslides and floods as a result of heavy rainfall. For these reasons and also so that an integrated and holistic view of hazard potential can be achieved, a “multi-hazard perspective” that recognizes the range of hazards that can affect any one place needs to taken.

In addition to naturally occurring hazards such as flooding, landslides, earthquakes, wild fires, volcanoes and droughts there is also growing concern over the potential effects of natural disaster triggered technological disasters – known as *na-techs*. The chlorine releases in the Czech Republic following the floods that swept across Europe in the summer of 2002 and the multiple hazardous materials releases triggered by the Turkey earthquake of August 1999 were examples which showed the potential danger of a natech disaster occurring near populated areas (Cruz et al., 2006). Na-tech events can also have transboundary implications, such as those experienced in January 2000 when a rapid overnight snowmelt event led to the failure of a tailings dam and the subsequent release of cyanide into the Lapus River in Romania. During the emergency, which was monitored by the Principal International Alert Centre for Accidental Pollution on the Danube River (PIAC), the toxin was carried downstream into Hungary and then Serbia, necessitating responsive measures to be taken in each country, before gradually diluting to a “safe” concentration (Cruz et al., 2006).

Exposure

Exposure focuses on the socially valued elements that may potentially be damaged by a hazard. It can be defined as the degree to which a natural or socio-economic system or natural or socio-economic community is exposed to potential hazards. Exposure can be measured in different ways, often through the use of monetary values although this can be problematic for valued elements that are not simply equated to a monetary measure.

Vulnerability

Although recognised as a multi-faceted concept vulnerability can be broadly defined as the degree of fragility of a natural or socioeconomic community or a natural or socio-economic system towards hazards.

Vulnerability can be viewed as a crucial focus for sustainable risk mitigation. This is because the term refers to a wide range of concepts and elements, from the physical fragility of buildings and infrastructures, to systemic vulnerability deriving from the interconnectedness of complex systems (e.g. power grids), to social and economic coping capacity. In other words, from a “hard” science perspective, whilst some buildings or transport networks can be regarded as intrinsically vulnerable to particular hazard events (e.g. seismic shaking) the concept of vulnerability is also seen to be of fundamental relevance within the social sciences. Whilst a basic taxonomic categorisation of “vulnerable” social groups (e.g. the elderly or the very young) can be appropriate in some circumstances other issues such as risk perception and risk tolerance can also have an important role to play in the economic and social sustainability of hazard exposed communities.

Risk

Whilst hazards are defined as potentially damaging phenomena it is only when a vulnerable community or system is exposed to the hazard that the potential for loss occurs. Therefore, it is the combination of the probability (or frequency) of occurrence of a natural hazard and the vulnerability and exposure of a receptor that is defined as risk. Risk can be simply expressed by the notation "Risk = Hazards × Vulnerability".

In this report we focus on the concept of sustainable *risk* mitigation – rather than sustainable hazard mitigation as used for example in Mileti et al. (1999) – because this enables mitigation to be concerned with both hazard and vulnerability and the ways in which these combine and interact to create risks.

Mitigation

Mitigation of hazards and risks is defined as any structural or non-structural measure undertaken to limit the adverse impact of natural hazards, environmental degradation or technological hazards (ARMONIA, 2006). This encompasses all manner of structural and non-structural measures from the construction of sea walls to land use planning, the development of seismic building codes and the development of generic or hazard specific forecast, warning and response systems.

This broad definition is appropriate for the scope of this book. However, it should be noted that a different meaning is applied in the field of climate change, where climate change *mitigation* relates to "a proactive strategy to gear immediate actions to long-term goals and objectives" (ARMONIA, 2006). In particular in this use mitigation is conceived as relating to the implementation of measures designed to reduce either the anthropogenic emission of greenhouse gases (GHG) or the concentration of GHGs in the atmosphere, principally in order to reduce the atmospheric greenhouse effect (e.g. increasing renewable energy generation is seen as a mitigation measure) (IPCC, 2007/b). In this field other measures such as building in an allowance for increasing future sea level rise into coastal and flood defences and developing technologies to reduce the effects of increased solar heating inside buildings are termed *adaptation*.

Resilience

In contrast to vulnerability, resilience is regarded as a positive property and is defined as "*the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to restore or maintain an acceptable level of functioning and structure*" (ARMONIA, 2006). In this sense and from the sustainability perspective, the use of the term resilience can be seen as being more encompassing than solely concentrating on a system's physical resistance i.e. a system's ability to endure hazard effects without damage or change.

In terms of the scientific projections of future climate change it is becoming increasingly apparent that an understanding of the complex and interrelated attributes of resilience is needed to guide the development of adaptive management techniques and practices for systems at all scales.

Participation

Questions of who is involved in developing local strategies for mitigating hazard and risk and influencing or taking decisions are important for sustainability. The principles discussed earlier stress the need to widen involvement beyond just expert hazard managers, including a wide range of stakeholders and in particular members of local communities. Participation can take many different forms and be directed at different aspects of policy and governance relevant to hazard and risk mitigation. What is important is that participation is meaningful, that it is effective in involving different social, cultural and ethnic groups (linking to equity considerations) and that it includes opportunities for involvement by those that could potentially be affected by hazards and/or mitigation actions (Brown and Damery, 2002; Pearce, 2003; Renn et al. 1995). Only through more participatory processes can legitimate decisions be taken and local responsibility and consensus building fostered and developed. Through wide involvement better, more locally appropriate strategies for hazard and risk mitigation can also be developed.

Precautionary Principle

The precautionary principle has to-date largely been discussed in the context of various forms of technological and social risk (O'Riordan and Jordan, 1995; Harremoes, 2002). At a European scale it is though included in the Maastricht agreement and part of the European juridical toolbox and can also be applied in the context of sustainable hazard and risk mitigation. The precautionary principle is difficult to define in a precise and uncontroversial manner. It has rather been described as a framework of thinking:

> "*The precautionary principle is an overarching framework of thinking that governs the use of foresight in situations characterised by uncertainty and ignorance and where there are potentially large costs to both regulatory action and inaction*"
>
> (Harremoes, 2002, p. 192)

Some key underlying concepts involved in applying the precautionary principle include:

- Proportionality of response or cost effectiveness of margins of error to show that the effective degree of restraint is not unduly costly. Part of the valuation benefit is the avoidance of risk by "playing safe".

- Preventative anticipation to take action in advance of scientific uncertainty or acceptable evidence.
- Burden of proof is focused on those who propose change rather than those effected by the change.

The precautionary principle is particularly relevant in the context of uncertain changes in the patterns and severity of hazards under future climate change or in relation to na-techs. There is, for example, a need for a precautionary approach to decisions taken now that could have significant implications for future hazard exposure and vulnerability. Such decisions could include, for example, the construction of nuclear power stations in low lying coastal environments at risk from sea level rise and coastal flooding and major urban developments on the edges of existing flood plains or in areas likely to become more at threat of forest fire or drought as climatic patterns change.

Equity

In the Mileti et al. (1999) principles of sustainable hazard and risk mitigation both intra and intergenerational equity are included. Intragenerational equity is concerned with patterns of inequality at the present time, for example, inequality in who is most at risk from hazards or who is most vulnerable or least resilient. Experience and research has shown that those that are poor, excluded or marginalised for various reasons are often most at risk from disasters (Walker et al., 2006; Wisner et al., 2004; Pelling, 2003). A sustainable approach therefore needs to be concerned with mitigating risks in ways that take account of the vulnerabilities of different people and that are fair to different parts of the community. Although this is an important consideration, actually determining what constitutes equitable and fair in this context is not straightforward and many different positions can be taken.

Intergenerational equity refers to the need to take account of the interests and needs of future generations, rather than only addressing the current day. As well as this being a principle with a strong moral and ethical grounding, there are also economic reasons for pursuing intergenerational equity. Under given circumstances, pre-event adjustments compared to post-disaster losses are not only affordable but can be also beneficial in economic terms. Large amounts of money can be saved through prevention, by reducing people's exposure and vulnerability to major threats. Until recently only the costs of reconstruction have been computed: nevertheless, recent disasters have shown that emergency intervention expenses can be extremely high. Furthermore, the latter often escape ordinary controls and budgeting, so that their exponential growth is overshadowed in the aftermath of the disaster. Should the same money spent on search, rescue, and temporary evacuation be devoted to prevention, the reason for such an expense would be reduced by an order of magnitude. Prevention is more sustainable than post event intervention; when sound land uses are decided, when updated building techniques adopted, future generations will not have to pay for extensive damage not to mention the loss of life implied by a natural calamity. This should be regarded as a crucial issue: many definitions of sustainable risk mitigation practices put the accent on coping capacities of communities and societies; nevertheless there is another aspect that should not be neglected, that is the capacity to reduce losses in advance, before an extreme event strikes, avoiding losses through a sensible combination of structural and non structural mitigation measures.

1.7 Organisation of this Book

To begin with the project attempted to develop an image of Europe at risk (chapter 2), largely based on results of previous projects in the two fields of study concerned. The results can be summarised in the first yellow box below: a first set of images can be proposed as far as well known risks, like floods, storms, forest fires or earthquakes are concerned. The ambition was to provide a more comprehensive assessment, including notions of exposure, vulnerability and social perception. However, in these respects very little is available at the entire European scale, and only partial and limited pictures can be provided.

However, it is not sufficient to be concerned with patterns of risk as they are today, the future orientation of the project meant that it was necessary, despite the large uncertainties involved, to consider possible future patterns of risk (chapter 5), which will not necessarily or be likely to reproduce the established, well understood ones. In this respect any attempt to provide probabilistic assessment is misplaced. More important is the analysis of past and present trends (chapter 3) that may help us enhance our understanding of future patterns of risk, some of which involve significant surprises deriving both from new/emerging threats (like climate change but also more complex chain of events, including the na-tech) and from patterns of exposure and vulnerability, due to the rapid development of societies and technologies in Europe as well more widely in the world.

In this new framework, the factors to be included in risk assessment and in climate change scenarios are not fundamentally different: both consider not only physical vulnerability of exposed systems, but also other relevant aspects such as systemic, social and economic vulnerability as well as the vulnerability of the natural environment that becomes relevant not only in the face of climate change but also in case of na-tech induced by natural events. This interpretation of the present situation in Europe, with a simultaneous view into the future, requires a revision of existing mitigation strategies and opens the door to new research endeavours (chapter 4). Changes are required in order to tackle not only inconsistencies that are already widely acknowledged for well known forms of threat and risk, but also to address new and emerging hazards and unexpected patterns of risk emerging due to changes in society and technologies involving unimaginable forms of exposure and vulnerability.

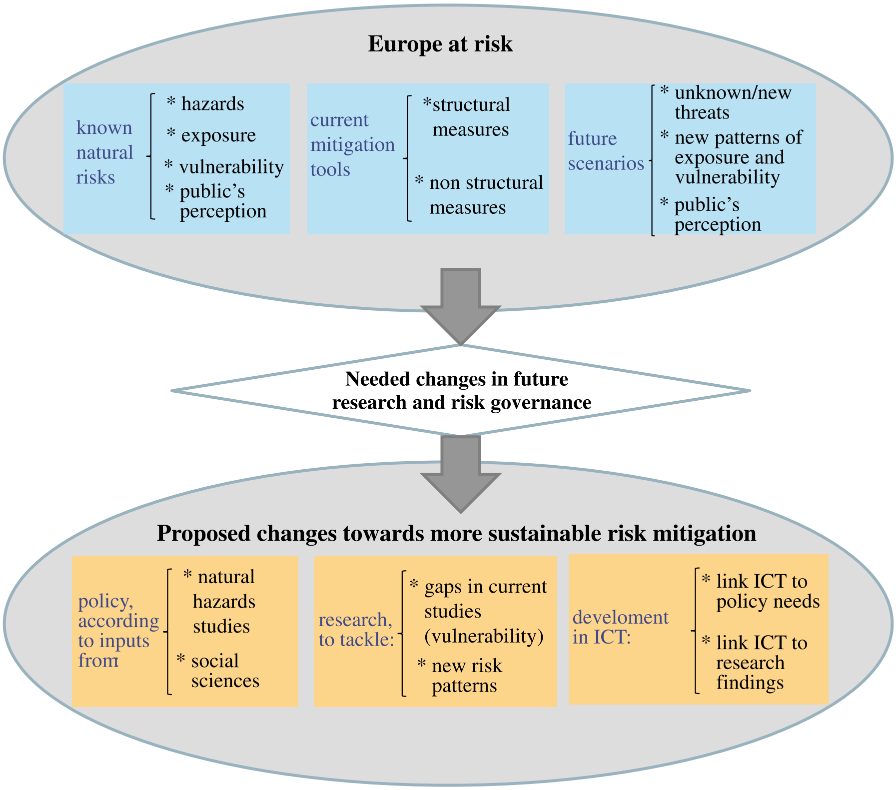


Fig. 1.3. The framework for the scenario project and book

We propose that such a shift in thinking (chapter 7) should indicate a more integrated approach towards risk reduction in general, derived from multiple phenomena and stresses, in the context of a more sustainable framework, in which mitigation strategies are considered and judged on larger criteria than immediate capacity to solve contingencies arising from crisis and emergencies.

These are the pillars of a fundamentally changed framework to better accommodate risk mitigation practices. Policy, as already widely recognised by the scientific community, has to be developed in a comprehensive way, rather than in separate domains as has been the case up to now. Risk governance approaches are needed that address hazards and vulnerabilities at multiple-levels and that include "end-users" and the participation of various publics with visions of possible solutions to environmental crises as well as to "natural" disasters.

Future research needs to address issues that have not been dealt with satisfactorily or at all until now. These include gaps in knowledge regarding practically all hazards, and particularly macro-categories like vulnerability of different sorts; new and emerging threats and risk patterns, which by their very nature require further investigation. An important topic that has been rather neglected until now refers to the potential impact of known and new risks on the natural environment, for example in terms of lost biodiversity or ecosystems resilience.

Finally, an important role has to be played by the ongoing development in the field of technology, for which a fundamental challenge stands out – the necessity to better fit with needs arising from both policy and scientific arenas. As Quarantelli (1997) has argued, too often technology is used simply because it is available, regardless of whether it is able to respond to the specific demands arising in the field of risk or emergency management.

2

Europe at Risk (Following EU-Funded Research on Hazard and Risks)

G. Delmonaco, F. Atun, A. Ceudech, H. Deeming, A. De Roo, D. Lumbroso, A. Galderisi, M. Kallache, J.P. Kropp, S. Kundak, D. Molinari, F. Tweed, S. Wade, G. Walker, M. Dandoulaki, J. Barredo

2.1 Introduction

This chapter regarding present risk conditions, has been structured using significant "images" of Europe, addressing the hazard, exposure and vulnerability factors recognised as crucial components of any risk assessment. To draw such a picture, results of past research at the European level were extensively searched, showing achievements and gaps in data provision, as in current understanding of the most important risk parameters. What clearly emerges is the need to develop tools and methods for assessing risks on a European scale, beyond the individual evaluations that each country may have developed within national borders. The relevance on a European scale can be appraised either in case of regional events, transboundary in their nature, or as far as the consequences of events are taken into account.

Because of systemic links, in fact, and the growing interdependence of infrastructures, and social and economic assets, an event in a given area may have repercussions miles away and on apparently distant systems.

2.2 Hazard Perspective: What Emerges from Research Carried out at the EU Level and in EU-Funded Research

2.2.1 Hazards by Type

Three types of hazards can be recognised in Europe: those having the potential to produce regional disasters, often transboundary (typically floods); localised hazards that will produce local events, as the largest amount of physical damage will be concentrated in the area of occurrence (large landslides, avalanches); and finally events that could be considered local for their individual occurrence, but which may manifest contemporarily in several places

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

(typically storms, as the Lothar and Martin storms in December 1999, see Sanson, 2001).

These three categories involve different problems regarding dealing with emergencies, costs associated with reconstruction, and the resulting risk; these derive from a combination.

Regional Hazards

As far as regional hazards are concerned, there are clearly a number of issues that must be investigated: the integration of knowledge base data, models and tools for assessment between countries that have a threat in common (like countries sharing a large river basin); the identification of vulnerable areas and objects that may be damaged and become an induced hazard in their turn (for example na-tech), involving neighbour countries downstream; the definition of shared crisis response and finally defining rules for recovery and reconstruction, especially when the latter is made with the help of common European funds. In this regard, the Elbe case in 2002 constitutes a good example of the implications of this type of transboundary hazard, affecting large areas and multiple communities. Looking at the problem this way, it becomes extremely useful to refer to agreed-upon maps and models showing how a feared event may spread on a regional basis or across nations.

Floods

On the basis of EM-DAT data, which will be thoroughly discussed in the next chapter, floods caused the death of a thousand people and direct losses of up to 60 bn Euros in the decade 1998–2009. The most severe events hit Italy, France and Switzerland in the year 2000 and the countries sharing the Elbe catchment in 2002 (see Box 4.3). Regarding flood hazard mapping, even if excellent studies have been carried out among European researchers, these results are not suitable for global analysis. In fact, they do not cover the whole of Europe and cannot be compared to each other, mainly because of inconsistencies in adopted hazard indicators.

Indeed, unlike in other fields of study, like seismology, in flood management there is no agreement on a common hazard indicator so, generally, different studies explain flood hazard in different ways.

The reliability of maps largely depends on available long-term data bases, scientific experience and technical organisational structures. The best experience and maps have been developed by some European river basin authorities, particularly in Northern Europe and in Italy. These are rather advanced as far as methodological aspects are concerned.

Nevertheless, in the last few years, two attempts have been made to represent the whole of Europe from a flood hazard perspective. The first (Fig. 2.1) was developed within the ESPON project 1.3.1 and the second (Fig. 2.2) by the Joint Research Centre (JRC).

As underlined by ESPON's authors themselves, the project's results must be seen only as a first attempt to organise existing data. This means that often they are not representative of the real situation or are too generalised and statistically rough, because of the difficulty in gaining data from the European research institutions and because of the impossibility of carrying out new research to obtain full datasets (Schmidt-Thomè, 2006b).

In particular, regarding floods, the map in Fig. 2.1 shows the average value of large flood events (recorded in the "Global Active Archive of Large Flood Events" of the Dartmouth Flood Observatory, in the period 1987–2002) for each NUTS-3 area.

If hazard is defined as "a potentially damaging physical event [. . .] characterised by its timing, location, intensity and probability" (ARMONIA, 2006) it is clear that the above map cannot be considered a hazard map because it does not adopt intensity indicators (e.g. water depth, velocity, etc.) or probability ones. In fact, the observed period is too short for any kind of statistical

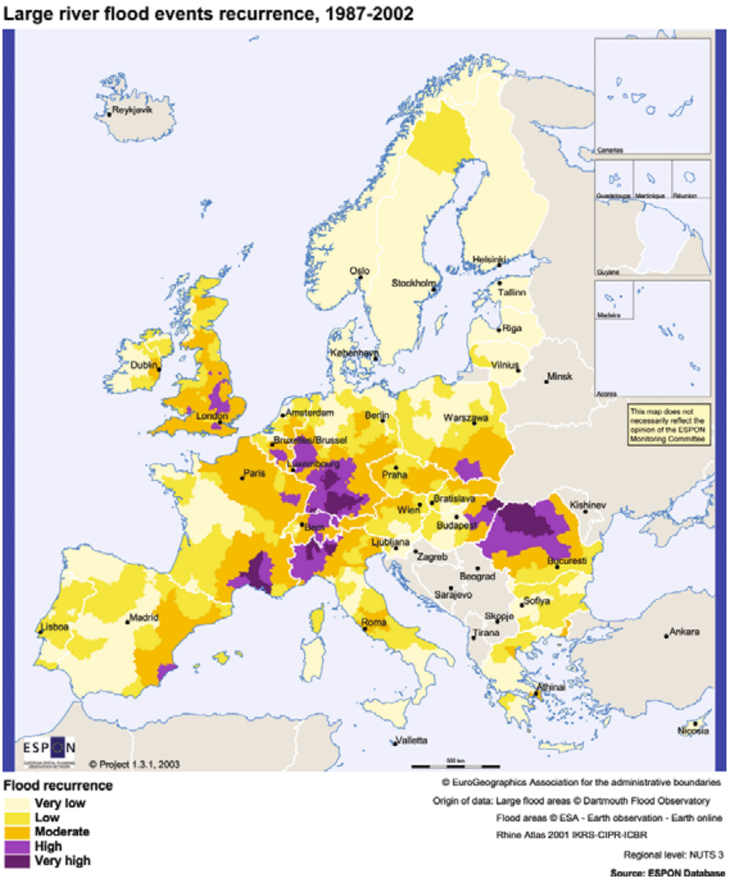


Fig. 2.1. Europe flood hazard map (source: ESPON, 1.3.1, 2006)

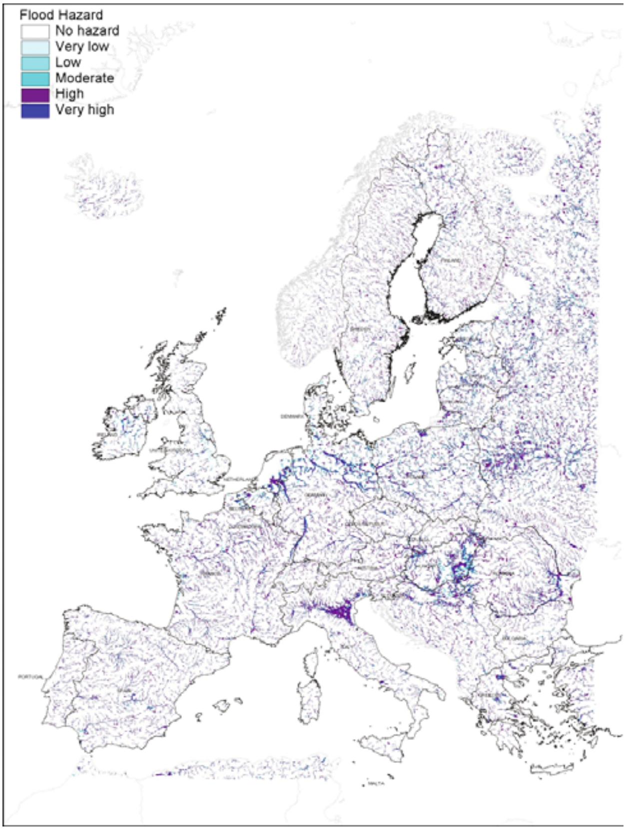


Fig. 2.2. JRC's flood hazard map (source: Barredo et al., 2005b)

analysis so what can be said is that the map shows Europe from a flood disaster perspective.

The aim of the JRC project was instead to support the development of the European Flood Directive by producing "flood hazard and flood risk maps at the European scale, to provide a harmonized overview of flood prone areas" (De Roo et al. 2007).

In this case (Fig. 2.2), flood hazard was obtained by using a 1 km grid digital elevation model and the European Flow Networks, developed at JRC. Water depth determines the hazard. Extreme water levels have been estimated by using an elementary function based on upstream catchment size. An algorithm was developed to find the elevation difference between a specific grid-cell and its closest neighbouring grid-cell containing a river (De Roo et al. 2007).

Unlike the previous map, the JRC's can be considered a hazard map, even though the extreme water levels function does not include event frequency. Nevertheless, the authors, aware of this, are working both on improving the map's spatial resolution and on adopting the hydrological model LISFLOOD (De Roo et al. 2000).

Regarding the hazard spatial distribution, Fig. 2.2 points out that floods are a relevant problem for the entire European territory.

Indeed, unlike seismic hazard, flood risk is a generic label for different phenomena (e.g. river floods, flash floods, etc.) affecting several European regions. However, some areas are more prone to flooding than others: namely the major river basins (mainly the Po, the Elbe, the Danube and the Rhine ones) and the largest mountainous areas (like Alps and Carpathian regions).

Volcanic Hazard

Volcanoes are localised in correspondence with unstable areas of the Earth's crust, such as plate boundaries, oceanic ridges, etc. (see Table 2.1).

Volcanoes can be differentiated according to their type of eruption. The type of volcanic activity can be explosive with viscous magmas. Vesuvius, the Phlegrean Fields, Stromboli and Vulcano in the Aeolian islands belong to this type of volcano.

Volcanoes of ridges are characterised by less viscous and therefore more fluid magmas and their shape is rather flattened. This type of volcanic activity is frequent in Iceland and in Sicily, Italy, due to Etna, the largest volcano in Europe.

Because of their geological characteristics, severe volcanic eruptions are rare events; therefore a time span of hundreds of years is not relevant to assess the potential risk, in contrast to more frequent phenomena such as

Table 2.1. Main European volcanoes

Country	*Volcanoes*
Greece	Kos, Methana, Milos, Nisyros, Santorini, Susaki, Yali
France	Puy de Dome, Pelée (Martinique), Soufriere Guadeloupe (W. Indies)
Great Britain	Soufriere Hills (Montserrat), Tristan Da Cunha (Atlantic Ocean)
Holland	Saba (West Indie)
Italy	Lipari and Volcanello, Etna, Sabatini, Stromboli, Vesuvio, Vulcano, Campi Flegrei
Iceland	Askja, Eldfell, Heimaey, Eldgja, Grimsvatn, Herdubreid, Hekla, Hveravellir Hot Spring, Katla, Krefla, Laki, Oraefajokull, Strokkur, Surtsey, Viti
Azores	Agua De Pau (San Miguel), Don Joao De Castro Bank, Fayal, Furnas (San Miguel), Graciosa, Monaco Bank, Pico, San Jorge, Sete Cidades, Terceira
Canaries (Spain)	Hierro, La Palma, Lanzarote, Tenerife
Norway	Jan Mayen

Table 2.2. People affected by natural hazards during 1980–1990 (source: Chester et al. 2001)

Type of hazard	*Approximate number affected*	*Number of affected (% total)*
Droughts	952,200	57
Floods	524,600	32
Windstorms	150,300	9
Earthquakes	28,400	2
Landslides	3,100	0.2
Volcanoes	620	0.04
Wildfires	610	0.04

floods, earthquakes and landslides. Some studies referring to the period 1980–1990 highlight the entity of this relationship in terms of involved population (Chester et al. 2001) (Table 2.2).

A map representing areas in Europe where a known volcanic eruption has occurred in the last ten thousands years has been produced by the ESPON project (see Fig. 2.3).

It is worth noting that the highest damages due to volcanic eruptions were registered between 1906 and 1956 (Table 2.3). However, the damage that some

Table 2.3. Volcanic disasters in EU during the 20th century (source: EM-DAT: The OFDA/CRED International Disaster Database, Université Catholique de Louvain, Brussels, Belgium)

Date	*Country*	*Location and description*	*Main recorded damages*
April 1906	Italy	Vesuvius, Campania Region	700 people killed
March 1944	Italy	Vesuvius, Campania Region	26 people killed, 14,000 homeless
July 1956	Greece	Volcano	48 killed
January 1973	Iceland	Eldafjell, Heimaey Island	5,200 affected, 24,700 USD damage
September 1979	Italy	Etna, Sicily Region	9 people killed, 24 injured
May 1983	Iceland	South-east region	Not reported
September 1984	Iceland	Mount Krefla	Not reported
December 1991	Italy	Etna, Sicily Region	7,000 affected
July 1995	Great Britain	Sufriere Hills, Montserrat	12,000 affected
October 1996	Iceland	Volcano Grimsvotn, Nother area	16,500,000 USD damage
July 2001	Italy	Etna, Sicily Region	3,100,000 USD damage
2002–2003	Italy	Stromboli, Sicily Region	Not reported

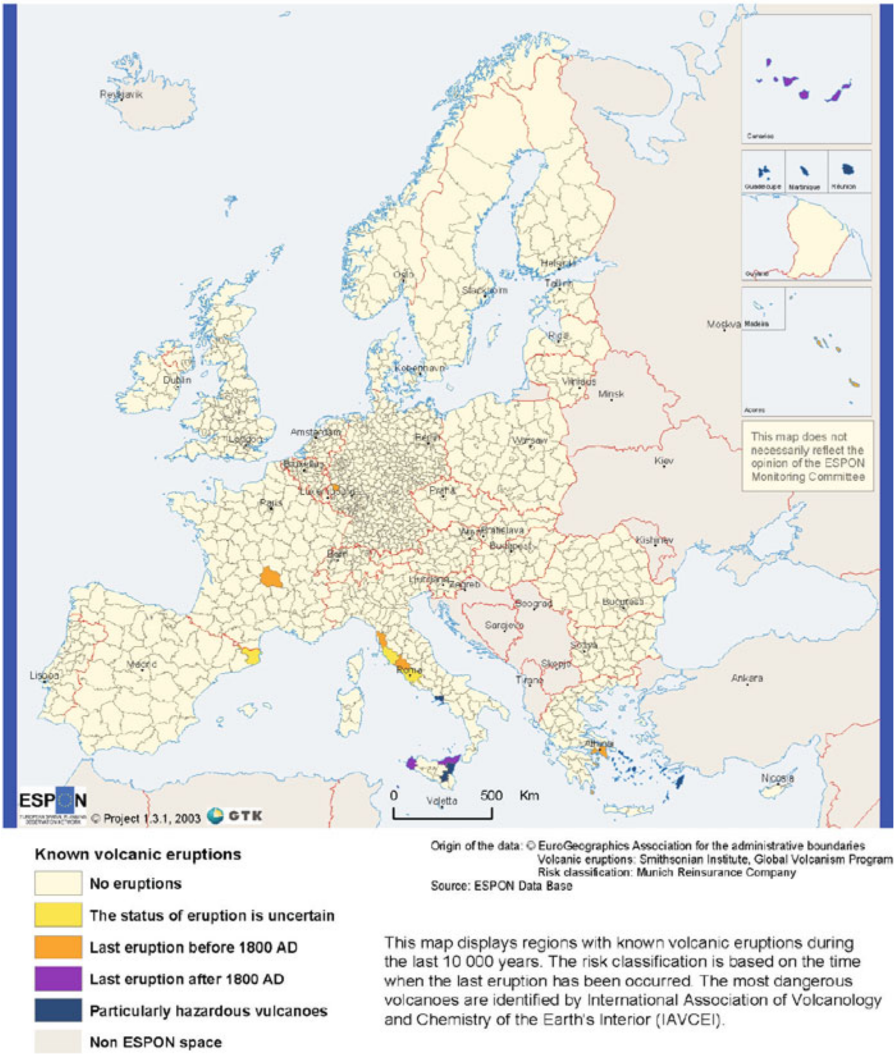


Fig. 2.3. Map of volcanic events in Europe (source: ESPON, 1.3.1, 2006)

volcanoes could cause today would be significantly more severe. For example, the Vesuvius eruptions in 1906 and 1944 affected an area that was much less densely populated and built up than it is nowadays.

In the 1970s and 1980s, eruptions occurred mainly in Iceland, hitting areas characterised by very low urbanisation.

In the 1990s some events occurred at Etna, characterised mainly by lava flows from very high altitudes, permitting the evacuation of inhabitants. Other events affected the Grímsvötn volcano in Iceland (where the damage was due

Fig. 2.4. Eruption of Grímsvötn, Iceland, 1996

to the flood caused by melting ice as a consequence of the subglacial eruption, see Fig. 2.4) and the Island of Montserrat. The latter was particularly catastrophic in terms of damage to goods and disruption of normal lives. As well as 23 victims, 50% of the population had to be evacuated, 75% of the island was covered by ashes and several facilities like schools and hospitals were destroyed.

The most recent events occurred in Italy, in Sicily and on Stromboli Island, where a volcanic eruption lasted for a long time and was articulated in several phases.

On 28 December 2002, Stromboli started an effusive eruption after 17 years of quiescence. Two days later, two landslides, with a volume of five million cubic meters, descended from the "Sciara del Fuoco" into the sea, triggering a tsunami which damaged buildings close to the beaches of Stromboli village.

Some volcanic zones, such as Ischia and the Phlegrean Fields, have to be considered as active even though eruptions have not occurred during the last century. Today these areas are characterised by a very high population and urban activity density. For example, the last eruption of the Phlegrean Fields took place in 1538 and produced the "Monte Nuovo" in just one night (Fig. 2.5), after a period of quiescence lasting approximately three thousand years, and was one of the less violent eruptions experienced in the area.

Moreover, some volcanoes are characterised by different types of eruptions during different temporal phases (Chester et al. 2002), which can produce very different outcomes. Vesuvius belongs to this type of volcano. The 1631 eruption is considered by volcanologists as an example of the worst scenario if eruptive activity were to recur. After the 1631 eruption, until 1944, on Vesuvius there was predominantly open-conduit activity. In this period 18 Strombolian

Fig. 2.5. Monte Nuovo, Campania region

cycles can be distinguished, separated by brief periods of quiescence, lasting less than 7 years and producing a final violent eruption. Within each cycle, frequent, predominantly effusive eruptions took place known as "intermediate" eruptions. The 1906 eruption was the most violent one in the 20th century. The most recent 1944 "terminal" eruption was both effusive and explosive and marked the volcano's transition to a state of closed-conduit activity.

Vesuvius' wide variety of eruptive behaviours is generally attributed to the alternation of periods of open-conduit activity and longer periods of quiescence with closed conduit, followed by major Plinian or Subplinian eruptions.

The open-conduit periods are characterised by persistent Strombolian activity, frequent lava effusions and sporadic, but even more dangerous, both effusive and explosive eruptions.

It must be considered that the temporal intervals between the several phases of the volcanic activity are remarkable, while the evolution of the human settlements has been very fast, in particular during the last 50 years, determining the huge urbanisation of many volcanic areas, especially in Italy.

Furthermore, outcomes of volcanic eruptions may have significant effects on wider areas than those directly involved, as a consequence of systemic vulnerabilities. For example, in the 2002 Etna eruption, Catania airport was repeatedly closed because of the dense ash cloud, with repercussions on national and international air traffic. Further systemic damage, extended to several systems beyond air traffic, can be easily imagined in the case of a Vesuvius eruption, as will be discussed in Chapter 6.

Multi-Site Hazards

Multi-site events are clearly much more difficult to analyse and forecast; they are generally related to meteorological events that can virtually occur anywhere. Nevertheless they are receiving increasing attention from institutions and the insurance industry, because of the large amount and the extent of damage they can cause in a short time.

Storms

According to the Munich Reinsurance Company (Munich Re, in the following), storms are, worldwide, the main cause of economic losses by natural hazards (Munich Re, 2005), consequently attracting large "audiences" in the last few years.

According to a recent report produced by the EEA (2010), Europe has been hit by 11 large storms in the last decade (1998–2009). The deadliest was Lothar in 1999, causing 151 casualties; the most damaging were Kyril in 2007, causing more than 7.7 bn Euros damage, and Klaus in 2009, with 4.5 bn Euros.

Because of the difficulties concerning their prediction (which is only possible several hours to a few days in advance, depending on weather conditions) many tools and projects are currently oriented towards storms forecasting, such as the ESTOFEX (European STOrm Forecast Experiment) project, TSR (Tropical Storm Risk) consortium and RMS® (Risk Management Solution) *Europe Windstorm Model*.

Moreover, storm risk assessment is also quite developed within Europe, with Germany and insurance companies leading the research. In particular, in regard to storm hazard mapping, the only two available maps are from CEDIM (Center for Disaster Management and Risk Reduction Technology, at the University of Karlsruhe and the Geoforschungszentrum in Potsdam, Germany, see Fig. 2.6) and the Swiss Reinsurance Company (Swiss Re, in the following). In both cases, hazard is expressed as the probability of occurrence of maximum wind speed at a certain place, showing a good agreement on storm hazard indicators within the scientific community.

The Swiss Re's map shown in Fig. 2.7 has been developed by *Eurowind*, a probabilistic model designed to assess storm risk in Europe, which Swiss Re developed in co-operation with the EQECat enterprise. The calculations are based on the careful reconstruction of 180 European historic winter storms, dating back to 1947, and also include the most recent events (Anatol, Lothar and Martin). More than 8000 model storms have been generated from this data, in accordance with the observed relationship between storm frequency and intensity. The map shows the peak gust velocity (in metres per second) to be expected locally about once every 50 years (Bisping et al. 2000).

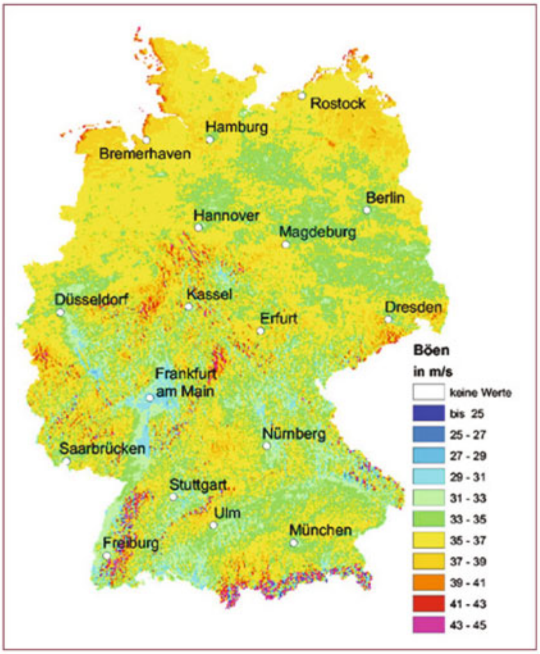


Fig. 2.6. CEDIM's storm hazard map for Germany (source: Hofherr and Kunz, 2010)

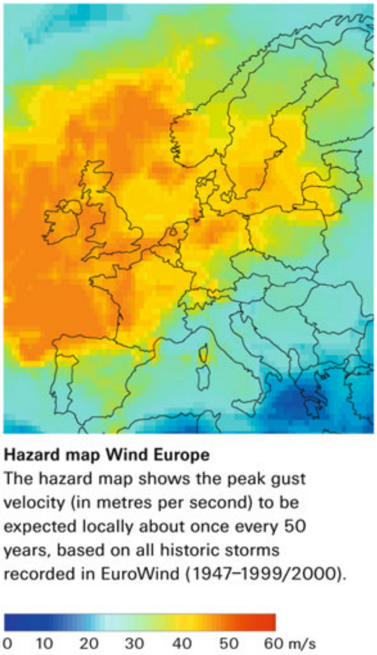


Fig. 2.7. Swiss Re's storm hazard map

Moreover, some "inventory maps" are also available at European level, which supply a general overview of localisation of prone areas. Figs. 2.8 and 2.9 can be reported as examples. The first one comes again from ESPON project 1.3.1. It has been developed using available data from the World of Natural Hazards CD-Rom (Munich Re, 2000). The storm hazard is represented according to the probability of occurrence, as reported by Munich Re itself. It shows a high probability of occurrence for the northern regions and a medium-low probability of occurrence for central Europe. The second one is from EEA (European Environmental Agency) and shows the course of major storms between 1998 and 2002. It actually corroborates the previous maps. It must be pointed out that storm hazard cannot be reduced. Therefore, future research should focus mainly on reducing the extent of damages caused by

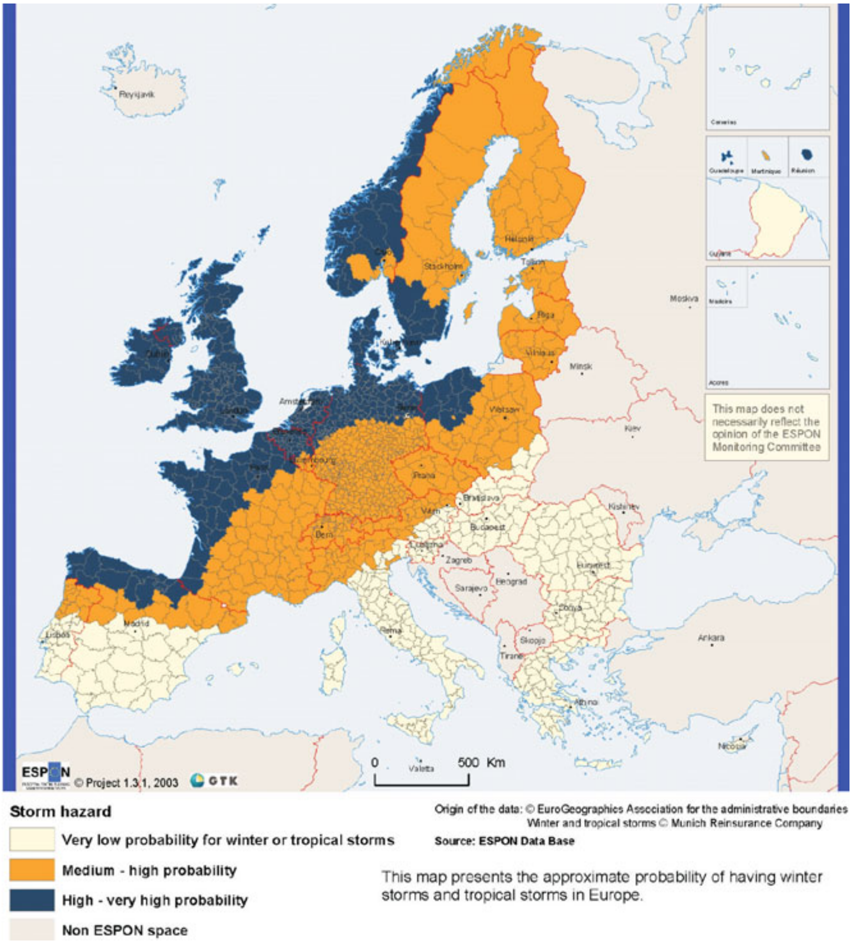


Fig. 2.8. Storm hazard in Europe (source: ESPON, 1.3.1, 2006)

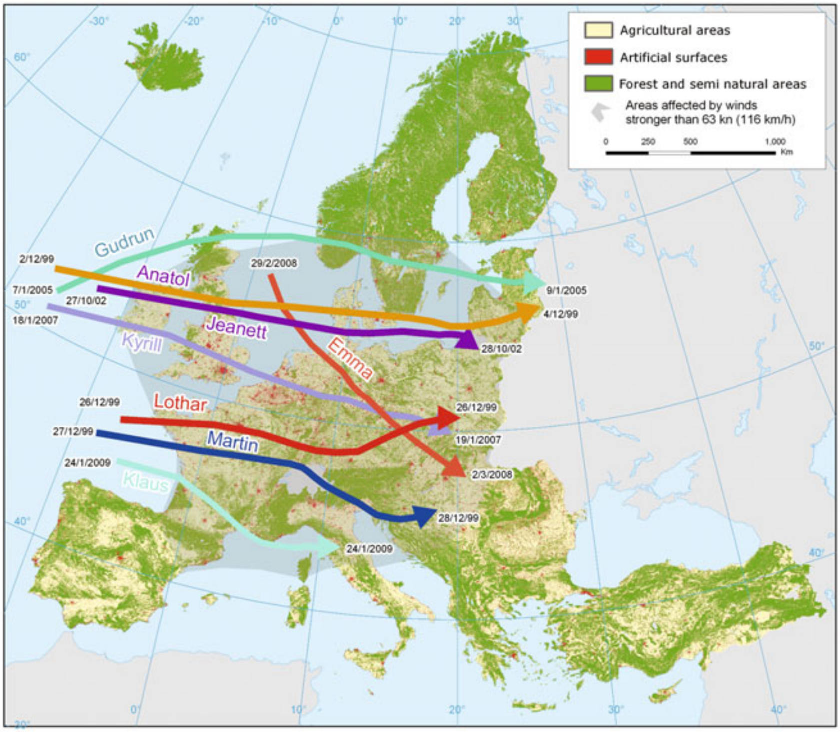


Fig. 2.9. Course of latest major storms (source: EEA, 2010)

storms, by suitable territorial planning, building codes and, above all, an appropriate emergency response which must be agreed on, integrated and coordinated among affected regions. In this regard, a European perspective is crucial.

Hailstorms

Research in the field of hailstorm risk management is not so developed, even though hail produced by severe thunderstorms can cause severe, although localised, damage. An example is the hailstorm in Munich in 1984 that injured 300 people and caused economic damage of Euro 1.5 bn (Zimmerli, 2005). So far, the only available maps and models have been provided by Swiss Re, because of the great impact this kind of event has on the insurance system.

The model developed by Swiss Re is a probabilistic, event-based one, which evaluates risk as a combination of exposure, vulnerability and probabilistic hail events. In particular, the hazard characterisation (that is, in this case, the definition of "a representative probabilistic events set which realistically simulates the hail activity to be expected in the future") is based on a dual approach, "linking detailed observed data from the recent past to lower resolution long time scale records" (Zimmerli, 2005). Unfortunately, no free hazard maps or results are available.

Local Hazards

Local hazards are of interest in the present research because they may occur in a particularly vulnerable environment and may provoke extended effects with respect to the relatively small physically damaged area whenever systemic and functional vulnerabilities are relevant. Furthermore, the difference between multi-spot and local hazards is not that sharp: when mountain areas are concerned, rather diffused instability conditions can be identified, with several large areas exposed to a multiplicity of large to small landslides of different types as well as avalanches. In this case, it is hard to say whether or not some of those hazards may be triggered by the same initial meteorological event, with repercussions that may be regional if not transboundary, as some mountain chains are shared by several EU countries (like the Pyrenees and the Alps). To a certain extent, also, the recognition of a threat as being multi-spot or local is strategic with regard to its treatment: considering it a local hazard will lead to case-by-case measures and mainly structural defences to protect against this or that mass or snow movement. When many localised hazards are viewed on a wider geographical scale, various preventative measures can be considered from a broader perspective, including redistribution and relocation of settlements, houses and infrastructures.

Landslides

A landslide is a typical example of an individual event that usually involves a small area but may produce heavy losses in terms of fatalities and economic damage. Research on landslides has been traditionally very active. Many detailed hazard maps are available at country level, mainly reporting existing phenomena, so it is better to call them "inventory maps" instead of "hazard maps". These maps usually display slow and known movements, missing landslides characterised by a sudden triggering, a very fast evolution (high velocity, long run-out) and difficult prediction at slope scale. Due to their characteristics, these types of mass movements should be effectively investigated in terms of hazard-prone areas (susceptibility). No detailed view at European level is available, due to the complexity explained above.

The best experience is coming from the Global Disaster Risk Hotspots project (see Dilley et al. 2005), funded by ProVention, in collaboration with the World Bank, the Norwegian Geotechnical Institute and other partners. Fig. 2.10 depicts the European landslide hazard zoning produced by the Norwegian Geotechnical Institute. It is a very general view, based mainly on geological and topographic data, that shows a spatial hazard distribution which makes Iceland and the southern portion of Europe the most prone areas.

Moreover, it must be mentioned that, as for previously analysed hazards, ESPON project 1.3.1 has produced a landslides hazard map. Nonetheless, it

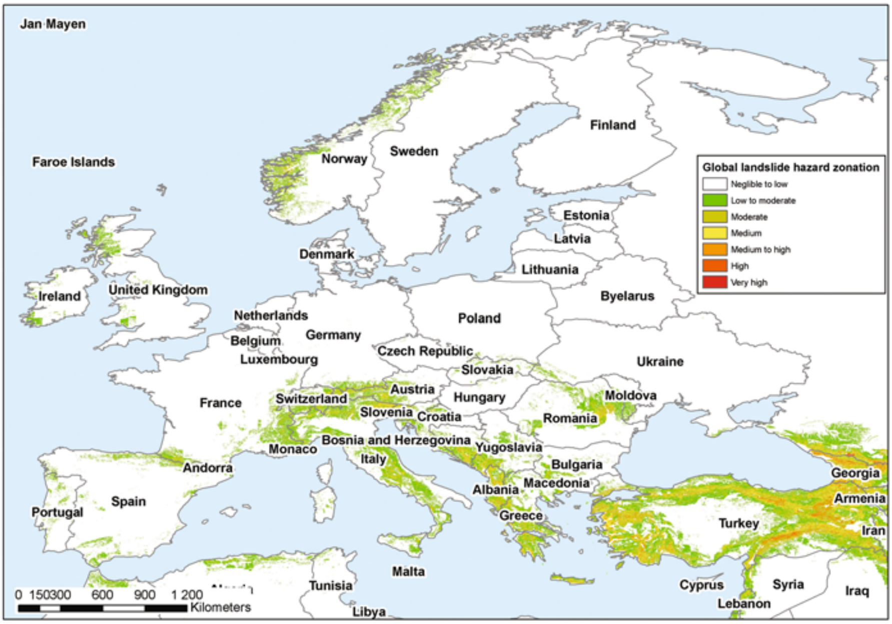


Fig. 2.10. Landslide-prone areas according to the Norwegian Geotechnical Institute and published in the EEA Report, 2010

cannot be considered totally reliable. In fact, in order to represent the hazard at NUTS-3 levels (which are too coarse compared to landslides events), the authors developed a questionnaire that was sent to all geological surveys of Europe. Based on experts' opinions, the geological surveys were asked to mark those NUTS-3 areas of their respective countries where landslides may occur. Then, a simple overlayi was made, without any consideration regarding probability. For this reason, ESPON's map is not reported but simply mentioned in order to point out the difficulties in managing landslide hazard.

Snow Avalanches

Snow avalanches have many common features if compared with landslides, mainly in terms of event typology and consequences. Most studies have been developed on local scales, focusing on a certain region or situation. Nevertheless, a general European view of the spatial hazard distribution is given by ESPON project 1.3.1, which displays those NUTS-3 areas where avalanches might occur. The map, reported in Fig. 2.11, shows that avalanche hazard is widespread throughout all European mountain regions.

It must be pointed out that the map does not display frequencies or probabilities because they depend on weather conditions. As a consequence, avalanche maps must be updated regularly.

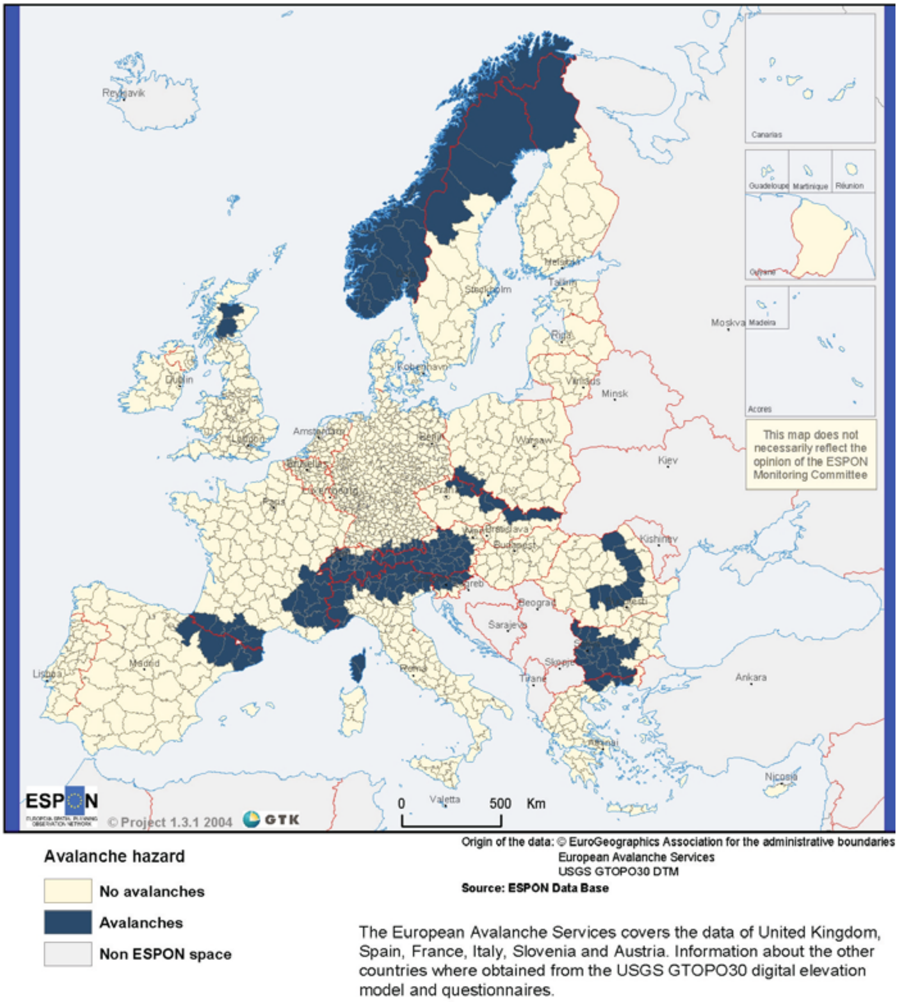


Fig. 2.11. Avalanche hazard in Europe (source: ESPON, 1.3.1, 2006)

2.2.2 Hazards by Geographical "Distribution"

Looking at recent and less recent disasters, one gets an impression of a geographical distribution of hazards and risks within the European continent. Maps produced in previous projects corroborate this initial intuition. A rather neat distinction can be made between northern countries and those pertaining to the Mediterranean basin. In the former, floods and meteorological related hazards represent the main threat, while the latter is exposed also to forest fires and major geological hazards, in particular earthquakes and volcanic activity. Landslides and avalanches are obviously concentrated in mountain areas. A question that can be asked is whether or not such a distribution has an impact on how risks are perceived politically and even scientifically in the European Union.

Earthquakes

It is well known in the scientific community that among natural and technological disasters, research in the field of seismic risk is rather advanced and seismic risk mapping is also quite developed.

However, most studies have been carried out on local scales (e.g. South Italian regions, Greek regions, Balkan regions, etc.) and it is only since the 1990s that there has been increasing interest in analysing the entire European territory.

In particular, the first seismic hazard map for the European-Mediterranean region was produced by the Global Seismic Hazard Assessment Programme (GSHAP), as part of the Global Seismic Hazard Map. The project was conducted in the period from 1992 to 1998 with the aim of "improving global standards in seismic hazard assessment". In particular, "the GSHAP was designed to provide a useful global seismic hazard framework and serve as a resource for any national or regional agency for further detailed studies applicable to their needs" (Giardini et al. 1999).

The GSHAP's map was based on the compilation and assemblage of hazard results obtained independently in different test areas and multinational programmes (Giardini et al. 2003). This assemblage of results was made possible thanks to the agreement between seismologists regarding the use of a common hazard indicator, that is peak ground acceleration.

The first GSHAP's map version was then improved by the European Seismological Commission (Working Group on Seismic Hazard Assessment), which combined GSHAP's results with the seismic source model developed by The International Geological Correlation Program project n.382 (Seismotectonics and seismic hazard assessment of the Mediterranean basin+– SESAME). The resulting map is shown in Fig. 2.12.

It depicts Peak Ground Acceleration (PGA) with a 10% chance of exceedance in 50 years for a firm soil condition. PGA is the most commonly mapped ground motion parameter because current building codes that include seismic provisions specify the horizontal force a building should be able to withstand during an earthquake (Giardini et al. 2003).

In the map, lighter colours represent lower hazard whilst the darker represent higher hazard (Giardini et al. 2003). As expected, the most hazardous areas are concentrated in Southern Europe (mainly in Italy, Greece, Turkey) corresponding to tectonic plates margins, while only a small portion of Europe is actually exposed to the hazard.

The ESPON project 1.3.1 reports a more detailed version of the GSHAP map (Fig. 2.13), in which the average value of the grid points inside each NUTS-3 unit was adopted as a representative of each unit. As admitted by

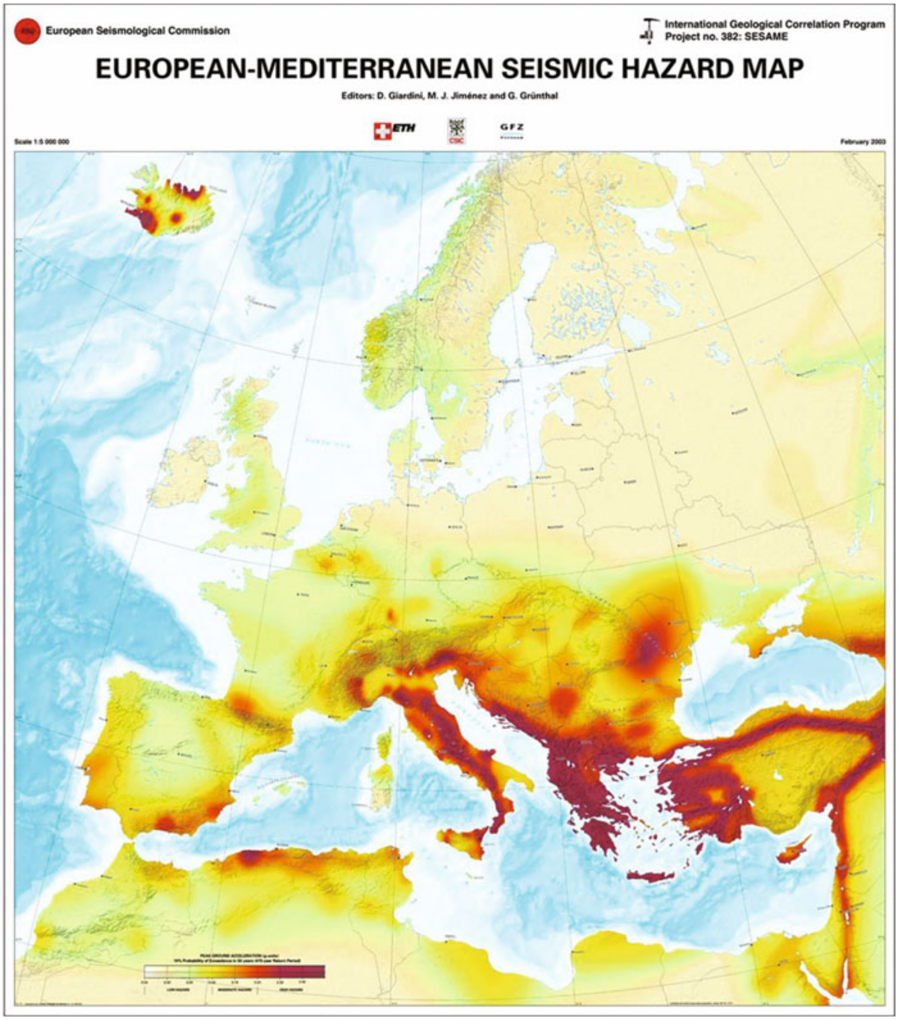


Fig. 2.12. GSHAP's seismic hazard map (source: Giardini et al., 2003)

the authors themselves (Schmidt-Thomé, 2006a), this method lowers the effect of the peak values in the various areas, but permits information corresponding to administrative units to be conveyed.

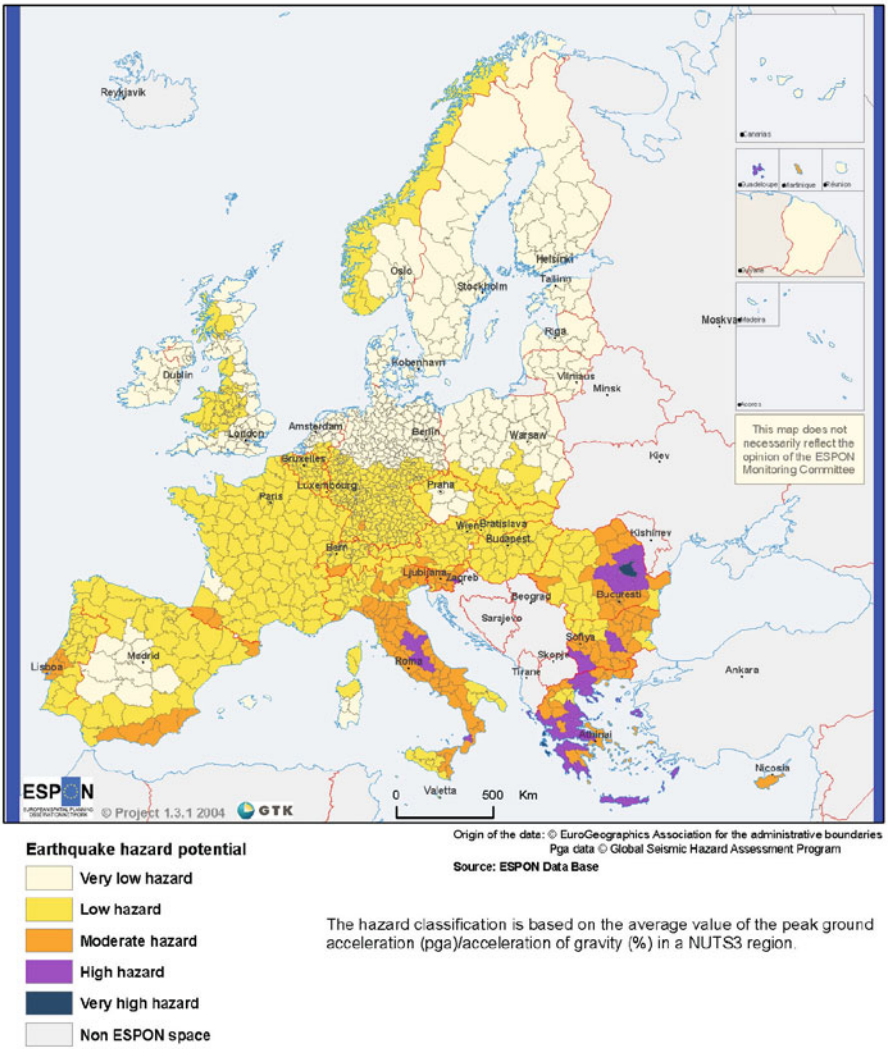


Fig. 2.13. Seismic map of Europe (source: ESPON, 1.3.1, 2006)

Forest Fires

Forest fires are certainly a hazard significantly influenced by climate change, as prolonged periods without rain and drought favour the conditions for igniting fires and for their rapid spread over large areas. They also represent a typical multi-site hazard, particularly when several large fires occur simultaneously in different locations. This was the case in summer 2007 when Spain (Canarias), Southern Italy (Puglia, Calabria and Campania regions) and Greece (Peloponnesus) were severely hit. These simultaneous events produced a significant burden on the European fire-fighting system, as resources had to be deployed from one afflicted region to another rapidly enough to face particularly severe situations that threatened forests as well as villages and infrastructure.

Besides the disagreement on common indicators (which is the case also for other hazards), in the forest fire domain there is a general disagreement regarding what should be considered as a "fire risk". According to the most widely accepted references, fire risk is simply the potential for fire ignition, the chance of fire starting as determined by the presence and activity of causative agents (FAO, 1986; McPherson et al. 1990). Nevertheless, different approaches to forest fire risk assessment, which take into account both probability and expected outcome of the undesired event, have recently been proposed (Bachmann and Allgoewer 1999; Chuvieco et al. 2003).

As a consequence, available hazard analyses are based on different approaches. Here the two maps drawn within the EFFIS project (European Forest Fires Intervention System) (2011) and ESPON project 1.3.1 are reported.

The EFFIS map, resulting from one of the most recent European reassessments, was obtained by working on historical fire records, stored in the EU forest fire database (which is built with the data provided by member states and managed by JRC), while additional GIS data layers (in particular the administrative boundaries of GISCO and the CORINE 2000 database) have been processed. The basic features of the map are constrained by available data at the EU level and, predominantly, by the spatial resolution of fire location data, which are not given as geographical coordinates but as affected administrative regions. Therefore the maps are based upon NUTS-3 level polygons, which are taken as geographical units described by specific fire hazard indicators. The historical period considered for the analysis has been set to 10 years, taken as a reasonable compromise between catching a significant interannual variability of weather conditions (for which a long period would be desirable) and getting a realistic picture of the current conditions (for which a period not too extended should be considered for homogeneity reasons). This is especially important for the socioeconomical driving forces, continuously changing in time and so important for forest fires in Europe.

Two main indicators have been proposed: fire density, i.e. fire frequency normalised over time and space, and burned forest fraction, i.e. the forest burned area normalised for time and forest land area. The two derived maps (Figs. 2.14 and 2.15) provide an estimate of the spatial distribution of fire hazard in EU and they currently cover the ten EU states most exposed to forest fires. Maps show the most hazardous areas in the Mediterranean region and some hot spots in Central Europe.

Similarly, ESPON's map (reported in Fig. 2.16) is a combination of vegetation zones and forest fires reported in the ATSR World Fire Atlas for the period 1997–2003. Map reliability depends mainly on the limitations of the database used. In fact, ATSR data come from a satellite that detects only night fires with a periodical cycle of three days.

To obtain forest fire hazard, both the vegetation zones and the observed fires were categorised into five classes. The forest fire hazard on NUTS-3 level

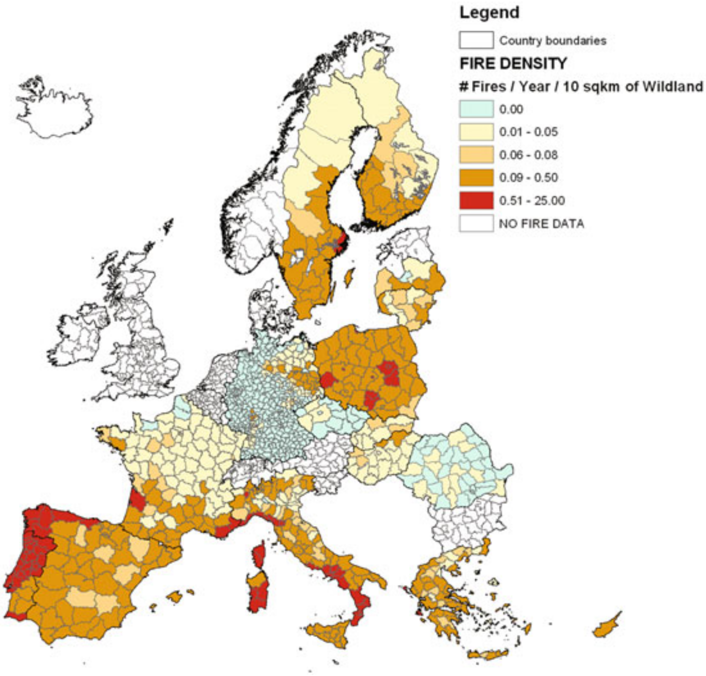


Fig. 2.14. Fire density map (source: EFFIS, 2011)

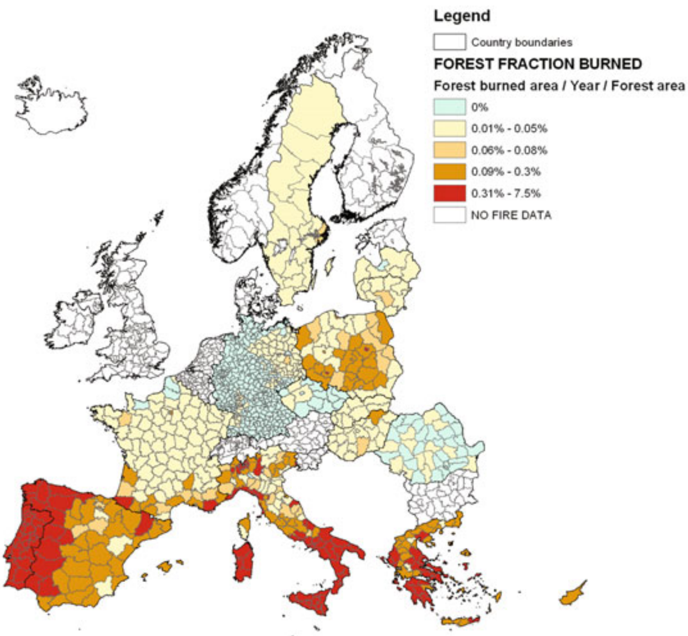


Fig. 2.15. Forest fraction burned map (source: EFFIS, 2011)

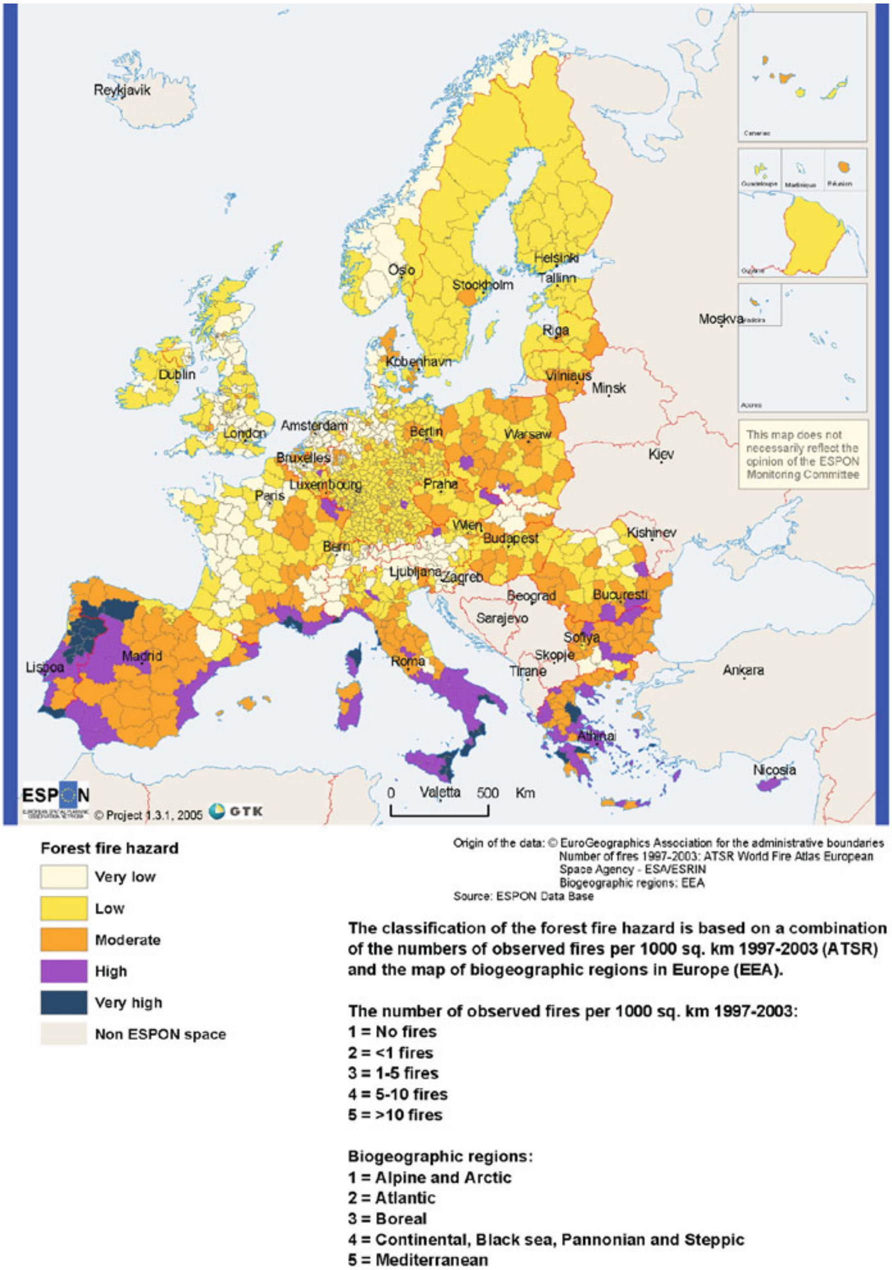


Fig. 2.16. ESPON's forest fire hazard map based on fire density map based on burned forest fraction hazard map

was then calculated as the sum of the vegetation zone class and the forest fire class, providing an output in agreement with ESPON's results.

2.2.3 Current Detectable Patterns of Climate Change Effects

Climate[1] is a sophisticated and abstract scientific concept which cannot be perceived directly, while actual weather events are indeed individually perceptible. Climate change is an inherent process for the entire earth. Concerning geological times, manifold factors control the climate system. External factors, such as solar energy flux, volcanism and Milankovic (1941) cycles (periodicities of orbital parameters, i.e. changes in eccentricity of earth's orbit or obliquity of earth's axis) force earth's climate on geological time scales and are beyond humanity's control. On the other hand, increasing human interference with earth's climate during the last 150 years is now widely accepted (IPCC, 2007a) and therefore can be seen as an internal factor. The central root cause of global warming is the release of greenhouse gases (GHG), mainly carbon dioxide, which are due to human activities (IPCC, 2007a). The warming effect of GHG has been well known since the middle of the 19th century (Tyndall, 1861). Atmospheric CO_2 concentrations from the last approximately 800,000 years have been reconstructed from ice cores, cf. Siegenthaler et al. 2005; Petit et al. 1999; cf. Fig. 2.17), showing that it is now approaching 383 ppm, approximately 200 ppm above the average of 180 ppm for glacial and approximately 100 ppm above the average of 280 ppm[2] for interglacial. 1850 was an interglacial and currently we are living in an interglacial, too. The associated temperature curve behaves in a similar way[3] to CO_2 concentration, making it clear that on historical time scales both are in an equilibrium. Now human interference comes into play. During a very short episode of approximately 150 years humankind increased atmospheric CO_2 concentration by more than 35% to a current value of 383 ppm. With respect to the underlying physics, it is very likely that temperature will increase in general. Regarding precipitation, we anticipate an overall increase as well, but with regional variations.

Regarding human interference, Stott et al. (2004) mention that it is very likely that global warming will impose additional threats of extreme weather events, although restrictions for prognoses exist. These are due to the instability of the climate system with respect to its initial state, the stochastic forcing by short-term weather variability and the superposition of volcanic, orbital and anthropogenic forcing. In particular, the latter is important (IPCC, 2001), since the main uncertainty about climate development for the next century depends mainly on humankind's behaviour itself, not on the lack of knowledge about the physical laws governing earth's climate system (Fig. 2.18).

[1] Climate is defined as the 30-yr average of weather.

[2] This was also the preindustrial value, i.e. valid until the middle of the 19th century.

[3] Atmospheric CO_2 concentration and global mean temperature are both externally forced by, e.g. the Milankovic cycles, but they are also dependent variables with complicated feedback loops.

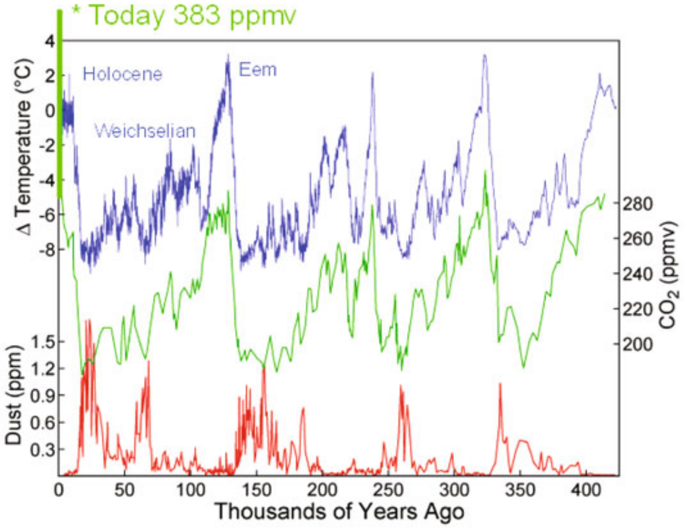


Fig. 2.17. Temperature, CO_2 and dust reconstruction for the last 400,000 yrs from the Vostok ice core (after Petit et al. 1999) showing the switching between glacial and interglacials. Recently the length of this climate proxy was enlarged to 800,000yrs (EPICA project)

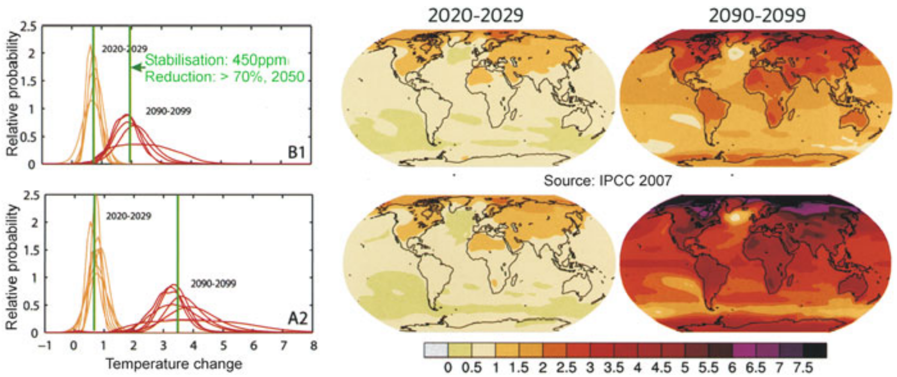


Fig. 2.18. Development of earth's climate for two different anthropogenic forcing. Global mean temperature around 2020 will be the same for both forcing since the greenhouse gases responsible for this development are already released. In case of the B1 forcing it will be possible to approach the 2°C target proposed by the European Union (from IPCC, 2007a)

Drought

As stated by Lavalle et al. (2006) and as agreed by the research community, "drought and water scarcity can be viewed from many aspects. Besides a lack of precipitation (meteorological drought) and a reduction in river discharge and water levels in lakes and reservoirs (hydrological drought), deficits in soil moisture give an integrative indication of a water stress situation at the land surface (soil moisture drought), as they combine the input and output of water by precipitation and runoff as well as the response of vegetation to a limited availability of water". As a consequence, drought hazard maps are based on different hazard parameters that make them difficult to compare. In fact, at the moment, comparable data on any of the three types of drought are not available for the entire European territory.

In the absence of a unique agreed-upon drought index, attempts have been made in order to map drought hazard at a European level. For example, the European Potential Drought Hazard Map (Barredo et al. 2005a, see Fig. 2.19) describes the likelihood of soil moisture deficits for 25 member states of the European Union (plus the two accession countries Romania and Bulgaria) at the administrative NUTS-3 level. Data were generated by model runs of the distributed hydrological model LISFLOOD that was driven by meteorological products of the ERA40 dataset of the European Centre for Medium-Range Weather Forecast (ECMWF).

South-Eastern Spain, Southern Portugal, Southern Italy (including Sardinia), Southern Greece, Eastern Romania and Bulgaria are the areas most affected by soil moisture deficits.

To a lesser extent, Hungary, Southern France and parts of South-Eastern Great Britain are areas prone to soil moisture deficits.

Within ESPON project 1.3.1 (see Fig. 2.19), precipitation scarcity was the selected indicator to produce a map displaying 100-year-long drought records at the NUTS-3 level. Available data are not enough to predict future areas that might be hit by droughts but it supplies a general overview at a European level.

Even with those limitations, ESPON's map shows interesting elements (Fig. 2.20). For example, in some Southern Europe regions (e.g. South Italy) usually associated with droughts, the situation looks less dramatic than others in the context of the Mediterranean basin, prone to a wide variety of potential drought levels (Portugal and Western Spain with the largest potential). This is probably because the drought problem in these areas is not directly related to precipitation but to other reasons not considered in the map, such as mismanagement or obsolete infrastructures. On the other hand, when precipitation index is considered, Northern European regions are also affected, even though they are not usually considered "at risk".

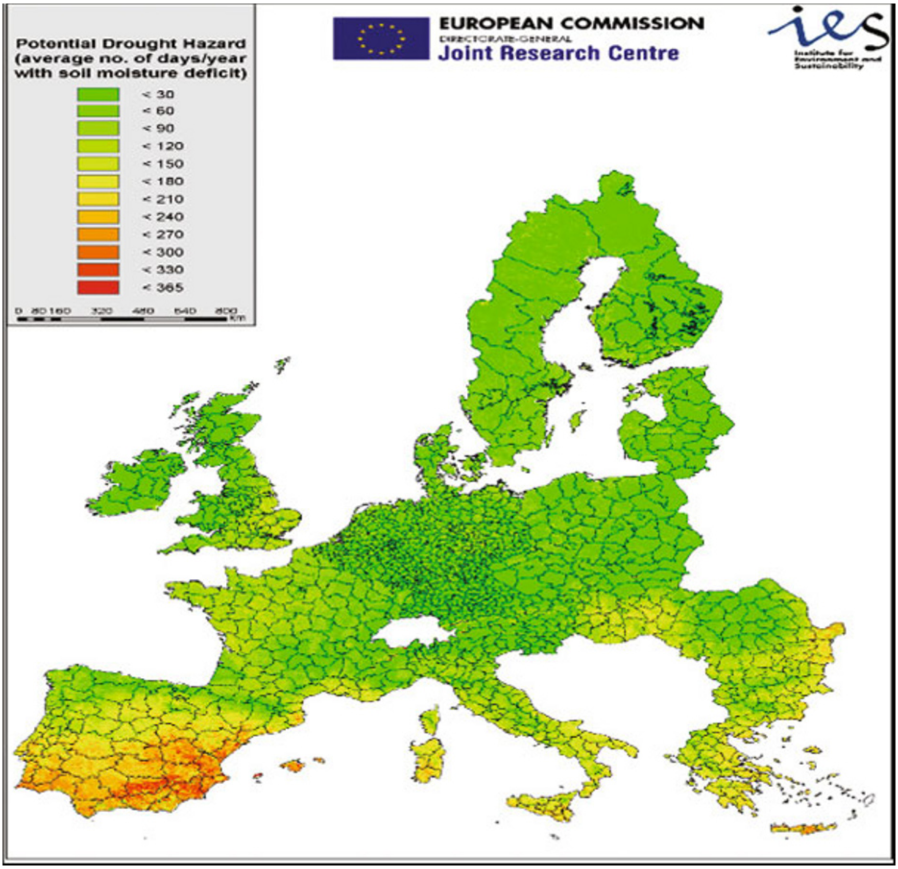


Fig. 2.19. European potential drought hazard map (Barredo et al. 2005a)

Sea-Level Rise

Sea-level rise, as coastal erosion, is a slow event that displays its consequences over long periods. At the European level, a number of research centres, organisations and projects have been funded with the goal of monitoring and studying the phenomenon, but hazard assessment is still at an embryonic stage. Regarding hazard mapping then, the research is even less developed. A first attempt has been made by the EUROSION project presenting data recorded by various monitoring centres. Fig. 2.21 reports the map. It shows that the phenomenon is relevant for the entire European coast.

Glacial Hazards

There are a variety of hazards characterising glaciated and recently deglaciated terrain (see, for example, Björnsson, 2004; Hewitt, 2004). Glacier floods due to lake outbursts or the sudden draining of internal water pock-

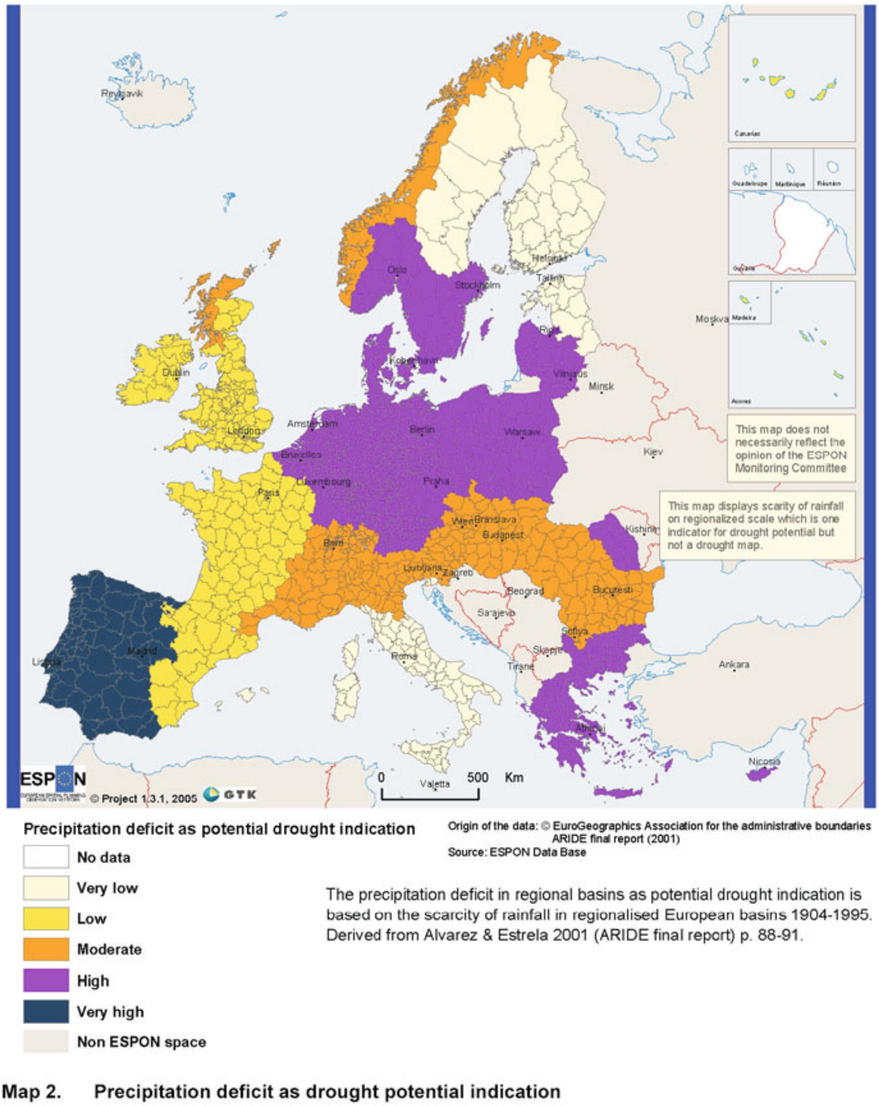


Fig. 2.20. Drought hazard map (source: ESPON, 1.3.1, 2006)

ets, and devastating ice avalanches are highly dangerous because they are notoriously difficult to predict. With the current recession of glaciers, such catastrophic events are likely in the Alps and in mountainous areas elsewhere in Europe. Knowledge and awareness of glacier risks has often been based on experience of historic events; an approach that has gradually been recognised as limited, given that varying environmental conditions can produce

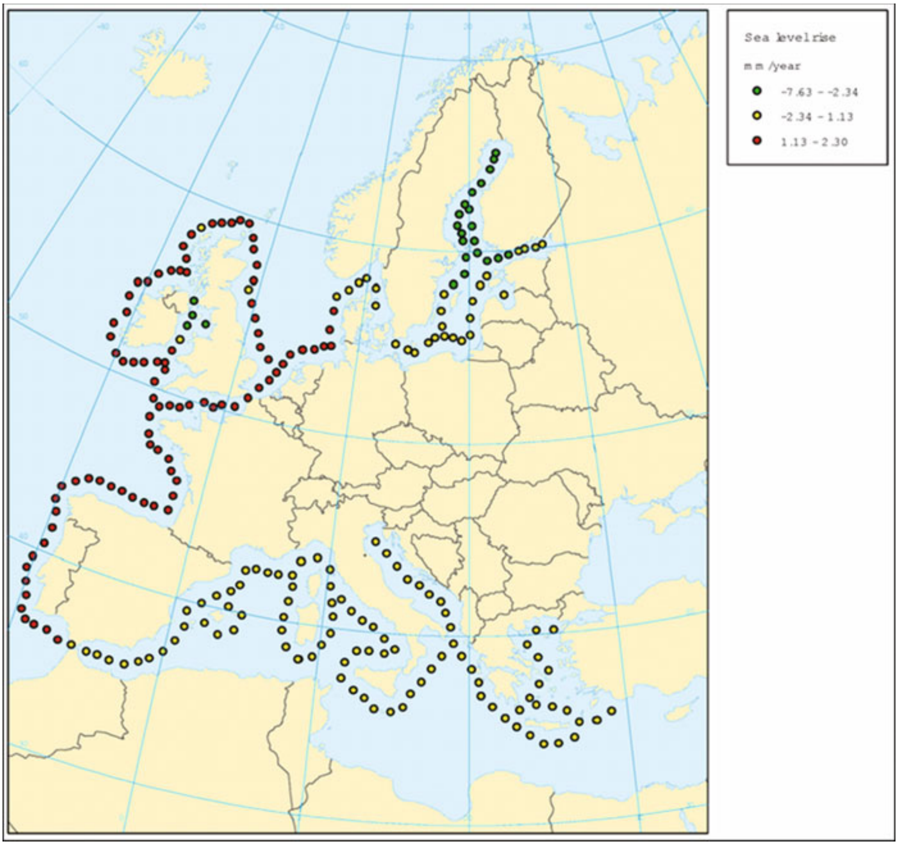


Fig. 2.21. Sea-level rise in the last two decades (source: EUROSION Project)

such events without any historic precedent. This is particularly significant in view of changing climate.

Climate change exerts powerful controls on glacial hazards. Mountain environments are particularly prone to changes in environmental boundary conditions, and climate change is already having implications for the formation of landslide and moraine dams and thus the potential for glacial floods as well as increased danger of snow and ice avalanching in some locations. The melting of glaciers not only creates the potential for the development of landslide- and moraine-dammed lakes (e.g. Korup and Tweed, 2007; Richardson and Reynolds, 2000), it also promotes paraglacial slope adjustment, especially where debris bodies and rock walls lose internal cohesion through melting ice cores and degrading permafrost (e.g. Ballantyne, 2002). Supraglacial lakes are becoming increasingly common and the development and drainage of periglacial lakes presents an additional threat (e.g. Haeberli et al. 2001). Maintained negative glacier mass balances contribute to more frequent ice fall and avalanches from hanging glaciers, raising the potential for catastrophic displacement waves in glacial lakes. A spatial corollary of this is that the impact of ice- and moraine-dam breaks is predicted to be most prominent in alpine headwaters subject to dynamic glacial fluctuations, whereas impacts related to climate-driven landslide dams can be more randomly distributed within a given catchment (Korup and Tweed, 2007).

Risks from some glacial hazards are increasing in locations such as the European Alps, the Nordic countries and Iceland. Numerous research institutes and organisations across Europe conduct research on glacial hazards. Work on such hazards also occurs as part of the civil protection strategies of specific nations (e.g. Iceland, Norway) and as part of academic research projects frequently reported by groups such as the International Glaciological Society. Glacial hazards have been considered as part of thematically wider European research projects (for example, examination of seismic signals as a prelude to volcanic activity, which subsequently triggers glacial outburst floods, featured as part of the FP5 project RETINA and the FP6 FORESIGHT project). There are, however, several projects that have focused specifically on glacial hazards and risks. For example, the objective of the EC FP5 GLACIORISK project (Survey and Prevention of Extreme Glaciological Hazards in European Mountainous Regions) was to develop scientific studies for detection, survey and prevention of future glacial disasters in Europe. Specifically, the project aimed to create a precise inventory of all potentially dangerous sites in Europe, to improve the scientific knowledge about glacial hazards by carrying out field investigations and numerical simulations on selected representative sites, and to provide guidelines for detection, prevention and mitigation of this type of risk (Richard and Gay, 2004). GLACIORISK identified six countries primarily at risk from glacier hazards: France, Switzerland, Italy and Austria in the Alps; and Norway and Iceland in Northern Europe. The project defined six types of glacier hazard applicable to these areas (see Table 2.4), presented a case-by-case scientific study of glacial hazards in Europe and identified seven key glacier risk sites (see Table 2.5).

The EC FP6 project GALAHAD (Advanced Remote Monitoring Techniques for Glaciers, Avalanches and Landslides Hazard Mitigation) addressed landslides, avalanches and glacier-related hazard mitigation, through the development of advanced monitoring techniques and the improvement of forecasting methods and tools. It aimed to reduce risk by using increased forecasting capacity to improve the effectiveness of pre-disaster management through advanced techniques for remote terrestrial monitoring. The supraglacial lake on glacier Belvedere, Italy, identified as one of the key glacier hazard sites in Europe by the GLACIORISK project (see Table 2.5), was a test site for monitoring in the GALAHAD project.

The focus of research on glacial hazards at European level has concentrated on identifying hazardous locations, gaining insight into the processes triggering glacial hazards and understanding the likely impacts. There has also been

Table 2.4. Glacier hazards in Europe (from the GLACIORISK project)

a) Glacial lakes dammed by unstable ice-cored moraine complexes, which are prone to catastrophic drainage (GLOFS)
b) Jökulhlaups due to sudden draining of internal water pockets or ice-marginal drainage from ice-dammed lakes
c) Low angle debris-covered glacier tongues on the threshold for formation of glacier-wide lakes (can form rapidly – 10 yrs)
d) Ice avalanches impacting directly, or transforming into debris flows
e) Failure of saturated glacial sediments, becoming debris flows
f) Catastrophic rock avalanches (sturzstroms), the most destructive type of landslide, triggered by earthquakes or melting permafrost in glacier headwalls. Slope stability problems associated with degrading permafrost are prevalent in the European Alps.

Table 2.5. Most dangerous sites in Europe identified as part of the GLACIORISK project

Glacier	*Country*	*Glacial hazard*
Belvedere	Italy	Drainage of a supraglacial lake
Arsine	France	Drainage of a proglacial lake
Rochemelon	France	Drainage of a proglacial lake
Taconnaz	France	Serac falls (triggering snow or ice avalanches)
Mönch	Switzerland	Serac falls (triggering snow or ice avalanches)
Jostedalsbreen	Norway	Length change (creation of temporary dams)
Grimsvötn	Iceland	Jökulhlaups

work on monitoring and improving predictive capacity through hazard forecasting. Research projects have identified that, until very recently, potentially dangerous sites such as moraine-dammed lakes have not been systematically surveyed or inventoried, suggesting that some communities in Europe might be exposed to glacial hazards without being conscious of them and without any management strategies or evacuation plans. Projects such as GLACIORISK have begun to remedy this situation, but more work is required to establish the extent of future risks from glacier hazards in Europe. Seeking appropriate management strategies and sustainable mitigation tools for environments prone to glacial hazards is critical, particularly given the backdrop of changing climate, the sensitivity of glacial environments, changing vulnerabilities and the inadequacy of many approaches to date.

2.2.4 Multi-Risk Images

As the Hotspots project carried out by the World Bank has demonstrated (see Dilley et al. 2005), areas exposed to multiple hazards are more frequent than commonly accepted or thought of. In fact, when the focus of analyses are territories at risk rather than individual hazards, as has been the case until recently, one comes to recognise the fact that some areas may be exposed to a variety of threats, for which both prevention measures and emergency plans must be foreseen and prepared.

As research developed until now has mainly focused on sectoral hazards analysis, there have been few attempts to consider multi-hazard and multi-risk approaches. A distinction should be made between the latter two definitions, with multi-hazards referring to the presence of more than one natural hazard in a given area, and multi-risk referring to the total damage that may derive from the occurrence of several independent events or from the combination of one or more hazards in one particularly unfortunate occurrence.

There are not many theoretical approaches available in the field. Deliverable 3.1 of the ARMONIA Project provides an extensive overview of what has been produced in Europe and worldwide with respect to multiple risks assessments. Among the European projects that have used this type of approach, the TEMRAP project can be quoted and the more recent MEDIGRID, constituting a technical platform for treating and combining data related to different hazards.

As for other reasons, a common European vision regarding how a multi-risk study and mitigation plan should be developed does not exist. In the ESPON project an index method was proposed, scoring nations and regions according to mainly subjective judgements regarding the severity and frequency of hazards and exposure levels. Such attempts may be encountered in other subnational initiatives, but they are subject to criticism on the part of scientists as well as of various public bodies (communities, political authorities, agencies involved in mitigation and rescue activities) because of the large room for arbitrary judgement sometimes leading to completely false or biased results. Furthermore, ranking regions and localities this way does not substantially improve what we know about risks in those areas or contribute to finding solutions to minimise and losses.

Other approaches seem more promising, though they are necessarily carried out on a smaller scale, so as to grasp specific aspects of the concerned areas. According to those approaches, hazards affecting the same zone may interact in two ways: first, exposed systems may suffer from either one hazard impact or from another. Therefore expected damage results from the sum of two or more impacts, due to the variety of natural hazards existing in the area of concern. Mitigation strategies must be carefully designed not to reduce resilience to one impact while trying to enhance it with respect to another. A second way in which natural or natural and technological accidents may interact is being interconnected in the same chain of damage and losses, in an individual occurrence. While the scientific community has become more familiar with na-techs, interactions between natural hazards are still perceived as a niche area of study and in many cases models are not available or not universally agreed upon to assess their probability of occurrence and their potential severity. Such na-na events may include landslides provoked by earthquakes, floods worsened by landslide phenomena with solid transport, lahars and landslides as a consequence of volcanic eruptions or after forest fires.

An interesting attempt to carry out a multi-risk assessment has been carried out in the city of Cologne, Germany and is described in Box 2.1.

Box 2.1
Case Study:
Multi-Risk Assessment for the City of Cologne, Germany

Description: Cologne has a population of approximately one million that is exposed to the three hazards of windstorm, flood and earthquake. The aim of the study discussed here (see Grunthal et al. 2006) was to assess the losses in terms of economic damage to these three hazards.

Different hazard types are not comparable because they are described by different strength parameters. For example wind is measured by its speed, floods by discharge or water level and earthquakes by ground motion. Exceedance probabilities for various events were calculated for wind storms, floods and earthquakes. For the hazards to be comparable, the magnitude of different probability events needs to be converted to a measure of damage or loss.

To estimate losses caused by various hazards it is necessary to evaluate the assets that are potentially exposed and to use a uniform database for a consistent risk comparison. The replacement value for buildings and contents in the year 2000 was used for different economic sectors, from which a unit value per land area in Euro per m^2 was calculated. For residential areas the number of buildings, households and cars was multiplied by the corresponding insured average for Cologne. The asset value for postcode areas and Cologne as a whole was determined.

For each of the natural hazards the losses were calculated for a set of events with the potential to cause damage for various distinct exceedance probabilities. The wind storm hazard return period was computed from a 30-year record and extrapolated. A gust factor was computed using an empirical formula since gusts were considered to cause more damage than sustained wind. Losses caused by wind storms were calculated using an empirical damage function.

The flood hazard was assessed using water depth based on the frequency distributions from the Cologne gauge. Depths were then computed for flooding over the city using a 50 m resolution Digital Elevation Model (DEM). The losses were calculated from relationships between water depth and damage.

The earthquake hazard was derived from long-term records of activity in the area, totalling 400 events. Damage curves were produced using 800 buildings that were surveyed and had their earthquake resistance assessed; each building was then assigned a vulnerability class. The losses were estimated from the distribution of damage grades with intensity for each building class.

Vulnerability curves were calculated for each type of hazard. These are shown in Fig. 2.22. These show that for frequent events the damages/economic losses are dominated by windstorms and floods, and for infrequent events damages are greatest in earthquakes. Losses due to flooding do not take into account responses to the hazard such as temporary barriers, early warning, adaptive behaviour and precautionary measures, which can considerably reduce losses.

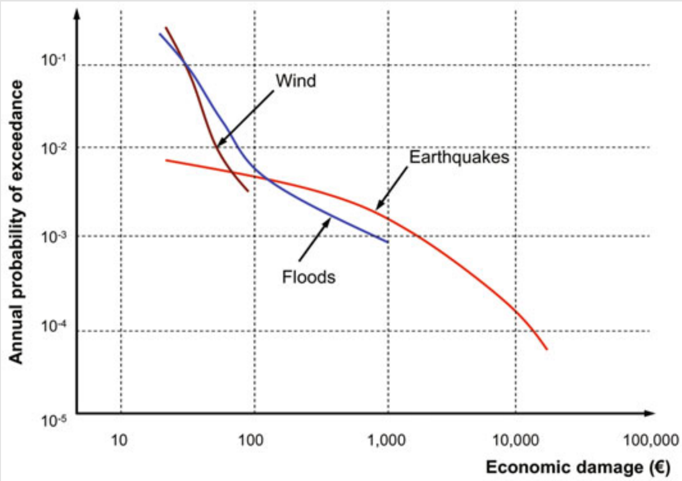


Fig. 2.22. Vulnerability curves for windstorms, floods and earthquakes for the city of Cologne for economic damage to buildings (modified from Grünthal et al. (2006))

Discussion: The vulnerability curves with direct monetary losses as an indicator of risk provide better and more complete information for disaster management than other proxy measures of risk. Multi-risk curves allow the significance of different disaster types to be evaluated using the same units. However, care is required when comparing probable losses due to different hazards since rather different methodologies and assumptions have been used to compute both the hazard distribution and the damage curves. For example, seismic and flood hazard and damage curves for Cologne are much more accurate than for wind hazard, which is based upon one 30-year record.

This method raises awareness and the ability to develop tailor-made mitigation strategies by giving directly comparable risk metrics. However, this approach integrates damage at the highest spatial level. For spatial planning purposes, maps giving expected losses are more useful although this requires a much more detailed spatial resolution of exposure and damage curves. The study also acknowledged the need for uncertainties to be integrated into calculations as the present damage loss graph implies precise values.

Box 2.2.
Multi-Hazards Threaten Istanbul and Turkey

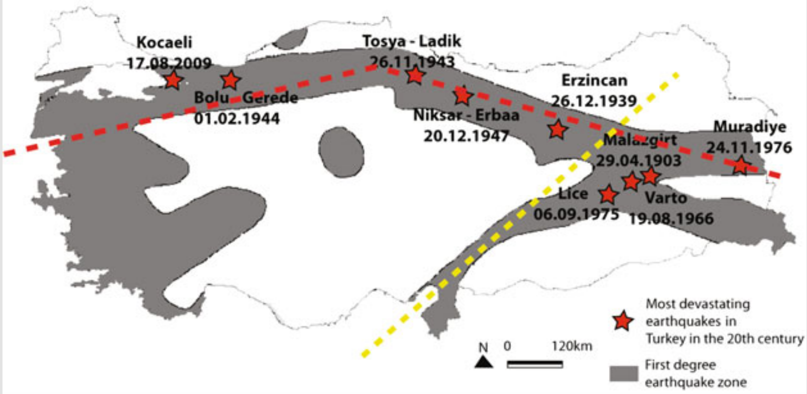
Istanbul is located at the border of South-Eastern Europe, where it represents a major megacity that has constituted a vital bridge between Europe and Asia for centuries. Today it plays a relevant economic and cultural role in the region and connects Turkey with Europe and Western countries in general (Erkut and Ozgen, 2003).

Losses due to severe natural extreme events may provoke significant ripple effects in the region and beyond, as a consequence of the many cross-border links, depending on large flows of capital, people, goods and knowledge (Cappellin and Batey, 1993).

Furthermore, Istanbul constitutes a good example of a megacity threatened by a multiplicity of hazards, both natural and man-made.

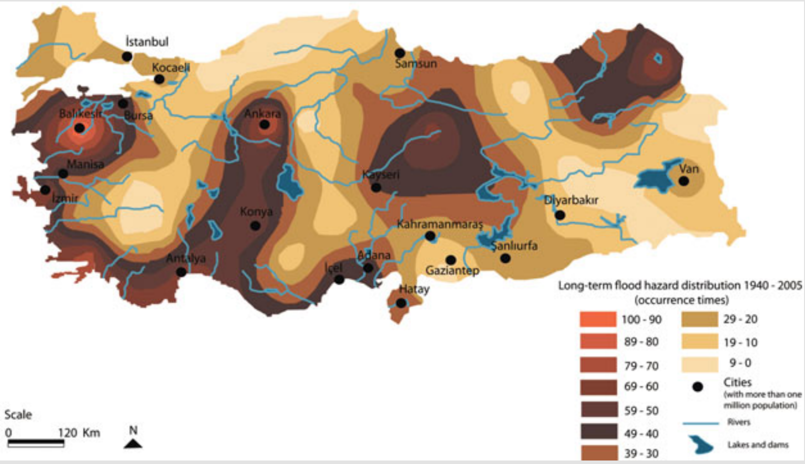
To better understand the probable impacts of disasters, natural threats and different forms of vulnerability should be considered in their mutual relation. In the 1950s, Istanbul experienced a rapid mass urbanisation process the insufficient planning system was not able to face. Large squatter areas arose at the fringes of the city. In several decades, these quarters expanded not only horizontally but also vertically, thanks also to poor administrative regulations and to amnesty laws. Consequently, today it is estimated that more than 60% of the building stock of Istanbul has been developed without building or residential permits. Deficiencies in the physical structure of the city combined with socioeconomic gaps among residents has led to reduced coping capacity in the face of multiple threats.

Map 1 shows how seismicity is distributed in Turkey. Two major faults can be clearly recognised: the North Anatolian Fault (NAF, 1300 km-long), extending parallel to the Black Sea from east to west (the red line in Map 1), running in a southern direction (the yellow line in Map 1). Strong earthquakes have affected Anatolia throughout its history along those two main fault lines. In Map 1, the first degree of seismic zone and the nine most devastating earthquakes that occurred in the 20th century are overlaid. 75,000 people lost their lives in the Kocaeli (1999), Bolu-Gerede (1944), Tosya-Ladik (1943), Niksar-Erbaa (1942), Erzincan (1939), Malazgirt (1903), Muradiye (1976), Lice (1975) and Varto (1966) earthquakes.



Map 1. Seismic map of Turkey – First degree earthquake hazard zone and most devastating earthquakes in 20th century (modified from the earthquake hazard map of General Directorate of Disaster Affairs, Turkey)

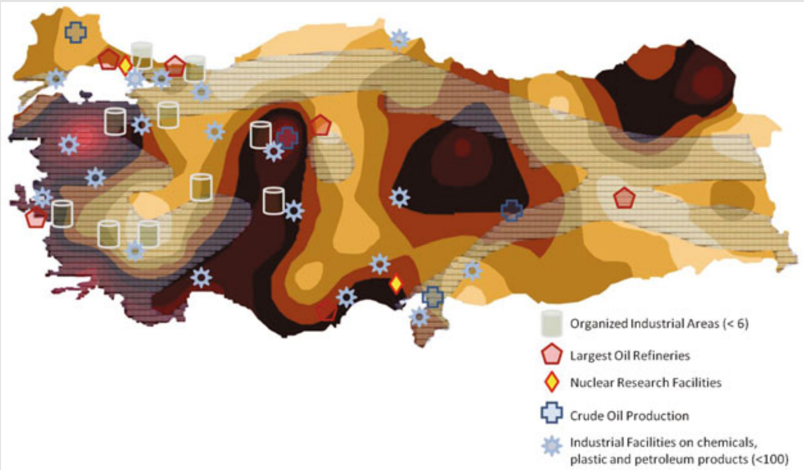
In Map 2 the regional distribution of floods occurring between 1940 and 2005 is given. Flood events are common along the branches of big rivers where urbanisation is higher, such as Istanbul, Kocaeli, Izmir, Antalya and Adana (the cities indicated on the map have a population of more than one million inhabitants). These events are largely due to the misimplementation of river rehabilitation in inner cities by narrowing river basins to provide land to



Map 2. Regional distribution of flood hazards that occurred in Turkey between 1940 and 2005 (modified from Ceylan et al. 2007)

expand settlement. On 9 September 2009, heavy rains lasting one day caused loss of lives and large-scale damage in different parts of Istanbul. The most affected areas were settlements and commercial/industrial facilities near and on the water courses.

In recent decades, natural hazards have not only caused deaths and other losses, but acted as triggers of accidents in industrial facilities. As experienced in the Kocaeli earthquake in 1999, several chemical substances spilled over the gulf, penetrating the soil, and the fire at the TUPRAS Oil Refinery lasted a couple of days. Considering the location of industrial facilities including chemical, plastic and oil facilities, crude oil production, refineries, plants and nuclear research centres, it can be noticed that they are mostly concentrated in the western part of the country, especially in Istanbul (Map 3). Map 3 shows that most of these industrial facilities are located in highly seismic zones and in flood-prone areas. Even though industrial facilities have to comply with specific building codes and safety regulations, deficient maintenance, lack of training of employees against multi-hazards and adjacent land use pattern can be evaluated as key components for the occurrence of a na-tech event.



Map 3. Overlay of flood, earthquake hazard and critical industrial facilities (modified from Ceylan et al. 2007; the earthquake hazard map of General Directorate of Disaster Affairs, Turkey and Database from sanayi.tobb.org.tr)

2.3 Exposure Perspective

In order to understand how the differently distributed hazards described in the previous paragraphs may impact on Europe, it would be necessary to carry out an extensive risk assessment study so as to obtain damage and victim estimates from the combination of hazard and vulnerability of exposed settlements and systems. At present, it is not possible to carry out such an assessment. Nevertheless, previous projects, in the fields of both natural hazards (see in particular ESPON) and spatial planning (related to the European space strategies) provide maps and indicators that may be used for this purpose.

Those data and maps provide some indications relative to exposure (mainly in terms of areas where economic goods, infrastructure and people are concentrated) and vulnerability (as will be discussed in the next paragraph).

Knowing where the largest concentration of people and goods is does not automatically provide an exposure index, which would require the overlay of this data onto the maps of the most hazardous areas.

What can be said comparing hazard and population distribution maps is, for example, that two main European areas pop up in terms of high population density (see Heiling, 2002, Fig. 2.23): Italy, virtually exposed to all natural hazards, and Central Europe, mostly exposed to floods.

The same comparison can be made considering economic aggregate indexes, providing an idea of economic assets and produced income generated in areas exposed to a variety of natural hazards.

It cannot be assumed that the most likely damaged areas are also those with the largest GDP or with the largest share in national and European economy; nevertheless a sort of southern–northern central corridor (in the so called "blue banana") producing more than 125% GDP per capita and contemporarily exposed to large natural risks (in particular floods, storms and to a smaller extent earthquakes in Northern and Central Italy, and in Southern France) can be identified (Fig. 2.25).

Looking at infrastructure, the areas identified as most densely populated are also more networked in terms of roads, railways and energy lines (see in particular high-voltage transmission lines) (Figs. 2.26–2.28). Again any damage forecast must be necessarily based on more detailed and smaller-scale assessments, able to geo-reference information regarding the expected phenomena and the vulnerability of critical networks. Nevertheless what can be seen from those pictures is a high aggregation of the latter in the areas that are mostly populated.

When looking at individual areas, one may recall recent events that struck important facilities with significant repercussions for the capacity to move goods and people across the continent and connecting with global markets. In Table 2.6, airports that were involved in or damaged by a recent event have been reported, detailing the amount of passengers and goods transited in the year 2005.

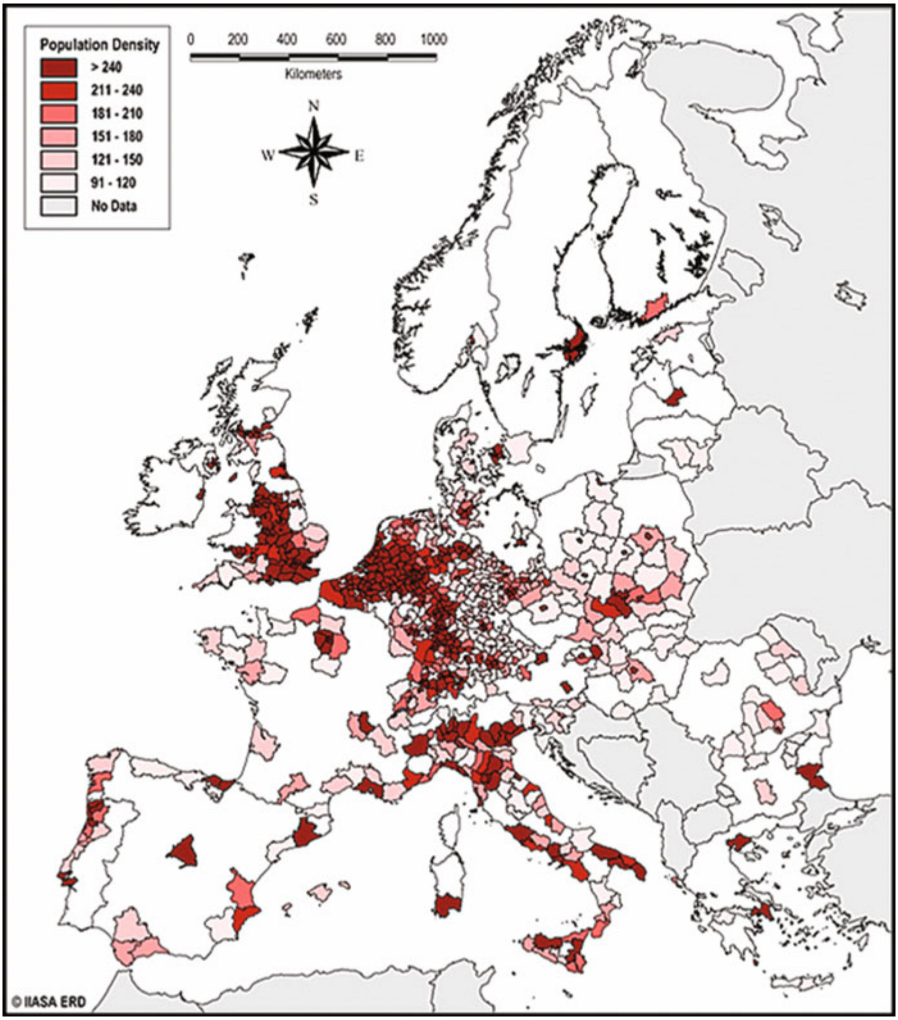


Fig. 2.23. Densely populated areas in Europe (inhabitants per km^2) (Heiling 2002)

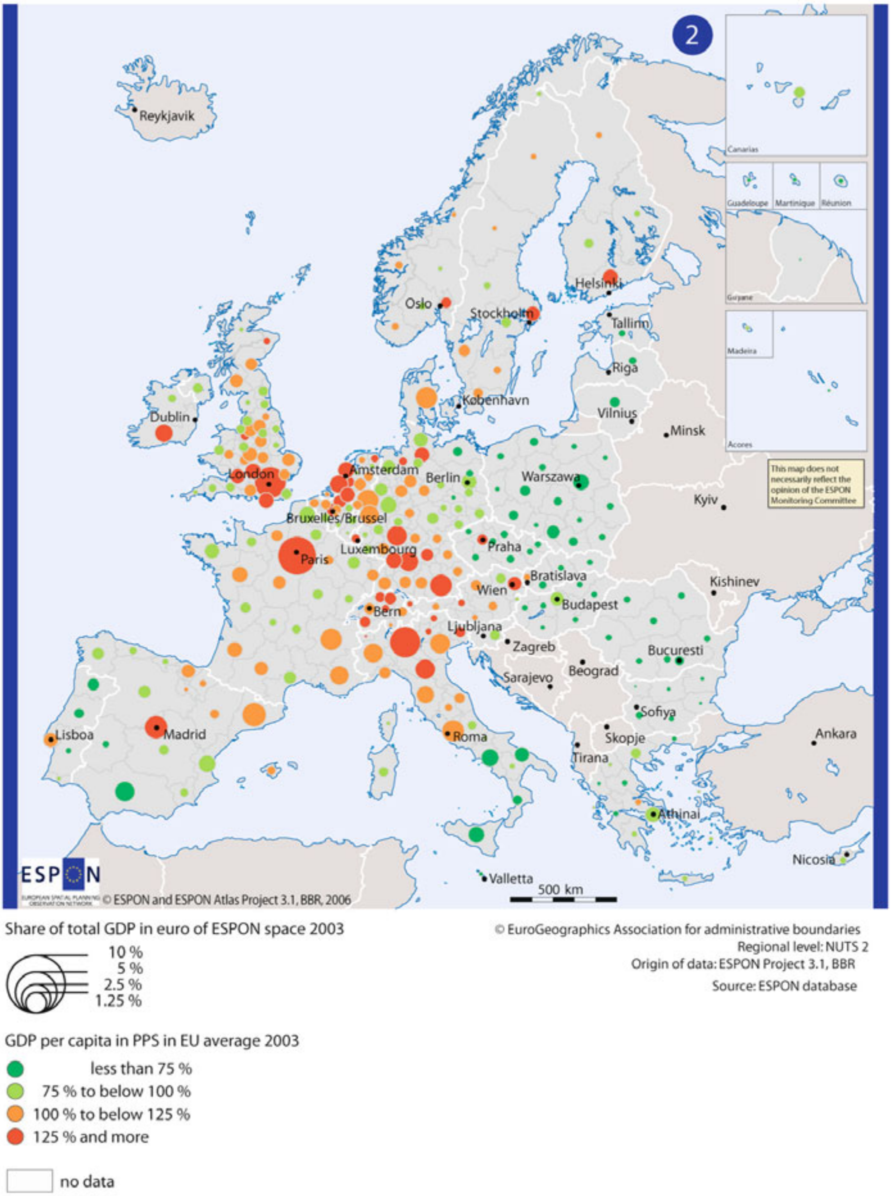


Fig. 2.24. Distribution of regional GDP (source: ESPON, 3.4.2, 2006)

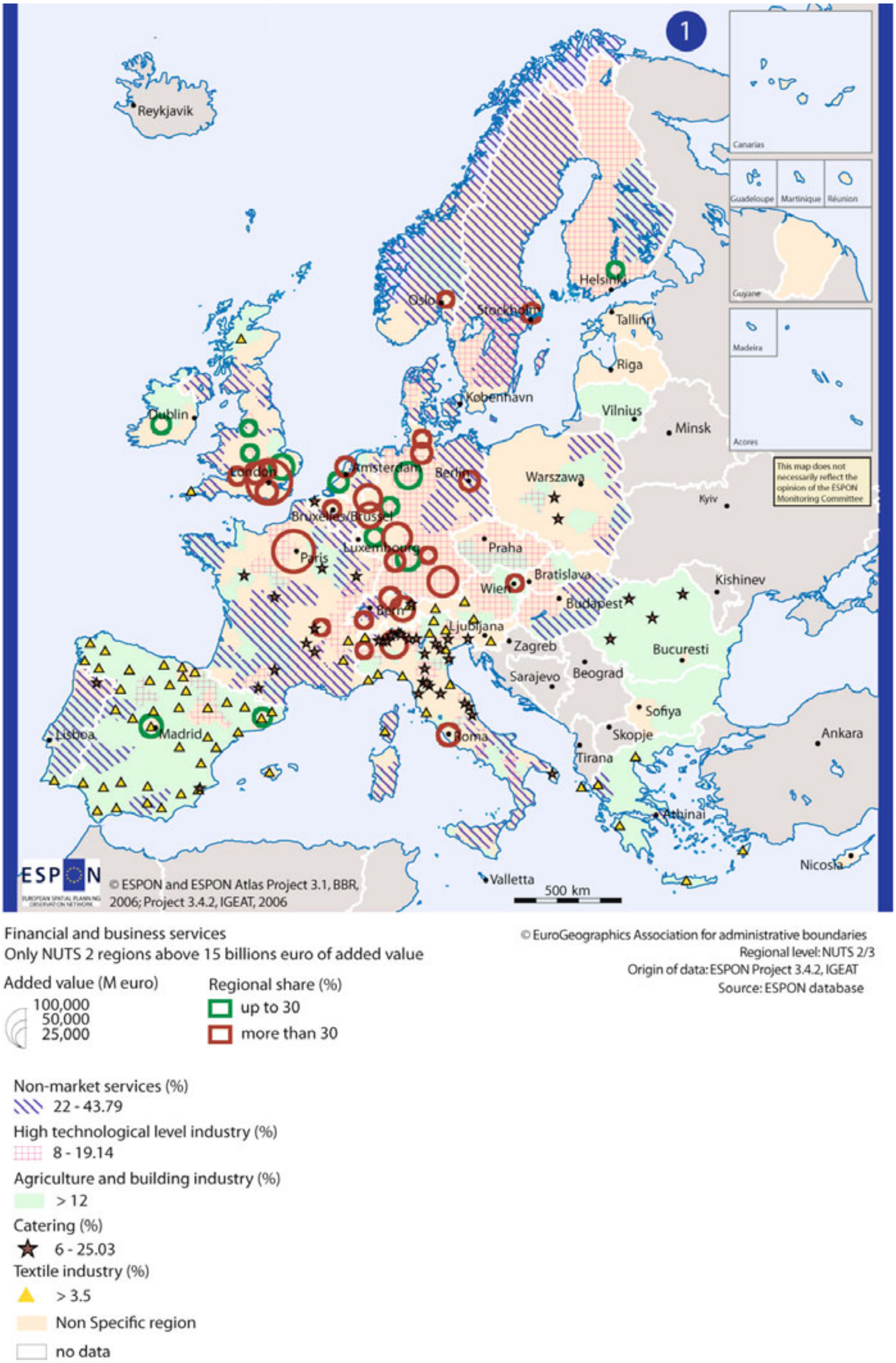


Fig. 2.25. Economic specificities on a regional basis (source: ESPON, 3.4.2, 2006)

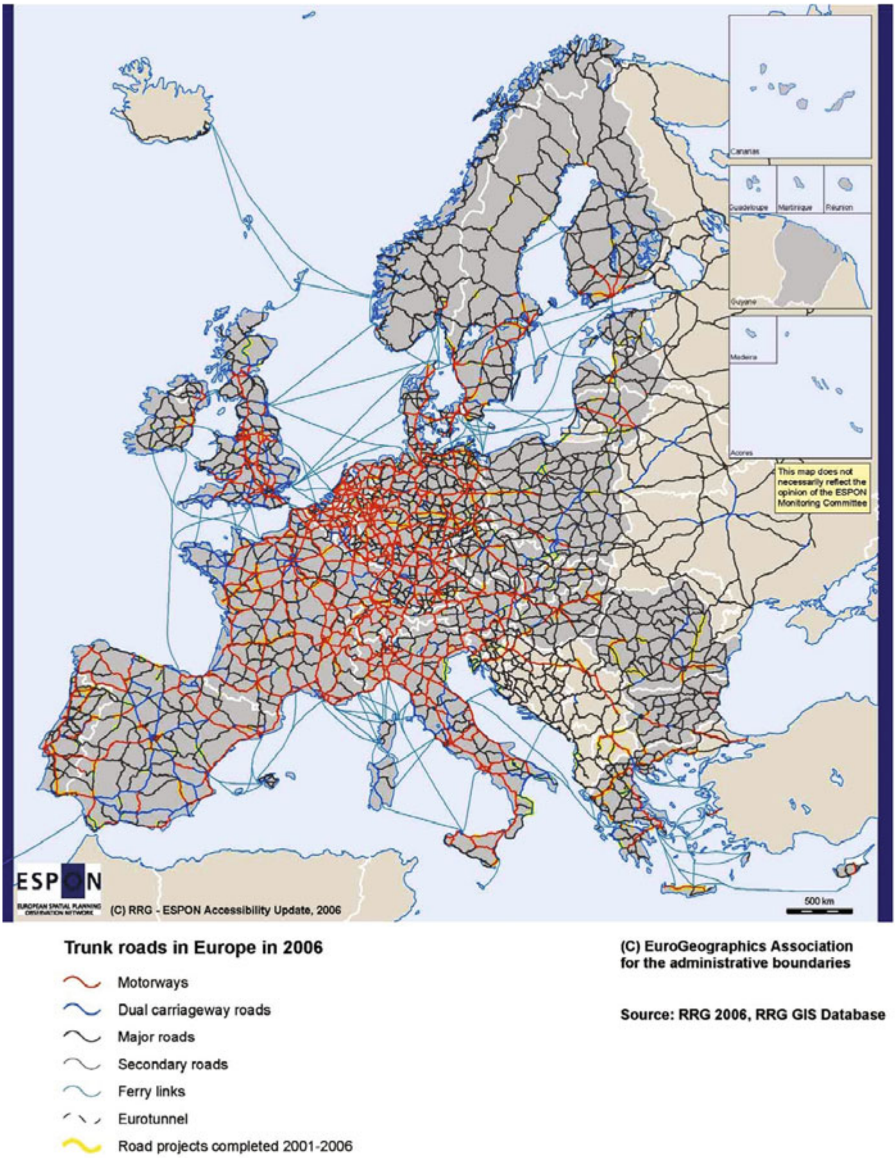


Fig. 2.26. Road network (source: ESPON, 1.2.1, 2006)

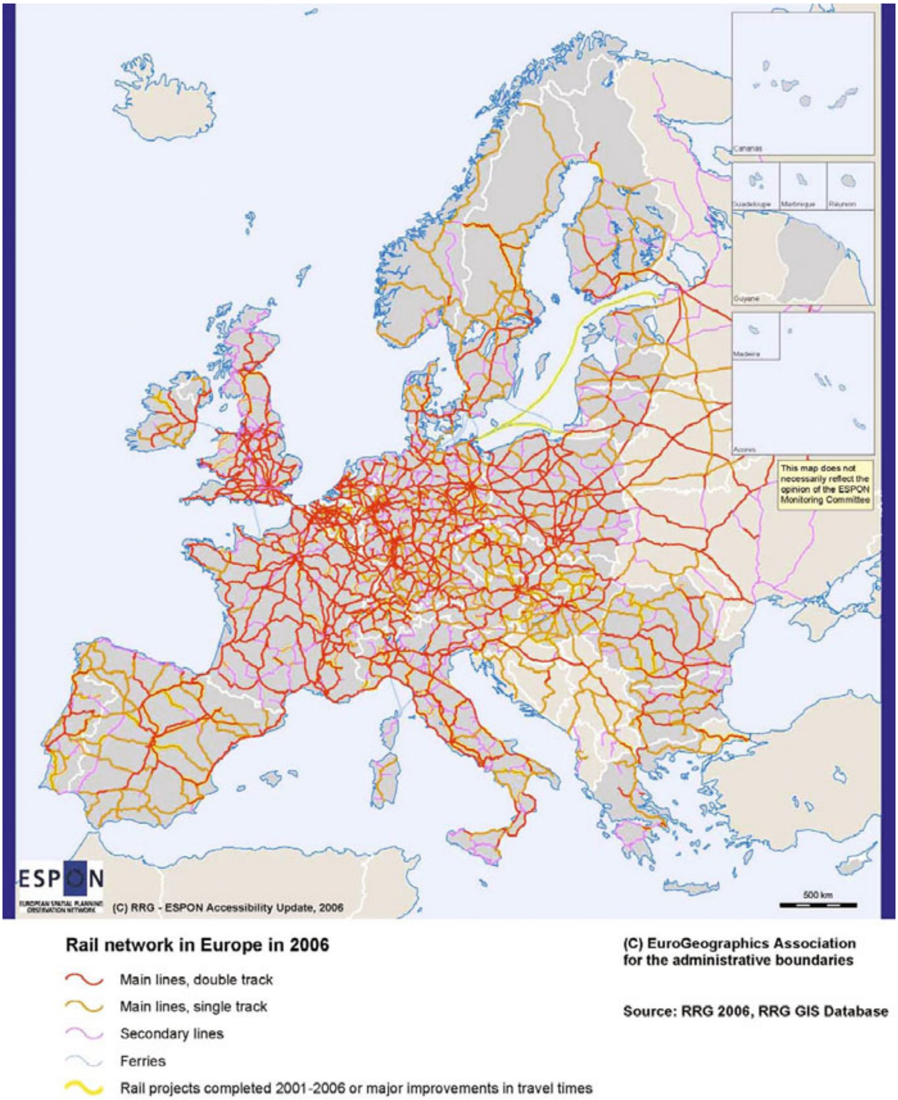


Fig. 2.27. Rail network (source: ESPON, 1.2.1, 2006)

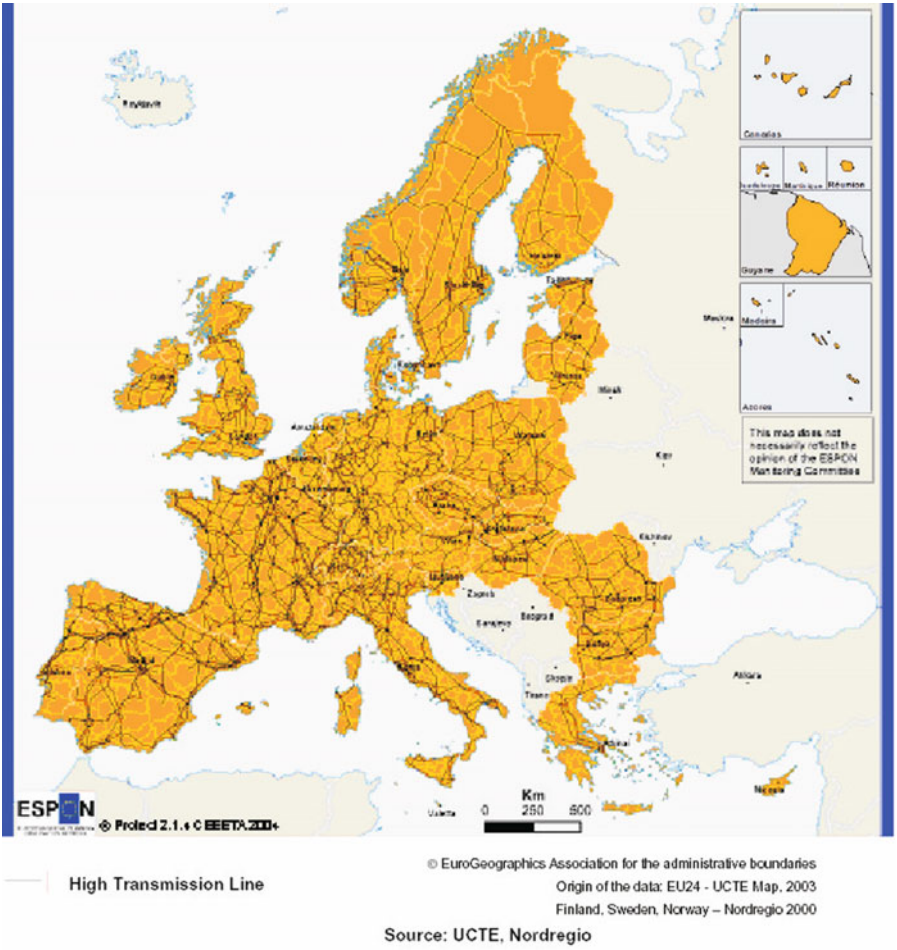


Fig. 2.28. High-voltage transmission lines (source: ESPON, 2.4.1, 2005)

A Special Look at the Historic Sites at Risk

An important aspect of European territory is the widespread presence of cultural sites (like monuments, libraries, churches, etc.). Fortunately, perhaps because of the high public awareness about this topic, a lot of data are available (see ESPON project 1.3.3, 2006). Here, the World Heritage Map (Fig. 2.29) published by UNESCO is displayed as an example. The same UNESCO has launched the project "Cultural heritage at risk", supporting worldwide initiatives aimed at assessing historic sites at risk from natural hazards. Clearly the first step is to integrate local information regarding the latter with the existing ancient monuments or historic centres. A mapping programme in this regard has been started, for example, within Interreg projects developed together by Italian, Greek and Spanish regions in the period 1999–2000.

2.4 Vulnerability Perspective

According to Hilhorst (in Bankoff et al. 2004, p. 53), a new paradigm has emerged during the 1990s, emphasising "the mutuality of hazard and vulnerability to disaster due to complex interactions between nature and society. [...] People, in this view, are not just vulnerable to hazards; but hazards are increasingly the result of human activity. [...] This has the important implication that vulnerability might not just be understood as how people are susceptible to hazards, but can also be considered as a measure of the impact of society on the environment".

Vulnerability is still a term in search of a commonly agreed definition, according to which it will be easier to identify clear indicators, at least partially measurable. As illustrated in the European ARMONIA project, there is a lack of such indicators, even in the simplest field of physical vulnerability, generally restricted to a limited number of objects (buildings and particularly residential buildings with few attempts to tackle public facilities' physical vulnerability) and to a limited number of hazards (mainly seismic hazard, with some recent experimental attempts in the field of volcanic, certain types of landslides and flood hazards).

As discussed in other parts of this research though, vulnerability is a crucial aspect to be considered not only to identify crucial differences among regions and areas equally exposed to the same level of a given hazard, but also to open a wider spectrum of mitigation alternatives, including physical consolidation of structures, reduction of coupled effects due to systemic vulnerability, reinforcement of people's capacity to cope, of civil protection organisations' reliability and coordination, etc.

As there are no universally accepted parameters to assess different types of vulnerability suffered by the built-up environment, the social and the economic system, there are no maps or tables representing European vulnerability to given natural and na-tech hazards.

What can be done at present is to open the floor for future advancements in this field, starting with some representations that already exist regarding features and aspects that can be viewed also in terms of vulnerability.

Another issue should be raised: It makes sense to consider a European perspective only regarding those vulnerabilities that produce ripple effects due to systemic connections, as in the case of some particularly important strategic facilities or plants with severe na-tech potential, lifelines and economic vulnerability of sectors that weigh significantly in the European market; in all other cases, vulnerability is better appraised locally or regionally, depending on the mitigation strategy to be adopted and on the responsible governmental level.

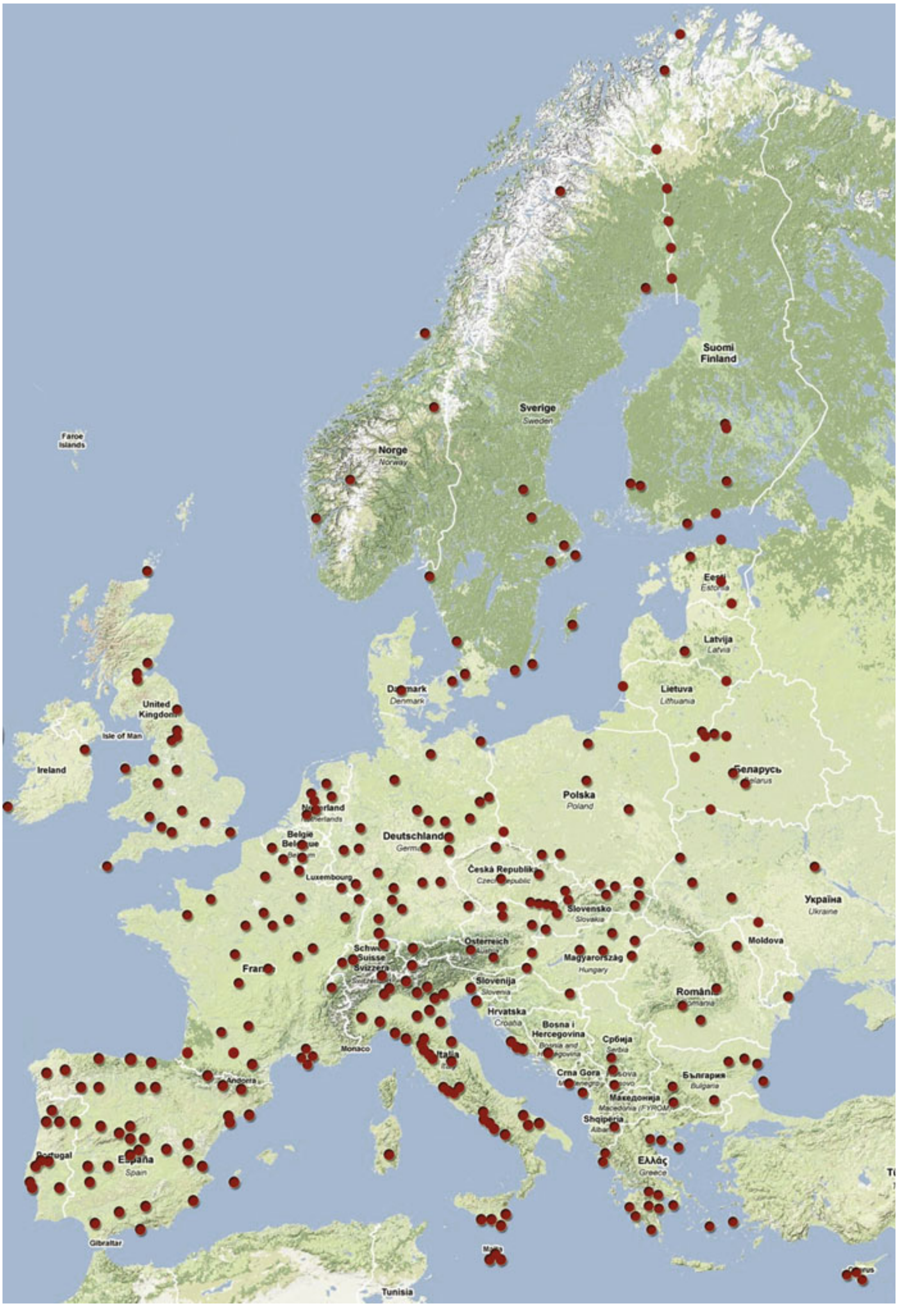


Fig. 2.29. UNESCO built heritage according to UNESCO list (project's own production)

Box 2.3
Case Study V3:
November 2000 Floods (Ireland)

Description: Between Sunday, 5 November and Tuesday, 7 November 2000 significant rainfall resulted in flooding in many areas of Ireland, mainly along the south and east coasts. There were two deaths reported and 436 people, from approximately three hundred properties, remained homeless during the flood event. Transport and power utilities were also seriously damaged. Lots of customers were without energy supply for hour/days. Some bridges were declared unfit for use while roads and railways were interrupted at different points. Consequently, some villages, harbours and suburbs were isolated. Even though the event hit a wide area and was very intensive (hazard), damages (risk) could have been limited if the emergency response had been more efficient (vulnerability). Actually, major damages were caused by the incapacity of the emergency services to cope with the event.

Discussion: Vulnerability is, in this case, the incapacity of the damaged areas to stand up to event, meaning to cope with the consequences of the flooding and reduce their negative effects. We can distinguish here between various kinds of vulnerability:

Organisational Vulnerability: Emergency response was slow in areas without an emergency plan and here it met with difficulties. For example, lots of people did not get sandbags or pumps in time to limit damage at their houses, some of the information given to the public was misleading and some people did not get any information at all. This could have been avoided if an emergency plan had been in place. The need for planning on a regional scale also became apparent. In fact, there was no coordination between first-aiders, emergency services, local authorities and service providers so nobody set up a viability plan to deal with disruptions in road and rail infrastructures. Some cities were not linked to each other for days.

Systemic Vulnerability: This depends on the degree of interdependence between damaged areas. As an example, in this case ambulances could not reach some areas because of the disruptions to roads and approximately five thousand customers were without energy supply because of damage to the substation in Dublin. It is meaningful that immediately after the end of the emergency, the Blood Transfusion Service issued an urgent appeal for donors. In fact, because of the flood, its mobile units were not able to travel, resulting in a shortage of blood, which put surgical operations at risk.

2.4.1 Physical Vulnerability Relevant at the EU Level

It would be relevant to find maps representing the main industries under the Seveso Directive, as they can be involved in a na-tech event (triggered by landslides, floods, earthquakes or volcanoes). Maps in Figs. 2.30 and 2.31 display the localisation of nuclear plants and refineries; other aspects that may be useful to consider are the major technological accidents in the period 1998–2002 and large oil spills in the period 1970–2001 (Figs. 2.32 and 2.33).

Clearly none of those indicate how vulneragle those elements are to damage in case of a natural extreme event, nevertheless those are crucial plants to be taken into account in a future assessment as the potential consequence of a na-tech in one of those facilities may provoke severe and extensive damage potential with consequences for the wholle of Europe (at least in terms of risk perception and legislative disaster-triggered innovation).

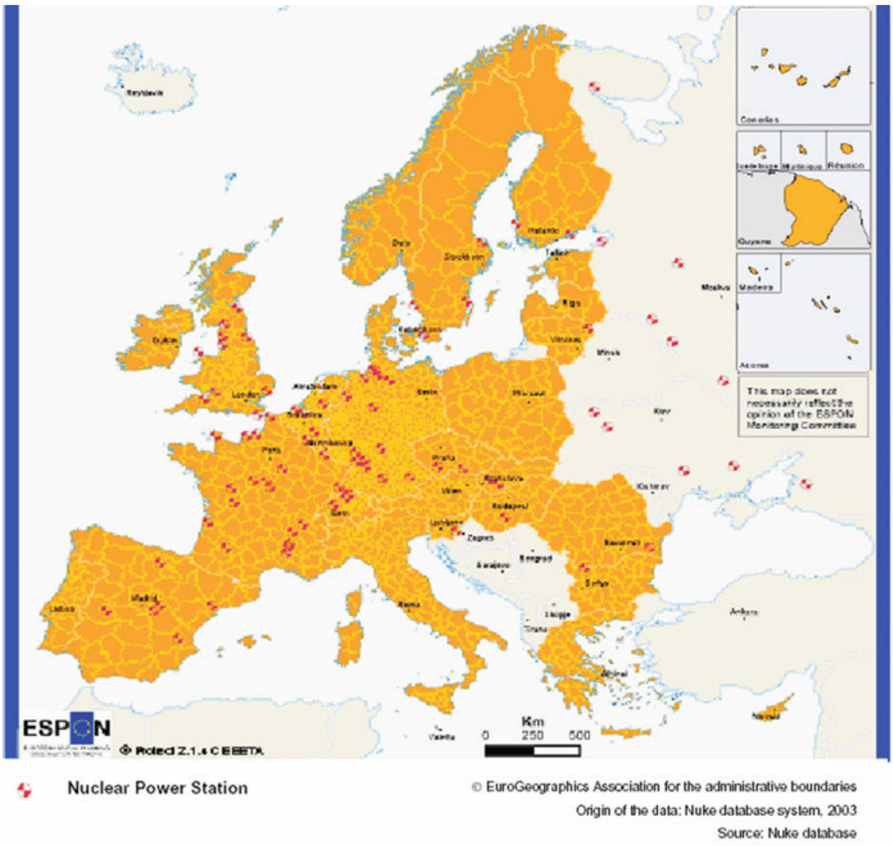


Fig. 2.30. Location of nuclear plants (source: ESPON, 2.4.1, 2005)

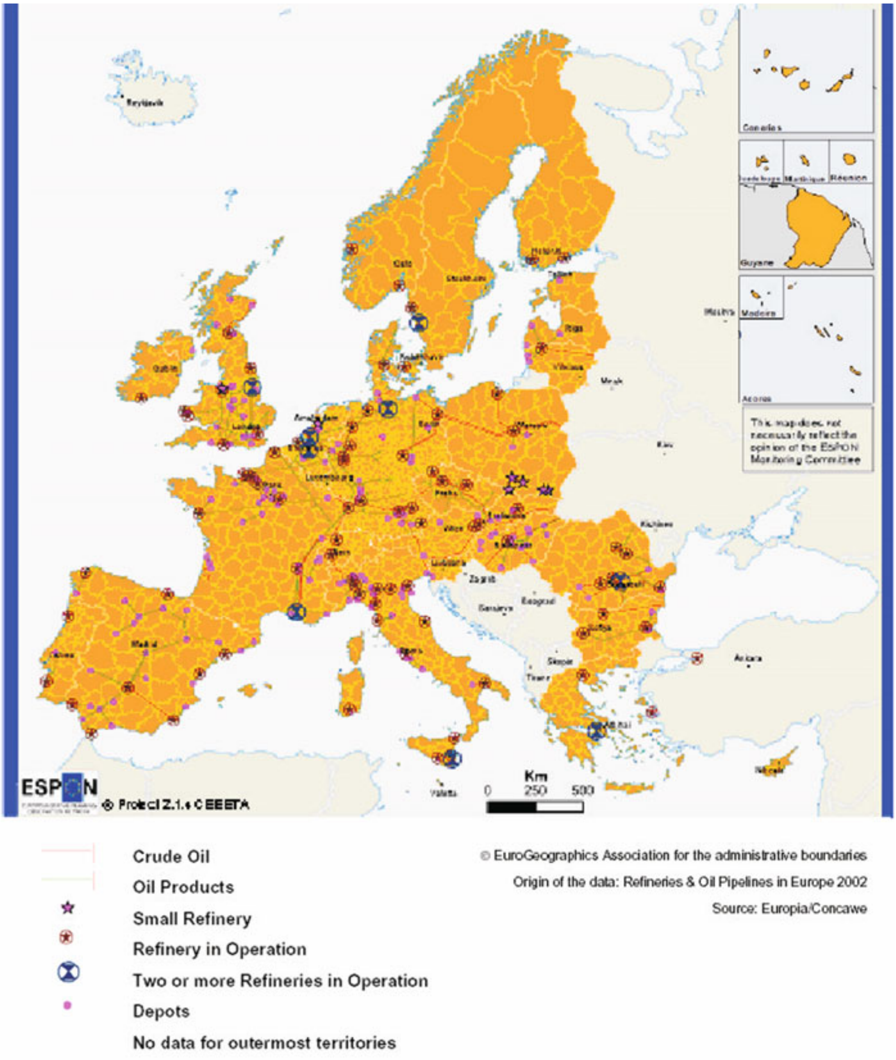


Fig. 2.31. Location of refineries (source: ESPON, 2.4.1, 2005)

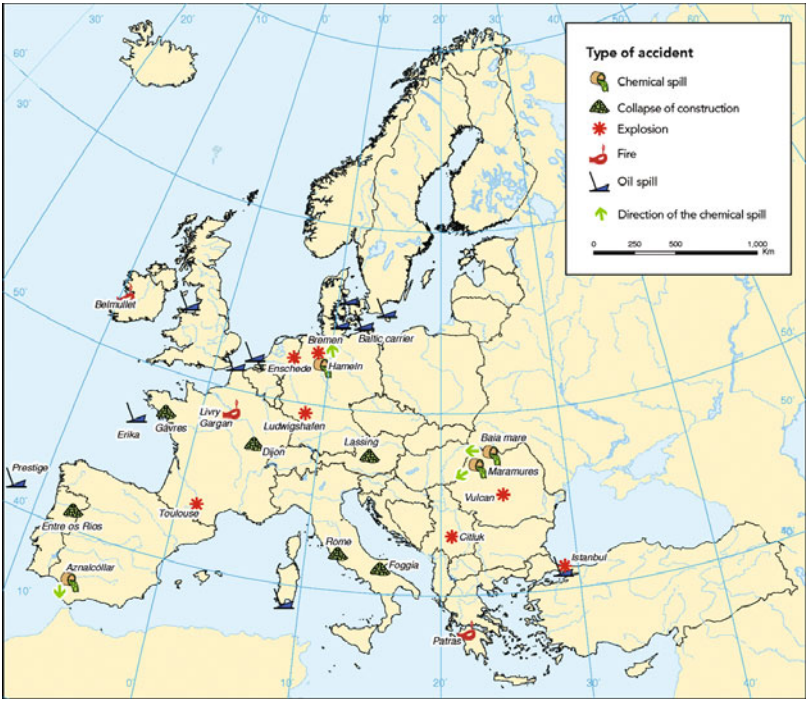


Fig. 2.32. Major technological accidents 1998–2002 (source: ESPON, 1.3.1, 2006)

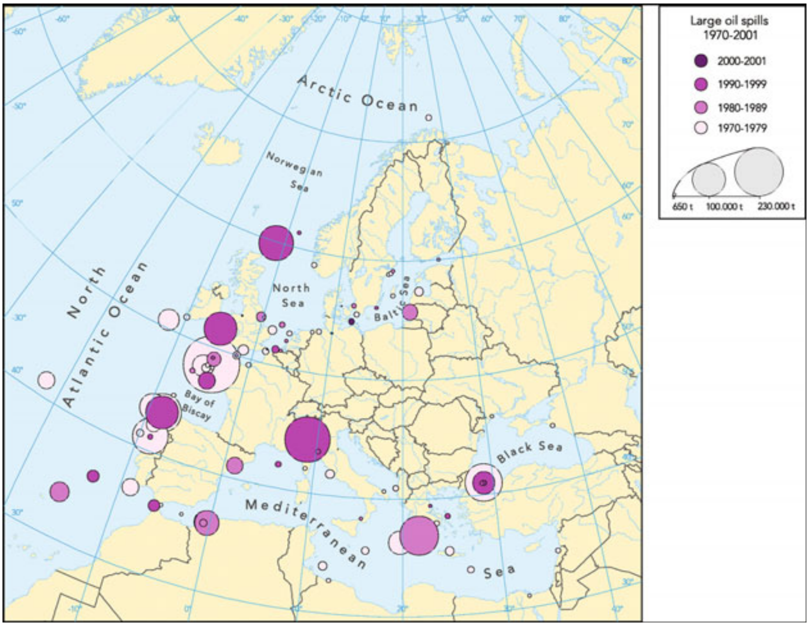


Fig. 2.33. Large oil spills 1970–2001 (source: ESPON, 1.3.1, 2006)

Box 2.4
Case Study:
Na-Tech Event; CSG Sandhurst, Gloucester, UK:
20 October–14 December 2000

Description: On 20 October 2000 a fire of uncertain origin occurred at a licensed waste management site in Gloucestershire UK. During the fire over 180 tonnes of organic solvents were ignited and burned for 16 hours. Sixty people were evacuated for their safety. On 3 November, during the clean-up operation, the fire-damaged site was inundated by flood waters from the adjacent River Severn (Fig. 2.34). Flooding returned throughout November and into December, mobilising toxic pollutants and hampering the on-site clean-up of licensed waste material as well as unlicensed BSE-contaminated and radiological waste (EA, 2001).

Fig. 2.34. Flood in the Gloucester area (source: picturenation.co.uk)

This combination of hazards resulted in a na-tech event where the effects of a technological hazard (the waste facility fire) were exacerbated by those of a natural hazard (the flood) occurring with spatial and temporal coincidence. In this case it is appropriate to use the ARMONIA (2006) definition in relation to both hazards i.e. as "a potentially damaging physical event, phenomenon or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its timing, location, intensity and probability."

Discussion: In this case the operators of the waste treatment facility had retained licenses despite previous enforcement actions over poor materials handling practices and local concern over the operation's effects on public health (Sharpley, 2003). Additionally, the proximity of the facility to a main water course resulted in the site's quantifiable exposure to a flood hazard event which, unfortunately, occurred at the worst possible time. The events were regarded as "extraordinary" by the authorities (EA and HSE, undated: 38) despite the acknowledgement that some poor management practice persisted throughout a relatively high number of inspection visits and enforcement procedures (e.g. in relation to the inadequate segregation of incompatible chemicals). The events highlight two aspects of *uncertainty*: (1) in relation to how hazardous yet essential industrial processes can be effectively regulated in locations which are also subject to the probabilistic risk of natural hazards and (2) in relation to how health effects can be quantified despite the fact that environmental monitoring fails to identify any objective evidence to support their existence.

2.4.2 Systemic Vulnerability

Systemic vulnerability can be considered with respect to two main facilities: providing welfare, such as health care, higher education, recreational and strategic for the economic system, and providing, for example, connections between markets, supplying tourist fluxes and carriage of goods.

Lifelines are clearly the first system one has in mind when thinking about ripple effects and systemic consequences of failures that may reverberate far away from the individual area (sometimes very small) where they originated.

It is with no surprise then that there have been European initiatives supporting investigations and research regarding critical infrastructures, as the latter transport people, goods and energy, connecting and supplying regions, nations and cities.

In fact, data regarding networks are the most widespread and updated, because of the great impact they have on the polycentric development of the European territory (as established by the European Spatial Development Perspective) and, as a consequence, because of the great amount of European funds allocated to research in this field.

An example of available data concerning the structure of road and rail networks and the classification of the main ports and airports is provided in Fig. 2.35 and Tables 2.6 and 2.7.

Also, in this case what is represented is not the actual systemic vulnerability, but parameters that are important to assess it, like the dimension of traffic involved by roads in terms of vehicles and transported goods (Figs. 2.36 and 2.37).

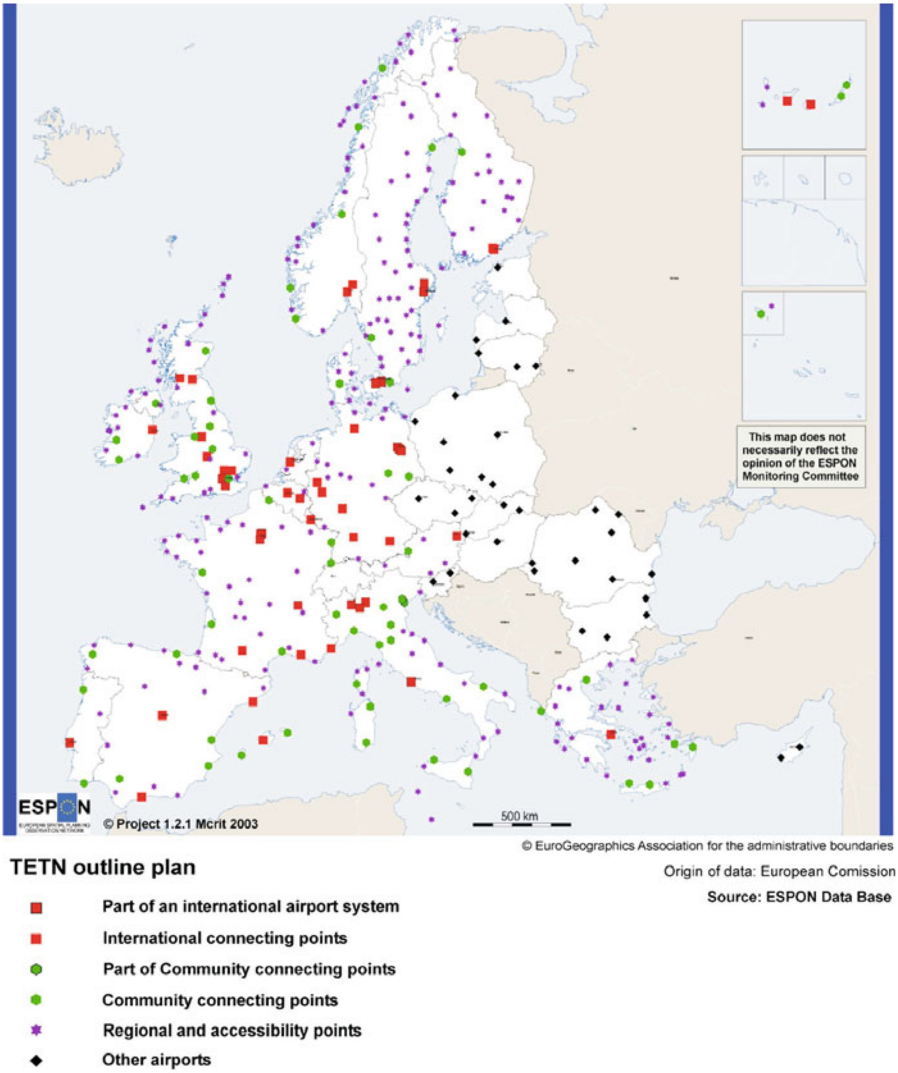


Fig. 2.35. European airports (source: ESPON, 1.2.1, 2006)

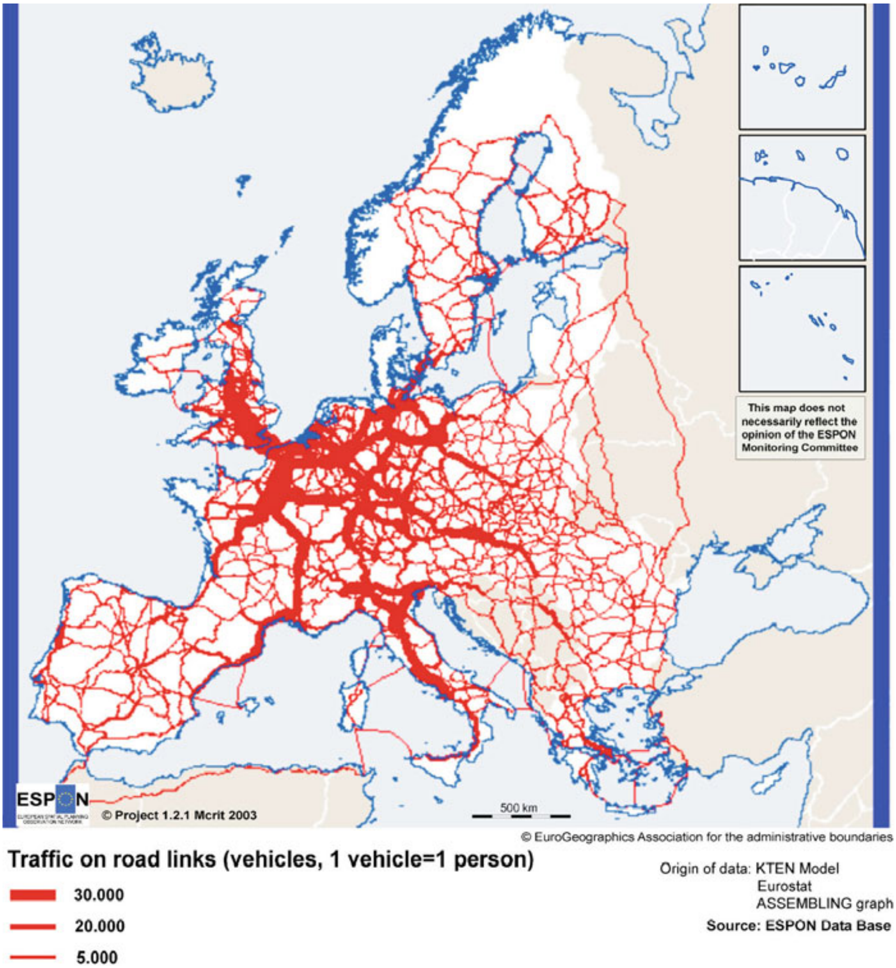


Fig. 2.36. Business traffic on roads (source: ESPON, 1.2.1, 2006)

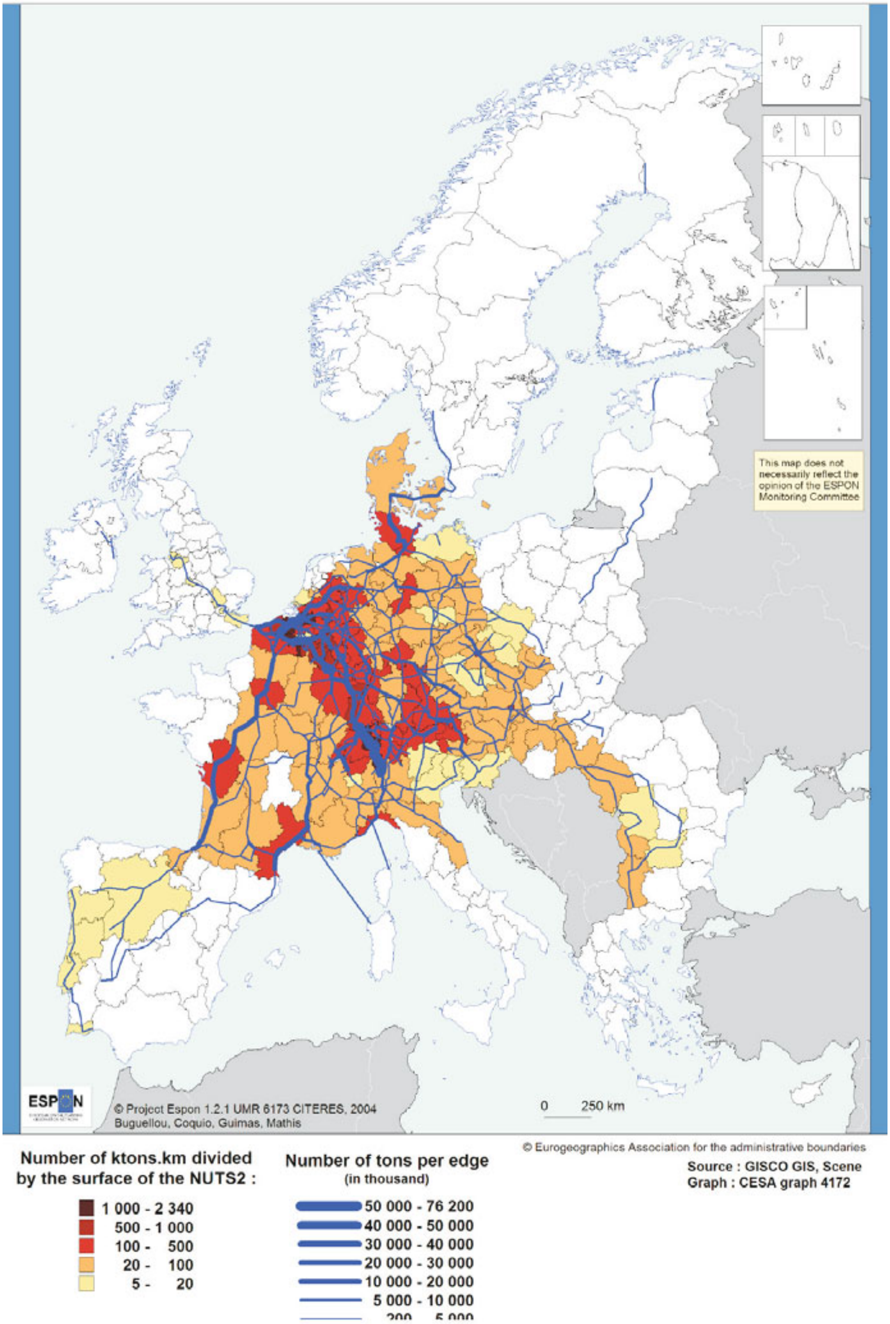


Fig. 2.37. Tons/km transit for NUTS-2 surface (source: ESPON, 1.2.1, 2006)

Table 2.6. Air traffic in 2006 in EU airports exposed to risks

Airport	*Hazard*	*Type of Data*	*I–XII*	*Comparison with 2005*
Prague	Floods	Number of aircrafts movement	160,213	+3.2%
		Number of passengers	10,777,020	+6.2%
		Cargo in kg	62,046,492	+6.5%
		Airmail in kg	5,727,916	+4.9%
Napoli	Seismic	Number of aircrafts movement	58,002	−3.1%
		Number of passengers	4,588,695	−0.7%
		Cargo in kg	5,268,000	9.3%
		Airmail in kg	2,341,000	−0.6%
Nice	Floods	Number of aircrafts movement	169,368	2.2%
		Number of passengers	9,798,511	4.37%
		Cargo in kg	10,356,377	−3.87%
		Airmail in kg	3,370,062	0.06%
Athens	Seismic	Number of aircrafts movement	180,936	−5.3%
		Number of passengers	14,281,020	4.5%
		Cargo in kg	105,356,377	−3.83%
		Airmail in kg	10,834,415	+11.61%
Dresden	Floods	Number of aircrafts movement	34,863	+5.57%
		Number of passengers	1,626,248	+4.29%
		Cargo in kg	7,116,000	+30.64%
		Airmail in kg	—	
Hamburg	Floods	Number of aircrafts movement	156,128	+3.1%
		Number of passengers	10,677,268	+7.92%
		Cargo in kg	—	
		Airmail in kg	—	
Barcelona	Floods	Number of aircrafts movement	180,442	−3.4%
		Number of passengers	26,972,303	+10.7%
		Cargo in kg	90,485,919	6.5%
		Airmail in kg	6,974,448	9.2%
Lisboa	Seismic	Number of aircrafts movement	124,100	+1.6%
		Number of passengers	11,234,700	+4.9%
		Cargo in kg	87,942,000	+0.3%
		Airmail in kg.	12,162,000	+2.5%
Tirana	Seismic	Number of aircrafts movement	15,400	
		Number of passengers	785,000	
		Cargo in kg	2,100,000	
		Airmail in kg	—	
Istanbul	Seismic	Number of aircrafts movement		
		Number of passengers		
		Cargo in kg		
		Airmail in kg		
Frankfurt	Floods	Number of aircrafts movement	477,865	+4.1%
		Number of passengers	51,106,647	5.7%
		Cargo in kg	1,839,084,000	+11.4%
		Airmail in kg	—	
Roma	Seismic	Number of aircrafts movement	367,074	3.72%
		Number of passengers	32,928,114	7.34%
		Cargo in kg	152,969,000	−0.5%
		Airmail in kg	—	

Table 2.7. Main European ports and their exposure to hazards

	Ports	*Mobilised containers (thousands of TEU = TEU = Twenty-Foot Equivalent Units)*	*Hazards menacing the port area (documented from past events or maps)*
1	Rotterdam NL	8,271	Floods, storms
2	Hamburg D	7,003	Floods, storms, nuclear facilities
3	Antwerp B	6,064	
4	Bremen D	3,469	Storms
5	Gioia Tauro I	3,261	Seismic, floods
6	Algeciras E	2,937	
7	Felixstowe UK	2,675	
8	Valencia E	2,145	Storms
9	Le Havre F	2,145	Storms
10	Barcelona E	1,916	Storms
11	Genova I	1,629	Floods, storms, seismic
12	Marsaxlokk M	1,461	Seismic
13	Southampton UK	1,441	
14	Zeebruegge B	1,197	
15	La Spezia I	1,040	Storms, seismic
16	Marseille F	916	Storms
17	Taranto I	763	Storms, seismic, nuclear facilities
18	Göteborg S	731	
19	London/Tilbury UK	657	Storms
20	Livorno I	579	Seismic, floods, storms
21	Thamesport UK	565	
22	Helsinki Fin	500	
23	Aarhus D	475	
24	Salerno I	412	Seismic, floods
25	Napoli I	348	Volcanic, seismic, floods
26	Salonicco H	336	Seismic
27	Kotka Fin	326	Seismic
28	Venezia I	291	Seismic, storms, floods
29	Klaipeda Lit	174	
30	Trieste I	171	Seismic, floods, storms

Box 2.5
The Italian Blackout on 28 Sepember 2003

Description: On 28 September 2003 the Italian electricity system completely collapsed as a consequence of two trees falling on vital nodes in the Swiss territory. As is widely known, Italy depends on external production for 25% of its internal electricity usage and therefore on energy imported from neighbouring countries like Switzerland and France. On that night (3:05) the blackout initiated and propagated through the system rather rapidly. Restoring electricity supply was relatively easy in northern regions (by 7 a.m. most regions had regained their electricity supply) but the blackout lasted more than one day (26 hours) in southern regions. Because of the time of night, damage was not extensive, but it affected 24-hour production and the "white night" in Rome, a particular event when all shops, museums and public places stay open overnight.

Discussion: This case study is particularly relevant to systemic vulnerability. The triggering event (two trees falling) clearly cannot be considered a major hazard: a non-event, or rather irrelevant event from a physical point of view, had rather catastrophic consequences. The Italian commission that investigated the reasons for the failure, found that all three redundancy and emergency systems that should have prevented the crisis failed one after another in a very short time. The first line of defence relied on transparent communication between Italian partner and exporting countries. It failed because Switzerland delayed the real alarm to a point when it was already too late. The second defence line relied on automatic devices that should have disconnected non-operable lines because of a lack of power: those failed as well. The third line should have guaranteed that Italy could continue operating as an island, disconnecting users in order to equilibrate demand and offer capabilities. This failed as well, for a number of reasons.

Also the restoration of the system to normal did not function properly, mainly because the emergency plan had never been tested and there were interpretation problems regarding the meaning of terms and procedures to be adopted. Furthermore it seemed that having only three control centres was problematic to balance the overload of work and checks to be carried out by technicians in those centres.

Box 2.6
Case Study:
The Kalamata Earthquake (Greece) in 1986

Description: On 13 September 1986, at 20:24 local time, the city of Kalamata (Prefecture of Messinia) and the surrounding settlements (34 major and small villages) was hit by a main shock of surface-wave magnitude, MS = 6.0 (Richter Scale), which resulted in an intensity of grade XI on the Modified Mercalli scale. The strongest aftershock of the series, measuring MS = 5.4, subsequently occurred on 15 September, at 14:41 local time. Damages were recorded for about 22,000 residential, commercial and office units. Out of the 9,800 buildings inspected, 22% of them were demolished, 21% suffered heavy structural damage, 26% light structural damage and 32% no or light non-structural damage. Public buildings and facilities fared slightly better (50% affected), although monuments and traditional structures (some of them old school buildings) were severely and extensively hit (80%).

Discussion: The damaging seismic activity that hit the area posed a severe "strength test" for the population and had a significant impact on the regional and (to some extent) national economy. The demanding and complex character of the numerous problems confronted necessitated a multitasking of local, regional and some state agencies and resources. The experiences from the emergency response, the relief phase, the post-disaster rehabilitation and reconstruction of the hit area can be seen as a "milestone" for seismic protection and management in earthquake-prone Greece.

Different vulnerability aspects were highlighted by the event:

Physical Vulnerability of Buildings. Individual buildings within the city collapsed completely, but total collapse conditions were not widespread. The vast majority of the structures built according to the 1959 Hellenic anti-seismic code suffered moderate to low damages.

In the city of Kalamata, two multi-storey apartment buildings totally collapsed during the main shock and another five followed during the aftershocks.

Systemic Vulnerability. This can be evaluated considering physical, social and organisational factors, deeply interconnected. It is also closely related to the *infrastructural (lifelines) vulnerability.* With respect to this case study, the earthquake triggered rockfalls on Mount Taygetos, which blocked the Kalamata-Sparti road and the road to Eleohori, the most damaged village in the area (113 out of 117 small houses were demolished). The downtown road network, especially in the historic centre, housing most of the city's economic life, was blocked by heavy debris. Moderate electric power supply failure was managed easily, while the OTE local telephone network suffered significant damage and required significant efforts to regain full function. The temporary failure of the telecommunication network, which was mainly due to overload caused by waves of simultaneous phone calls from panic-stricken citizens, obstructed the emergency response and aid actions. The city's transportation facilities (airport, national road network, railway and seaport) were only slightly affected and were thus able to readily respond to the increasing emergency demands.

2.4.3 Economic Vulnerability

In the same line as what has been proposed for lifelines, there are some maps that may support further appraisals of economic vulnerability in the EU, related to areas and sectors that once damaged would impact negatively on other areas and sectors because of their strategic role and position in the continental market (see Figs. 2.38 and 2.39).

An economic sector that may be significantly impacted by natural extreme events (and certainly by technological accidents with high contamination consequences) is tourism.

The map in Fig. 2.40 shows the main tourist fluxes across Europe, where the most important origin and destinations regions are clearly evidenced in terms of percentage. The risk condition in destination countries and regions is relevant to assess what the impact of a disaster might be on the tourist sector and also to produce likely scenarios, taking into account the large differences in terms of exposed population in high and low seasons. A disaster occurring during the high season would mean a significant burden for local civil protection and the need for coordination among crisis agencies of different countries.

Finally, the tourist sector is one where investments are often cross-boundary, with one nation investing in another, sometimes extra-European. In the latter case, as occurred when the tsunami struck South-Eastern Asia in December 2004, not only investment but also tourist presence in the damaged areas produced a further burden for the countries that were. That large disaster demonstrated the global nature of the consequences of natural hazards, due not only to the event's magnitude but also to the way investments are made and to the increasing international fluxes of people and goods.

2.5 Spatial Factors Contributing to Shape Images of Europe at Risk

2.5.1 Regions, Central versus Remote Places, Urban versus Rural

The ESPON project has depicted a rather complex image of Europe, pointing out some relevant dichotomies between rural and urban, industrial versus service areas, and central and marginal zones. Other global assessments, like the two reports conducted by the UNCHS on human settlements in 1996 and 2001 provide other perspectives regarding, for example, the different role of cities in the global context. In this section it seems relevant to ask how the different spatial pattern and structure of regions and territories contribute to shape the impact of natural disasters. In fact, only climate change has been considered this way within the ESPON project, while it is clear that territories characterised by concentrated versus dispersed residential areas, by industries

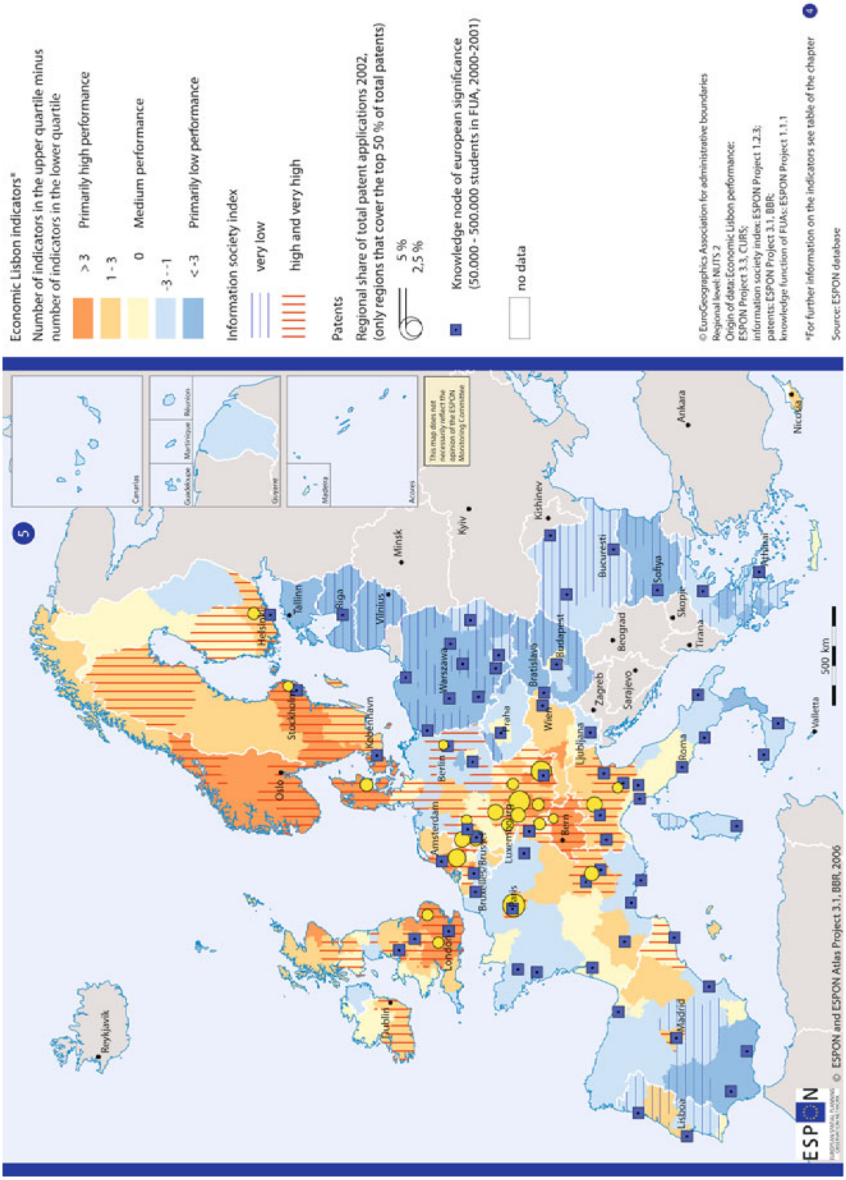


Fig. 2.38. European cluster of competitiveness and innovation (source: ESPON, 3.4.2, 2006)

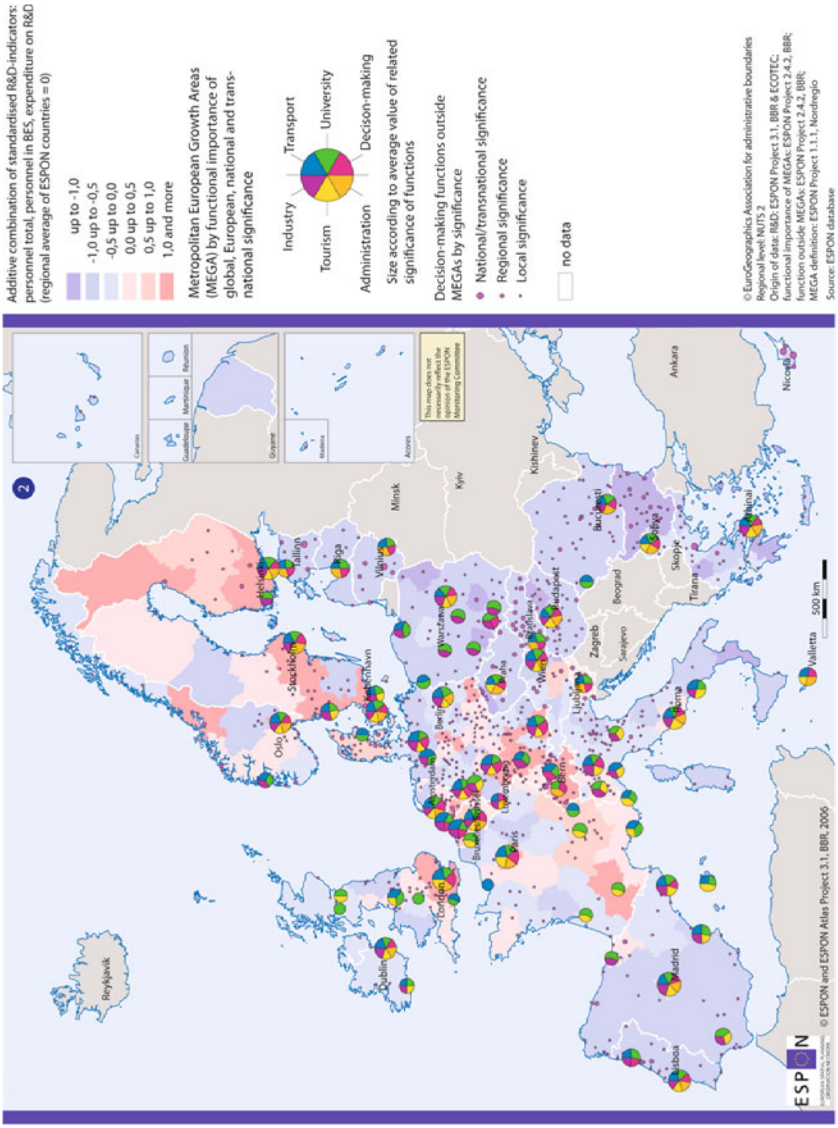


Fig. 2.39. MEGAs and competitiveness (source: ESPON, 3.4.2, 2006)

Fig. 2.40. Country of preference by outbound tourists per country (source: EUROSTAT, 2005)

versus services and by high versus low accessibility will respond differently to the threat posed by natural hazards. In this regard, previous work carried out in the field of risk and hazards studies can be of help in detecting those differences and trying to identify basic similarities and gaps among European regions as well as understanding how future research may be addressed so as to improve the capacity to tailor preventive tools to the needs of communities.

Deforming the map of Europe (Fig. 2.41) according to the time needed to reach one place from another, one discovers that accessibility is rather variable, with important implications for, for example, crisis management purposes. Of course such an issue cannot be drawn at a continental scale, but one may consider, for example, that metropolitan areas are certainly best connected to places where resources of various types can be displaced. One reason for not necessarily considering central places and metropolitan areas as being more vulnerable *per se* with respect to small cities or remote places is that concentration of services and facilities can be considered also a strength, a factor of copying capacity with respect to hazards.

In this regard the following aspects should be considered:

- Metropolitan areas are certainly exposed to secondary damage due to systemic vulnerability, as the large concentration of lifelines, utilities and services imply a higher dependence of one from the other: in case one fails,

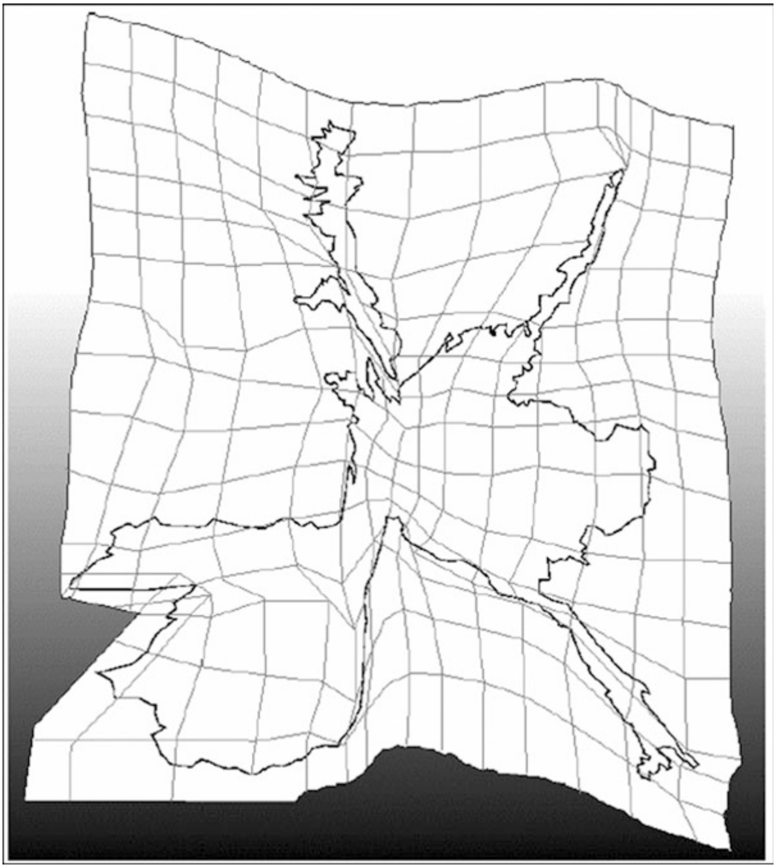


Fig. 2.41. Anamorphic deformation of Europe according to access time within different regions (source: Cauvin and Reymond, 1993)

the failure reverberates in all connected systems; nevertheless the existence of such facilities also implies better accessibility to potential sources of help and rescue as well as to centres of power where the allocation of funds for recovery and reconstruction are decided. Therefore, megacities' vulnerability should not be presupposed without any further investigation; instead a more insightful analysis should be carried out to grasp levels of interdependence and connectivity.

- Metropolitan areas and large urban centres are often exposed to na-techs more than other types of settlements: hazardous plants and infrastructures are vulnerable to given natural hazards, such as floods or earthquakes, and may turn into an induced threat, overloading the coping capacity of organisations and communities already suffering from the initial triggering natural extreme. While the potential for na-techs has been widely recognised in recent publications and international conferences and workshops,

there are still few tools to assess them satisfactorily and to address them in mitigation policies. Available studies are still at a descriptive stage, while exploration of chains of losses and failures actually leading to na-techs is still behind and has not been sufficiently modelled. Natural hazards are still considered as one of the many variables potentially triggering a so-called top-event in a dangerous plant, while the notion of a systemic chain of damages due to the complexity of contemporary urban settlements leading to a variety of outcomes depending on the specific context at stake has not been fully acknowledged and therefore is still underdeveloped.
- The notion of "rural" areas as provided by the ESPON project is not directly linkable to problems of coping capacity in the case of extreme events; if accessibility to resources and to places from which help may come is an important variable, mountain and remote areas are much more disadvantaged than plain areas. Furthermore, mountain places can be difficult to access also because of hazards (primary or induced) such as landslides and avalanches reducing the possibility to access a given centre. As stated by Lewis (1999), mountain and remote places are less vulnerable if they have the potential and the resources to cope locally, to a certain degree independently from external help.

In general terms, the ESPON project recognised natural hazards as one of the themes to be considered in analysing the European space; there is still the need to understand and develop tools to appraise how the latter enters in the formation of risk, and particularly in shaping the components of exposure and vulnerability. Furthermore, there is the need to understand how the present urban spatial patterns have been created by past processes and how transformations and new developments have changed risk conditions. For example, it would be extremely useful to understand how development in floodplains in the Elbe river basin contributed to the extensive damage recorded in 2002.

2.5.2 Cultural Factors: Differences in Perceiving and Tackling Risks

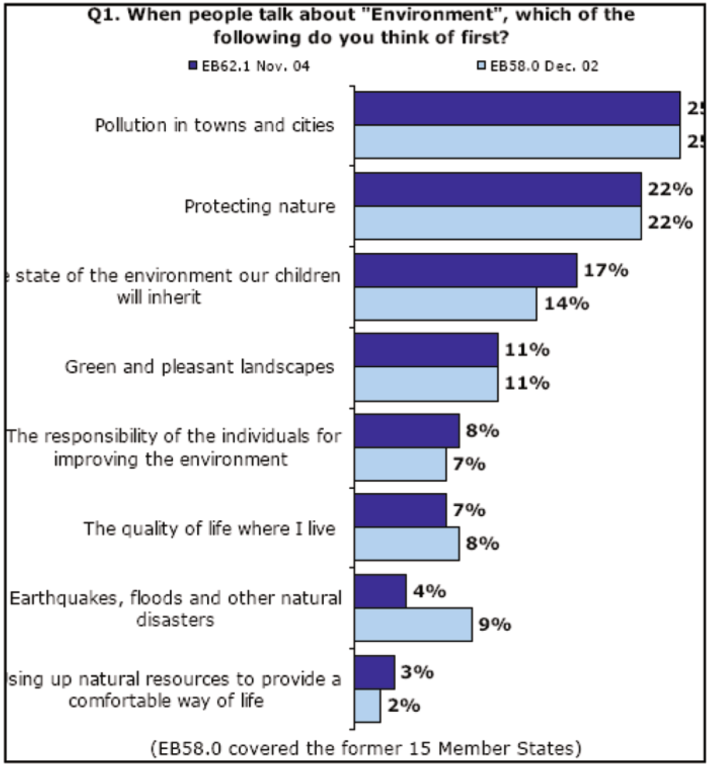
One aspect that may be interesting to investigate is the perception European citizens have regarding natural hazards and na-techs affecting their own community and the Union in general. There are a number of reasons why this may be important. As suggested by the "technical" analysis provided above, there are some risks, in particular flood, that have a rather high transboundary potential: the recourse to European funds for recovery and reconstruction may have influenced ideas regarding such risks, probably more in the directly damaged communities rather than in Europe as a whole. Nevertheless, the issue of who carried the burden of such common "solidarity funds" may be addressed at a certain point and raise concern about policies aimed at prevention at a European level, besides national ones. Furthermore, hazards may trigger na-techs, especially in metropolitan and industrialised areas. It may be useful to understand whether people are aware of the potential threat represented by dangerous plants in dangerous locations or simply exposed to a variety of natural hazards that may trigger accidents. Certainly, resulting contamination may concern much larger areas than those immediately hit by a given event, entailing effects for regions and countries reached by secondary consequences.

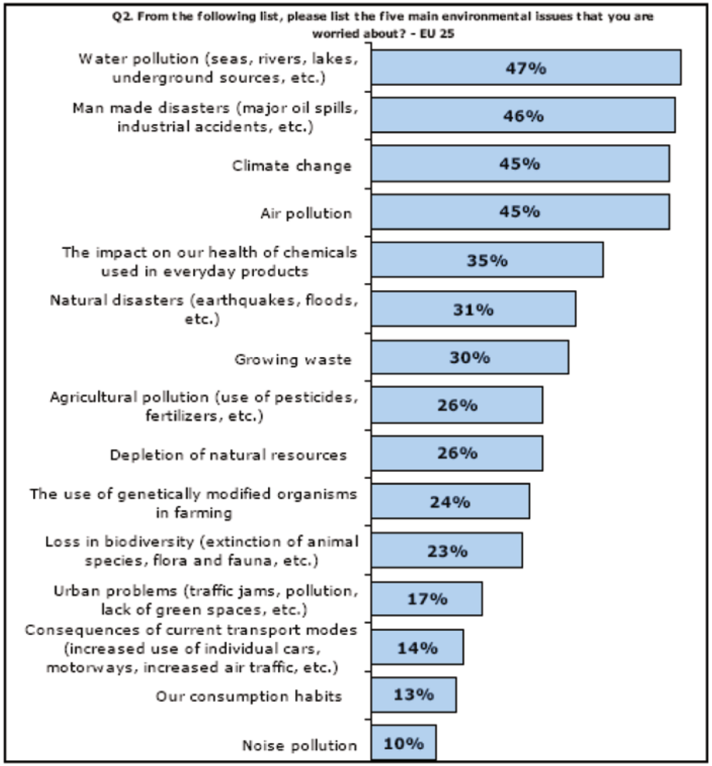
In order to design prevention policies and suggest "harmonised" ways to tackle risks that may provoke damage involving third countries, thus assuming a European relevance, it is therefore important to address the issue of how those risks are perceived (if they are) and what has been the reaction to mitigation policies.

Another important aspect related to "European-level" risks is ripple and systemic effects due to disasters that, though local, may entail large and severe consequences, either because citizens from various countries are involved in remote locations (like in the case of the tsunami in South-Eastern Asia in 2004) or because parts of the continent are deprived of basic utilities as a consequence of an event occurring in another country. Presented in this way, the problem may seem a bit abstract, nevertheless recent alarms regarding climate change and spread of infectious diseases have probably raised some concern also in the public regarding this type of "remote origin-close effects" risks.

A source that can be searched to gain some ideas regarding how European people rank natural hazards among other environmental issues is provided in the Eurobarometer inquiry (Figs. 2.42 and 2.43) "The attitudes of European citizens towards environment" in 2002 and 2004. Two questions contemplated "natural hazards" among the possible answers: what are the first issues that come to people's minds when talking about environment and the most worrying ones. Natural hazards appear in the seventh place for the first question and in the sixth place for the second in the 2004 survey, showing a decrease with respect to 2002. One reason provided by the commentators for this shift is related to the time of the survey, made after the Elbe flood in 2002 and before the tsunami in 2004. What emerges, despite fluctuations that can be observed to a certain extent also comparing to previous surveys (in 1999 for example), is that natural hazards are among the concerns European have in mind when talking about the environment. An interesting shift can be seen also regarding climate change, which took the third place in 2004, while it ranked only at the eleventh in 2002. The second place in terms of "fears" is maintained by man-made disasters. As the survey suggested, natural disasters, man-made technological disasters and climate change are considered as separate issues, without significant links. Such a statement may be questioned particularly when influences of climate change on some natural disasters and na-techs are considered.

A question that may be relevant relates to the perception of natural hazards in different European regions, so as to understand to what extent the geographical distribution of hazards that has been recognised in previous sec-





Figs. 2.42 and 2.43. European citizens' opinions according to the Eurobarometer enquiry 2005

tions is actually reflected in communities' minds. It would be interesting to reflect about whether or not people living in hazardous areas are conscious of the level of threat menacing their households. Some interesting reports and articles have been produced on the issue regarding the risk of flood (see Plapp, 2001 and 2006) and other hydrogeological risks (see RINAMED, Interreg project, 2004), while very little if anything is available regarding other threats, like earthquakes or volcanic activity. With respect to the latter, it must be underlined that the level of potential destruction and loss of life is much higher than in floods and this may be reflected in social perception, especially in the aftermath of a catastrophic occurrence. Another aspect that may produce differences in results from enquiries regarding public understanding of risks and potential losses relates to the number of threats menacing a given area contemporarily. In this regard, mountain areas constitute, in some cases, "hotspots" of hazard exposure and are in the meantime vulnerable from some perspectives, particularly when access to facilities and outside help is concerned.

From this point of view, studies of "natural hazards" perception in Europe would provide a more solid basis for proposing social vulnerability parameters, with respect to two main issues. The first relates to the determination of the best "measures" for social vulnerability. Some authors have already argued against the uncritical assumption that gender, age or income are *per se* indexes of vulnerability, suggesting instead to investigate what makes the elderly, the poor and women more fragile to some stresses in given cases (see Buckle, 2000). In their report for the Floodsite project, De Marchi et al. (2007) found that location, length of evacuation, flood impact, previous flood experience, level of trust and fire brigade membership are better than other independent variables to assess community vulnerability in the chosen sites of the Trentino Alto Adige region in Italy.

In the RINAMED project (2004), a sample of inhabitants in the mountain Valtellina area in the Lombardia Region were asked questions related to their perception of hydrogeological risk, particularly landslides and floods. Most respondents were inhabitants with deep roots in the area and clearly recalled the dramatic event in August 1987 when a huge landslide completely destroyed houses and an entire village. Researchers found that being at risk did not affect people's will to continue living in a place they are extremely satisfied with (78% would never leave the valleys). Other interesting results can be recalled. First, people living in first floors manifested deeper concerns and higher will to be informed regarding emergency procedures than others; second, those perceiving themselves more at risk recognised that wrong land uses, and overexploitation of land for construction and infrastructure could be considered as fundamental causes for risk.

Another interesting national inquiry was conducted by the Credoc-Ifen (Centre de recherché pour l'étude et l'observation des condition de vie, see Roy, 2005). A sample of 2009 people aged more than 18 in different regions were asked questions concerning how aware were they of risks affecting their community. A geography of perception could be drawn, showing significant correlations to actual exposure to different threats. In particular, 44% of residents in the western regions said they were mainly concerned by storms, while the highest level of natural hazards perception was registered along the Mediterranean. Interestingly enough, those interviewed recognised that the impact of natural hazards is worsened by human activity, and acknowledged the influence of climate change on the frequency of calamities (37% completely agree, 42% rather agree). Finally they assigned responsibility for prevention first to the state (34%), followed by municipalities (18%), departments and regions (respectively 16% and 12%).

The need to go deeper in understanding underlying motivation for taking preventative measures is recommended also by Grothmann and Reusswig (2006) in their survey regarding the Cologne case in Germany. The Authors, searching for applications of the "protection motivation theory" in the field of natural hazards and particularly of floods, attempt to analyse variables to assess both "threat appraisal" by households (traditionally named "hazards perception") and "copying appraisal", related to people's perceived ability to take effective measures to reduce the extent of losses and distress. In their introductory paragraph the Authors observe that research on the causes underlying "under-reaction" to natural hazards "is rare, especially in Europe and in Germany. From a regional perspective, most studies of precautionary adaptation or hazard preparedness were conducted in the United States. [...] US and European cultures are very different. Empirical research in Europe is needed before one can simply generalize the existing models across the Atlantic".

Secondly, this type of study provides a better insight into what constitutes an "operational" preparedness, rather than a generic reliance on written plans as an indicator of people's ability to respond correctly in case of need. In this regard, it may be worth mentioning an interesting survey conducted in the two active volcanic areas of Etna and Vesuvio (distinguishing between the red and the yellow zone, see Davis et al. 2005): while in the former respondents showed a moderate optimism regarding their own and the public authorities' capacity to cope, in the latter, while only 25% of those interviewed claimed to know about the general evacuation plan, 61% declared little if any confidence in its eventual success. Despite the limitations to this kind of "social perception" survey, one interesting result may be drawn from the comparison of the two cases: certainly the differences are due also to the physical characteristics of the threat, much more habitual for the inhabitants of the Etna area than for the Vesuvio; nevertheless significant social variables seem to matter as well, such as feeling a sense of community and the national civil protection bodies' general ability to cope (as proven by past experience). This example raises another important issue as far as a "European picture" is concerned: regional and local differences are sometimes very important within the same state, showing the limitations of any attempt to homogenise not only among states but also within individual nations.

Finally, understanding people's perception with respect to policies (not necessarily only those related to natural hazards) helps in the analysis of their expectations of state and public agencies. There are countries like Italy that expect state help and funding after an extreme event as a "natural right"; it may be interesting to compare to countries like the UK or France that implemented insurance against natural hazards a long time ago as one of the pillars for recovery and reconstruction.

3

Impact and Losses of Natural and Na-Tech Disasters in Europe

C. Margottini[1], G. Delmonaco, F. Ferrara

Information provided in previous chapters is complemented here by quantitative data regarding disasters that have affected Europe in the last 60 years. Work on global databases open to the public turned out to be more difficult than expected, highlighting the need for an open discussion about the quality, sources and completeness of databases from which information related to disasters can be found. It should be remembered that those data are often used to support the assumption of a general increase in the number of events and economic damages and they are broadly used by both the scientific and the political communities.

The chapter starts with a description of global databases that cover, among other continents, the whole of Europe, comparing their strengths and weaknesses with respect to local and national databases. Then the two publicly available ones, EM-DAT, provided by the Université de Louvain, and NatCat, managed by Munich Re, are the subject of a more thorough analysis. A comparison of extreme events, damages and victims' trends that can be derived using those two databases has been carried out for European countries.

Finally it has been shown how the same definition of damage is not trivial and conditions the way data are gathered and managed in databases. Because it is believed that damage estimates may be a very important tool for risk mitigation, by supporting assessment of vulnerability and exposure, proposals are made to improve current databases, in the light of the need to create a European system to monitor direct, indirect and secondary losses and victims due to extremes occurring within the Union's borders.

[1] The contribution of Daniela Molinari in elaborating the graphs is acknowledged.

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

3.1 Advantages and Limits of Disaster Damage Databases in a Global Perspective: A General Overview

One of the first systematic studies on the state of the art in losses reporting systems was undertaken by the International Strategy for Disaster Reduction (ISDR), based on a "systematic comparison for a sample of countries between the entries in EM-DAT, with world coverage, and DesInventar, concentrated on South America, in order to document and analyse their similarities and differences". The study was actually carried out by the University of Valle, Cali, with the inputs and comments provided by CRED, LA RED, IRI and UNDP (United Nations Development Programme).

In 2006, most of the aforementioned institutions, together with others (e.g. UNESCAP, UNOCHA, ProVention Consortium,[2] ADRC), participated in an international "Workshop to improve the compilation of reliable data on disaster occurrence and impact" held in Bangkok on April 2–4.

The purpose of this workshop, organised by CRED and UNDP, was to compile and synthesise experiences to date, particularly within Asia, in the development, enhancement and maintenance of historical databases on disaster losses. In preparation for the workshop, the two organising institutions prepared a preliminary paper, entitled "An analytical review of selected data sets on natural disasters and impacts", which summarises the content, presentation and accessibility of a selected group of international, national, regional and event-specific disaster loss databases. The objective was to provide a comprehensive overview of disaster databases in order to identify strengths and gaps in the current state of the art.

The workshop held in Bangkok constituted an important step towards the Global Risk Identification Program (online: http://www.gri-p.net), involving countries in South America, South Asia, North-Western and South-Eastern Africa.

The focus on developing and emerging countries can be explained by the fact that in the latter the death toll due to calamities is still extremely high, if compared to developed countries, where economic damage prevails. The major goal of the GRIP programme consists in reducing losses related to natural hazards, especially in very risk-prone areas, by promoting sustainable development. Within the programme, development and maintenance of National Loss Data Observatories is recognised as an important risk mitigation goal.

The main global databases, widely indicated as the most complete and better organised, are EM-DAT (www.emdat.be), a database developed by the Centre for Research on the Epidemiology of Disasters (CRED, Universitè Catholique de Louvain, Brussels), NatCat (www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/), maintained by Munich

[2] International coalition of institutions launched by the World Bank with the aim of reducing the human and economic costs of natural disasters in the developing world.

Reinsurance Company (Munich), and Sigma (www.swissre.com), kept by Swiss Reinsurance Company (Zurich).

The first feature differentiating them from others is the adopted scale, providing worldwide coverage.

An example of a National/Regional Database is DesInventar, developed in 1994 by the Social Studies Network for Disaster Prevention (LA RED). It covers 16 countries in Latin America and the Carribbean.

It should be underlined that there is no European database formulated with similar criteria to cover the European Union territories.

It may be interesting to compare EM-DAT's definition of disaster with that of DesInventar. In the latter "not every natural event (not every earthquake, for example) is a disaster; some events, in a specific combination with the vulnerability factors, could turn into a disaster", whereas in EM-DAT, the defining feature of a disaster "is the natural phenomena itself and not the conditions that enable the phenomena to cause damage" (ISDR, 2002).

Another feature, broadly granting a "global" feature to EM-DAT and Sigma, is provided by the large typology of disasters dealt with. In fact, they range from natural to technological disasters,[3] following a macro classification (Fig. 3.1), which includes also na-techs.

On the contrary, NatCat by Munich-Re deals exclusively with natural disasters. Specific technological disaster databases exist, for example, MARS and MHIDAS. MARS, acronym for Major Accident Reporting Sys-

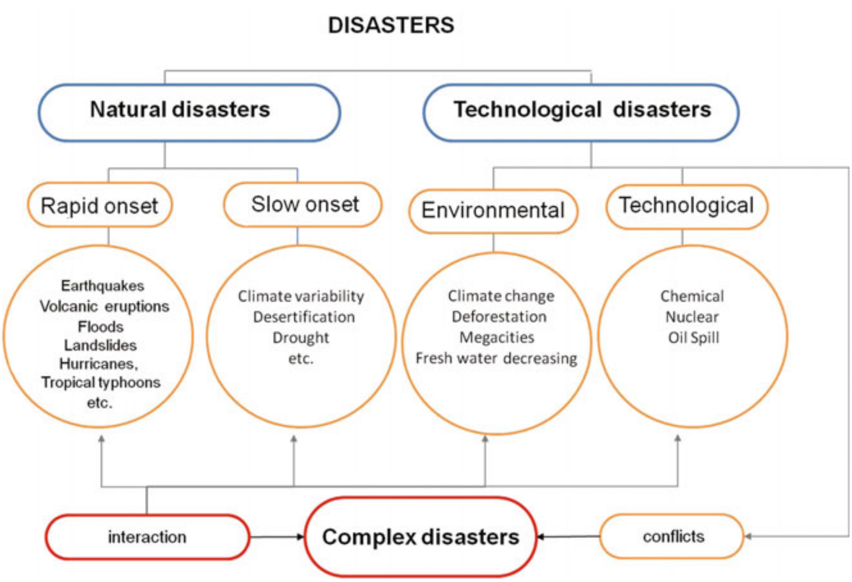


Fig. 3.1. Typology of disasters

[3] Instead of "technological disasters", a "man-made disasters" definition is used in the Sigma database.

Table 3.1. EM-DAT on the "1966 Florence Flood"

year	*seq*	*dis_group*	*dis_type*	*dis_ subset*	*event_ name*	*entry_ criteria*	*country_ name*	*location*	*no_ killed*	*no_injured*	*no_ affected*	*no_ homeless*	*total_ affected*
1966	*86*	*Natural*	*Flood*	–		*Kill*	*Italy*	*Florence, Venice*	*70*	*0*	*0*	*1300000*	*1300000*

total_dam 000's US$)	reconstr_dam (000's US$)	insur_dam (000's US$)	aid_contribution (000's US$)	start_ year	start_ month	start_day	end_year	end_ month	end_day	dis_mag_value	dis_mag _scale	latitude	longitude
2000000	0	0		1966	11	3	1966	11	3		kmÂ^2		

Table 3.2. The SICI database on the "1966 Florence Flood"

Location	*Municipality*	*Province*	*Region*	*Date*	Disaster type	*Dead*		*Missing*		*Injured*		*Homeless*		*Evacuated*	
						Exact	*Valued*	*Exact*	*Valued*	*Exact*	*Valued*	*Exact*	*Valued*	*Exact*	*Valued*
Lastre	Reggello	Firenze	Toscana	04/11/1966	Landslide	7				17					
Comune di	Castel-fiorentino	Firenze	Toscana	04/11/1966	Flood	1				8			1000		
Firenze	Firenze	Firenze	Toscana	04/11/1966	Flood	5				29	500	20000		evacuated	
	Poggio a Caiano	Prato	Toscana	04/11/1966	Flood	1						homeless			
	Castelfranco di Sotto	Pisa	Toscana	04/11/1966	Flood	3		1						evacuated	
	Empoli	Firenze	Toscana	04/11/1966	Flood	2								evacuated	
	Sesto Fiorentino	Firenze	Toscana	04/11/1966	Flood	2				4				450	
San Donnino	Campi Bisenzio	Firenze	Toscana	04/11/1966	Flood	5				100					
Via S. Ammirato	Firenze	Firenze	Toscana	04/11/1966	Flood	1				8					

(. . .)

Table 3.2 (cont). The SICI database on the "1966 Florence Flood"

Location	*Municipality*	*Province*	*Region*	*Date*	Disaster type	*Dead*		*Missing*		*Injured*		*Homeless*		*Evacuated*	
						Exact	*Valued*	*Exact*	*Valued*	*Exact*	*Valued*	*Exact*	*Valued*	*Exact*	*Valued*
Le Tinaie	Castel-fiorentino	Firenze	Toscana	04/11/1966	Flood	3									
Via Villa-magna	Firenze	Firenze	Toscana	04/11/1966	Flood	1									
Via Gavinana	Firenze	Firenze	Toscana	04/11/1966	Flood	5									
Via Masaccio	Firenze	Firenze	Toscana	04/11/1966	Flood	1									
Campo di Marte	Firenze	Firenze	Toscana	04/11/1966	Flood	3									
	Montelupo Fiorentino	Firenze	Toscana	04/11/1966	Flood	2									
	Pisa	Pisa	Toscana	04/11/1966	Flood	2									
Osmannoro	Sesto Fiorentino	Firenze	Toscana	04/11/1966	Flood	1									
Torre del Lago	Viareggio	Lucca	Toscana	04/11/1966	Flood	1									
	Campagnatic	Grosseto	Toscana	04/11/1966	Flood	1									

tem, is an outcome of the Member States of the European Union and the OECD, submitted to the European Commission Joint Research Centre in Ispra. It presently reports 603 records (http://mahbsrv4.jrc.it/mars/servlet/ShortReports – accessed on 5 December, 2007) about industrial accidents that have occurred since 1980, with information on the date of incident, type of industry, accident type, substance type, immediate effects (dead, injured, ecological harm, material loss), emergency measures taken and lesson learned.

MHIDAS, acronym for Major Hazard Incident Data Service (http://www.hse.gov.uk/infoserv/mhidas.htm – accessed on 1 February, 2008), is a publicly available fee-based international database reporting on disasters involving hazardous material. The database, maintained by AEA Technology on behalf of the UK Health and Safety Executive, offers worldwide coverage on hazardous material accidents, though it focuses mainly on the UK and the US.

Unlike EM-DAT or NatCat, some global databases deal with one hazard type only, such as floods, earthquakes or landslides. An example is the "Global Active Archive of Large Flood Events", maintained by the Dartmouth Flood Observatory (DFO), which reports flood events from 1985 to the present. The database, publicly accessible (http://www.dartmouth.edu/∼floods/Archives/index.html), is organised in fields related to the affected countries, location (and centroid), date, causes, magnitude, losses and additional comments. DFO uses its own event numbering for every year but also the GLIDE number, which constituted an attempt to homogenise and harmonise codes used to identify events in global databases.

Because of the scale and the way they are organised, global databases often omit minor and multi-site occurrences. Both, though, may constitute a significant challenge because of the cumulated effects over large areas, when several small events occur simultaneously, and over time, as far as minor but frequent events are concerned.

An example is provided by the comparison between the Italian SICI (http://webmap.irpi.cnr.it) (Sistema Informativo sulle Catastrofi Idrogeologiche, see Table 3.1 on pp. 94–95), which is now part of the Iffi database described in Box 3.1 maintained by the GNDCI of CNR, with a well-developed data system on flood and landslide events and the EM-DAT (see Table 3.1) for the period 1950–2003. The latter has recorded 38 (flood and landslides related) that provoked 1200 victims, while the first over one thousand minor and major events, with more than 1600 deaths.

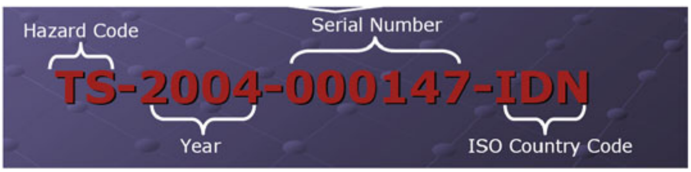


Fig. 3.2. A "GLIDE number" example

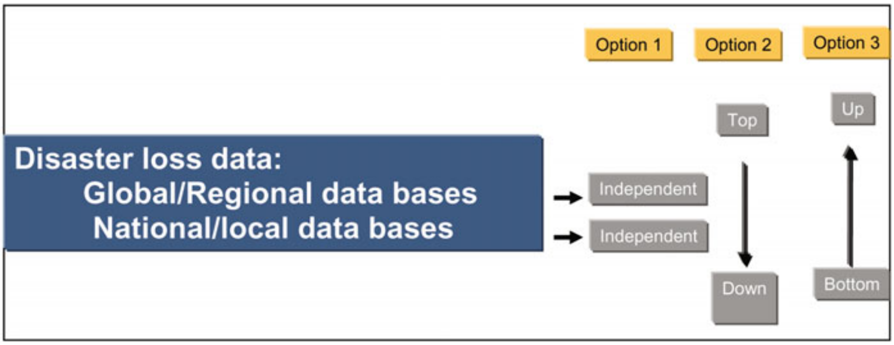


Fig. 3.3. Mechanisms of database feeding

Ways to better integrate between global and national databases in terms of sources are shown in Fig. 3.3.

Box 3.1
IFFI Project

European countries have experienced several flood and landslide events, but Italy is probably one of the most affected, at least in frequency. The occurrence of frequent events had a catalyst function towards the development of risk maps and connected database. The AVI project (Aree Vulnerate Italiane), on which the SICI catalogue is partially based, together with other national projects (SCAI project – Study of inhAbited Centres affected by Instability; CARG project about geothematic and geological map 1:50000), converged in the IFFI project. The latter is an inventory of Italian landslide phenomena, developed by ISPRA and presented to the public in November 2007 (available at the following address: www.mais.sinanet.apat.it/cartanetiffi).

The IFFI project addressed the need for standardised definitions and methodologies and the adoption of a suitable scale approach in developing natural disaster databases.

In fact, a preliminary survey carried out by the Italian National Geological Service had highlighted the existence of different databases, not always computerised, using different mapping scales and not homogenous criteria for phenomena census and cartographic representation. In this project, great attention has been dedicated to the methodology and a specific Work Group has been constituted with the aim of pointing out base criteria, the application of which would allow homogenous and comparison-fit results to be obtained at a national scale. A specific methodology was set to deal with data research, aerial photo interpretation, *in situ* survey, landslide inventory and mapping.

Apart from national projects, maps produced by regions, river basin authorities, universities and research institutes but overall, data collated by historical documents maintained by libraries and national, regional, provincial and local archives, represented fundamental sources. The historical research is recognised to be of primary importance for past events reconstruction and assessment of return period (prediction stage) of every type of phenomenon, with landslides being the example given. A quantitative and qualitative analysis of data homogeneity and inventory completeness at the regional scale has followed the data collection and registration phases. In particular, every event has been subjected to a quality check before its inclusion in the database. APAT has defined two levels: the first is related to shape, space and connection, and the second aims to check completeness with other datasets (AVI, SCAI, CARG, PAI).

The IFFI database, either alphanumeric or iconographic (e.g. documents, photos, films), contains all data about landslide inventories. It is constituted by various upload screens that allow data to be archived, updated and consulted, through the use of a key primary field "ID-landslide". In fact, every landslide event has its own code that allows an unambiguous identification over the whole national territory. A local–regional scale (1.25000) is adopted for landslide digital mapping.

Typical outcomes are bar charts reporting the number of landslides depending on favouring and triggering factors so as to point out main causes, bar charts on damage by category (e.g. buildings, roads, railways, cultural heritage, industries) and table containing technical parameters for each region (e.g. number and density of events, affected areas, index of landslides in hill areas).

The IFFI project, intended as cartography and related database, represents an important tool to analyse landslides, and is particularly useful in supporting hazard assessment and territorial planning, and making decisions to invest in mitigation measures.

3.2 Comparison between EM-DAT, NatCat and Sigma

In the following sections the three global databases of EM-DAT, NatCat and Sigma are compared, defining the strengths and weaknesses of each. The reason for this choice is rather clear: as they provide a global coverage addressing several hazards, they constitute the main source of information for Europe as a whole. Assembling the information of national databases is not only far more complicated, but may also have a rather unreliable result, as data and information gathered according to different criteria and methodologies would have to be aggregated.

It should be also pointed out that of the three databases, Sigma is not available to the public, unlike the other two. Therefore some comparisons will be limited to EM-DAT and NatCat (see Table 3.3).

Table 3.3. A strengths–weakness matrix applied to EM-DAT and CatNat databases (strength factors are shown in orange, weaknesses in purple, aspects that may be a matter of discussion in green)

	EM-DAT	*NatCat*
Access	Public	Partially public
Period covered	1900–present	79–present
Number of entries	16200 (October 2007) (700 new entries/year)	>22000 (800 new entries/year)
Typology of disasters	Natural (including epidemics) = 62% Technological + conflicts = 38%	Natural
Entry criteria	For country	For country
Entry thresholds	Present	Not present
Observation level	Global	Global
Resolution level	Large scale	Large scale
Accuracy in disaster picture	Not very detailed	Fairly detailed with reference to associated disasters
Georeferencing	Present	Present
Estimation of economic losses	No standard procedure	Own methodology
Coverage of economic losses	Uniform	Not uniform
Field filling	Not complete	Not complete
Priority sources	UN agencies	Lloyds, Reuters, reports from clients and insurance press
Searching options	Several	Several

Comparison has been carried out looking at four main criteria: ***definitions***, ***adopted methodologies*** regarding entry criteria, thresholds, query conditions, and quality assurance of information ***sources***.

3.2.1 Definitions of Disaster and of Main Records in the EM-DAT, NatCat and Sigma Databases

Definitions adopted for disasters are closely linked to the aim for which every database has been created. In line with its humanitarian perspective, EM-DAT defines a disaster as "a situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering" (CRED, 2006).

On the other hand, the NatCat and Sigma databases, created respectively in 1974 and 1970, have been designed to meet internal commercial policy and insurance companies' needs.

0	Natural event	No property damage (e.g. forest fire with no damage to buildings)			
1	Small-scale loss event	1-9 fatalities and/or hardly any damage			
2	Moderate loss event	10-19 deaths and/or damage to buildings and other property			
			2000-2005	1990s	1980s
3	Severe catastrophe	20+ fatalities Overall losses US$	> 50m	>40m	>25m
4	Major catastrophe	100+ fatalities Overall losses US$	> 200m	>160m	>85m
5	Devastating catastrophe	500+ fatalities Overall losses US$	> 500m	>400m	>275m
6	Great natural catastrophe "GREAT disaster"	Thousands of fatalities, economy severely affected, extreme insured losses (UN definition)			

Fig. 3.4. NatCat disaster classification (Munich Re, 2006)

As shown in Fig. 3.4, NatCat ranks disasters according to six categories of economic losses; only the sixth one, "great natural catastrophe", coincides with the UN definition, according to which "a natural catastrophe is great if the affected regions' ability to help themselves is clearly overstretched and supraregional or international assistance is required". As a rule, "this is the case when there are thousands of fatalities, when hundreds of thousands of people are made homeless, or when the economic losses, depending on the economic circumstances of the country concerned, and/or the insured losses reach exceptional orders of magnitude" (Munich Re, 2003). The focus on economic aspects is evident in those definitions, as well as in the inclusion of "insurance terms" in the definition of risk adopted by Munich Re (Fig. 3.5).

According to Sigma, "a natural catastrophe is a harmful event determined by natural forces. Usually, this event produces many single accidents involving

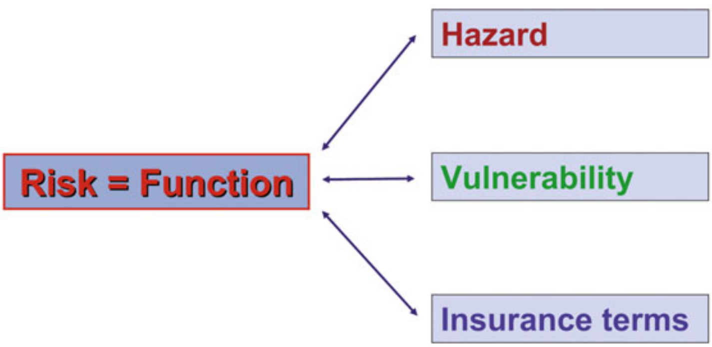


Fig. 3.5. Risk definition according to Munich Re approach

a lot of insurance contracts" (Swiss Re, 2007). In this case, as well, there is an explicit reference to economic aspects.

With respect to the individual records reported in the databases, EM-DAT provides an accurate distinction between "killed" (confirmed dead, missing and presumed dead), "injured" (people suffering from physical injuries, trauma or an illness requiring immediate medical treatment as a direct result of a disaster), "homeless" (needing immediate assistance for shelter) and "affected" (people requiring immediate assistance during a period of emergency, including those displaced or evacuated).

In NatCat, people can be "injured", "homeless", "missing", "evacuated" and "affected", while the Sigma database limits its reporting to "dead", "missing", "injured" and "homeless" people (Provention Consortium, 2002).

3.2.2 Entry Criteria and Definitions of "Disasters" in the EM-DAT, NatCat and Sigma Databases

Comparison between the databases shows a certain lack of standardised definitions with respect to what is considered a "disaster", a "catastrophe" and even "affected" people.

As far as the method of inclusion in the database is concerned, EM-DAT sets thresholds combining the number of killed or affected people, the call for international aid and the declaration of a major emergency. A disaster is defined according to the generating natural event (hurricanes, flooding and earthquakes are disasters), but also according to a threshold of affected people (ISDR, 2002).

One of the following criteria must be met to enter an event in the EM-DAT database:

- 10 or more people reported killed
- 100 people or more reported affected
- declaration of a state of emergency
- call for international assistance.

NatCat, instead, introduces an item in the database entry for each loss declared in a given event.

In Sigma thresholds are established as follows:

- 20 or more deaths
- 50 or more injured
- 2000 or more homeless
- Strict economic criteria (insured losses exceed more than $14m in respect of marine and $28m in respect of aviation or $35m in respect of all other losses and/or total losses in excess of $70m).

The absence of thresholds in NatCat (an entry is consequential to any property damage or any person affected) explains the large amount of data in

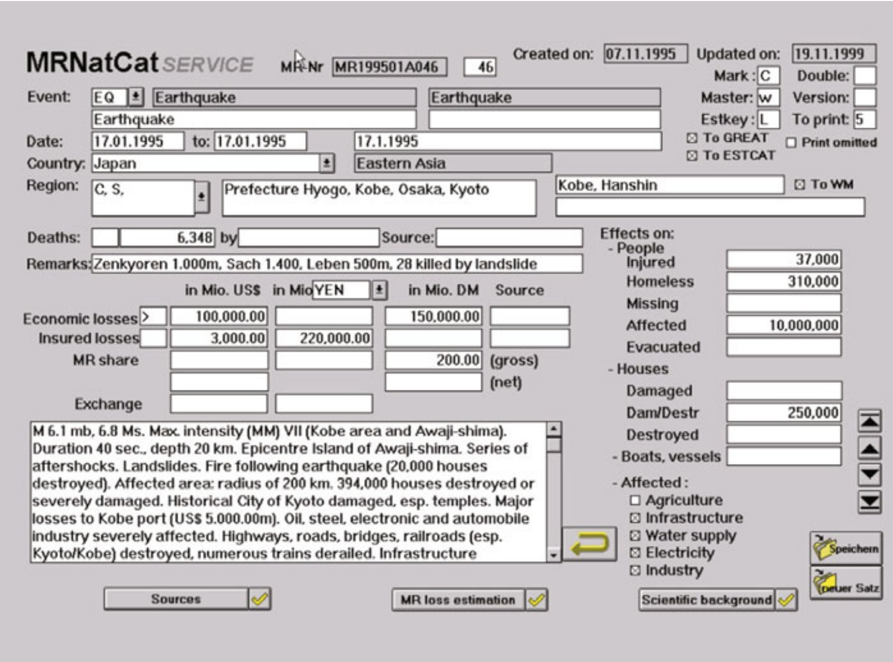


Fig. 3.6. Entry criteria in the NatCat database

NatCat. EM-DAT and NatCat make an entry for each nation affected, while Sigma records the same event affecting various nations only once (resulting in significantly fewer records).

In EM-DAT, data are considered at country level for two reasons. First, it is at this level that they are commonly reported and second, because it makes the aggregation and disaggregation of data possible. For droughts or food insecurities, which are often multi-year disasters, long-term impact must also be taken into account (CRED, 2006).

EM-DAT distinguishes two generic groups for disasters: natural and technological. Then, they are divided into 15 main categories, each covering more than 50 sub-categories. For the production of the tables, natural disasters are split into two groups:

- Hydrometeorological disasters: avalanches/landslides, droughts/famines, extreme temperatures, floods, forest/scrub fires, windstorms and other disasters, such as insect infestation and wave surges
- Geophysical disasters: earthquakes, tsunamis and volcanic eruptions.

Technological disasters are divided into:

- Industrial accidents: chemical spills, collapses of industrial infrastructure, explosion, fires, gas leaks, poisoning and radiation

- Transport accidents: by air, road or water means of transport
- Miscellaneous accidents: collapses of domestic/non-industrial structures, explosions and fires.

NatCat database distinguishes between the following types of events (only "natural"):

- Geological catastrophes (earthquakes, volcanic eruptions, land subsidence)
- Storms (e.g. tropical cyclones, winter storms, severe weather)
- Floods (storm tides, river floods, flash floods)
- Droughts (heatwaves, forest fires)
- Other occurrences (e.g. cold spells, avalanches, snow pressure).

Finally, Sigma breaks down natural catastrophes into the following:

- Floods
- Storms
- Earthquakes
- Droughts/fires/heatwaves
- Cold waves/frost
- Hail
- Tsunami
- Other.

"Man-made catastrophes" are subdivided into:

- major fires and explosions
- aviation and space disasters
- shipping disasters
- rail disasters
- mining accidents
- collapse of building/bridges
- miscellanous (including terrorism).

As can be seen, even though a few common points can be found, criteria adopted to classify disasters are substantially different. Fields included in EM-DAT databases are:

- DISNO (a unique disaster number for each disaster event)
- Country
- Disaster group (natural or technological)
- Disaster type and subset
- Date
- Humanitarian losses following the aforementioned classification
- Estimated damage
- Additional fields (geographical, value and scale of the event, the international status OFDA/EU response, request for international assistance, disaster/emergency declaration, the aid contribution in US dollars, sectors affected).

In NatCat and Sigma economic losses are much more detailed. In the restricted version of the first database, not only economic and insured losses are distinguished, but also Munich Re share (gross and net) and exchange rates are introduced.

The way events are entered into the databases creates a clear problem when comparisons between events recorded by the three providers have to be made.

The first problem refers to dates: the same event can be reported at different dates, especially for those disasters, like floods, that may start in one month and end one or more months later, and may even last two or more years.

NatCat and Sigma usually record a period for the disaster, while EM-DAT adopts the following approach: "in the case of sudden onset, the deaths are registered according to the *start year* of the disaster. In the case of slow onset, the number of deaths is divided by two and each half is attributed to each year of persistence. The same rule is used for people-reported injures. Reported economic damages are always attributed to the *end year* of the disaster because only after the disaster has concluded can the full amount of damages be reasonably estimated."

EM-DAT is aware that "these rules do not produce perfect data", particularly as a consequence of the decision to record events when they have been declared a humanitarian emergency.

Referring to losses, a comparative study on developing countries has shown a significantly better reporting of human impacts in EM-DAT if compared to Sigma and NatCat where, on the contrary, insured and uninsured damage are better reported. It must be underlined though, that both private companies provide limited information on countries with low insurance density (IFRC, 2005). None of the three databases expresses clearly how economic losses are computed.

The NatCat database is primarily based on official reports and information on the claims that are paid; for this reason it puts a strong emphasis on updating data, as very often reliable figures become available only a few weeks after the disaster impact.

Another valid reason for updating a database is the change in countries' borders, implying the need to aggregate or disaggregate losses according to the new national boundaries (e.g. in Europe: the break-up of the Soviet Union and Yugoslavia, and the unification of Germany).

Another problem affecting the identification of events in the three databases derives from disaster cascades, occurring when an initial event (e.g. earthquake, flood) triggers a second one (e.g. landslides). In this case there is often an ambiguity in attributing a disaster to the same main event or to independent ones, but occurring in the same period of concern.

3.2.3 EM-DAT, NatCat and Sigma Query Criteria and Available Documentation

The EM-DAT database can be searched by location (region/country), time-frame (period/year) or disaster (group/type). The publicly available information provided by Munich Re includes a short report searchable by country, time period or event type (limited to earthquakes, flood, volcanic eruption, storm, other) and provides georeferencing, but only on a very limited number of natural disaster types. Using the event (which may include more than one country) as the basis for each entry, Sigma is more limited as it does not allow queries using country names.

Being private firms, Munich Re and Swiss Re undertake useful analyses for their clients regarding risk and disaster trends. Thanks to their conspicuous financial and human resources, they produce high-quality analyses and publications on a regular basis (Provention Consortium, 2002).

In particular, the client-oriented product range, provided by NatCat, is made up of three main components:

a) Loss list and maps, providing an overview of individual occurrences or the loss history of a particular region with regard to individual or all natural hazards. Since precise geographical coordinates are available for all events, disaster maps can be compiled using different scales (world, national, regional maps)
b) Statistics and analyses, presented in the form of graphs or tables
c) Statements and brief reports, focusing on occurrence probabilities, return periods, loss dimensions, causes and trends.

Sigma issues a number of annual publications about the international insurance market with analyses of market trends and forecasts. In particular, the yearly report contains an overview of the catastrophes of the year, insurance information, trends and tables about major events connected with major losses.

CRED produces an Annual Statistical Review, including some detailed analyses, such as natural disaster trends and numbers (victims and economic damage) within a given period; trends by disaster groups, major natural disaster evolution by decade, comparisons with the previous two years, victims and economic damage by major type of natural disasters and details by continent. Other periodical publications are the CRED Crunch and Press Release (ISDR).

Because of its limited financial and human resources, as a general policy, EM-DAT has chosen to invest in improving public access to data at the expense of developing sophisticated analytical products (Provention Consortium, 2002).

As for the covered time period, NatCat includes events going back to the year 79, clearly longer than the 1900–today period provided by EM-DAT. Nevertheless a closer look makes this difference fade away, especially if historic trends have to be produced. In fact, only 3000 entries out of 22000 provided by NatCat relate to the period between the years 79 and 1980, while the large majority relate to more recent events.

3.2.4 EM-DAT, NatCat and Sigma Data Providers and Information Sources

The choice of information sources is influenced by databases' purposes.

EM-DAT, as a consequence of its humanitarian interest, prefers, as if primary source, governments and UN agencies (UNEP, OCHA, WFP, and FAO), NGOs (IFRC) and only as a second choice research institutions, insurance institutions (Lloyd's) and press agencies.

On the contrary, among its declared 200 sources, NatCat gives priority to the Lloyd's list, Reuters, reports from client and branch offices, and insurance press, and considers as a second choice the press and media, UN agencies, NGOs and world weather services. Sigma includes among its sources newspapers, the Lloyd's list, primary insurance and reinsurance periodicals, and internal reports.

In all the examined cases, the press is considered as a second choice source of information. In fact, as reported in research by the ProVention Consortium, "the original information is not specifically gathered for statistical purposes and so, inevitably, even where the compiling organization applies strict definitions for disaster events and parameters, the original suppliers may not".

Both EM-DAT and NatCat (Fig. 3.7) are remarkably transparent as far as their sources are concerned, making them public for every single disaster event.

Fig. 3.7. Background information provided for clients (Munich Re, 2007)

In an attempt to carry out a data quality check, Munich Re has created a data quality classification tree (Fig. 3.8), while CRED has developed a ranking system assigning information sources to different reliability levels.

3.3 Disaster Trends in Europe in the Last 50 Years: Comparing the EM-DAT and NatCat Databases

Disaster trends in Europe have been identified using the two publicly accessible databases of EM-DAT and NatCat, analysing data concerning events in the period 1950–2006.

Given the differences between the two databases, some data processing has been performed: first, records concerning the same event but involving different countries have been aggregated. Second, comparison has been limited to those events that are reported in both databases. Results are displayed in Table 3.4.

Table 3.4. Comparison of EM-DAT and NatCat databases by analysing data concerning events in the period 1950–2006

Database	*Number of events (1950–2006)*	*Events present in both database*
EM-DAT	532	116
NatCat	160	108

In total, 532 events are recorded in EM-DAT, 116 of which are also reported in NatCat; 160 natural disasters are registered in NatCat but only 108 are included also in EM-DAT. The discrepancy between the numbers relating to common events has two causes:

- In some cases, as for the chain of avalanches that hit France in 1970, one database reports only one event for the entire period of occurrence whilst the other registers two or more events with more specific information about the time.
- Other times, the same event is reported differently in the two databases, such as the meteo-hydrological events that affected the Italian "Valtellina" region in 1987. In this case, NatCat registered only one record under the classification of "landslide". But EM-DAT reports two records, one for the landslides that hit the region and another one for the storm linked to the disaster.

After the initial processing, three kind of analyses are then carried out, related to disaster type, trends and geographic distribution.

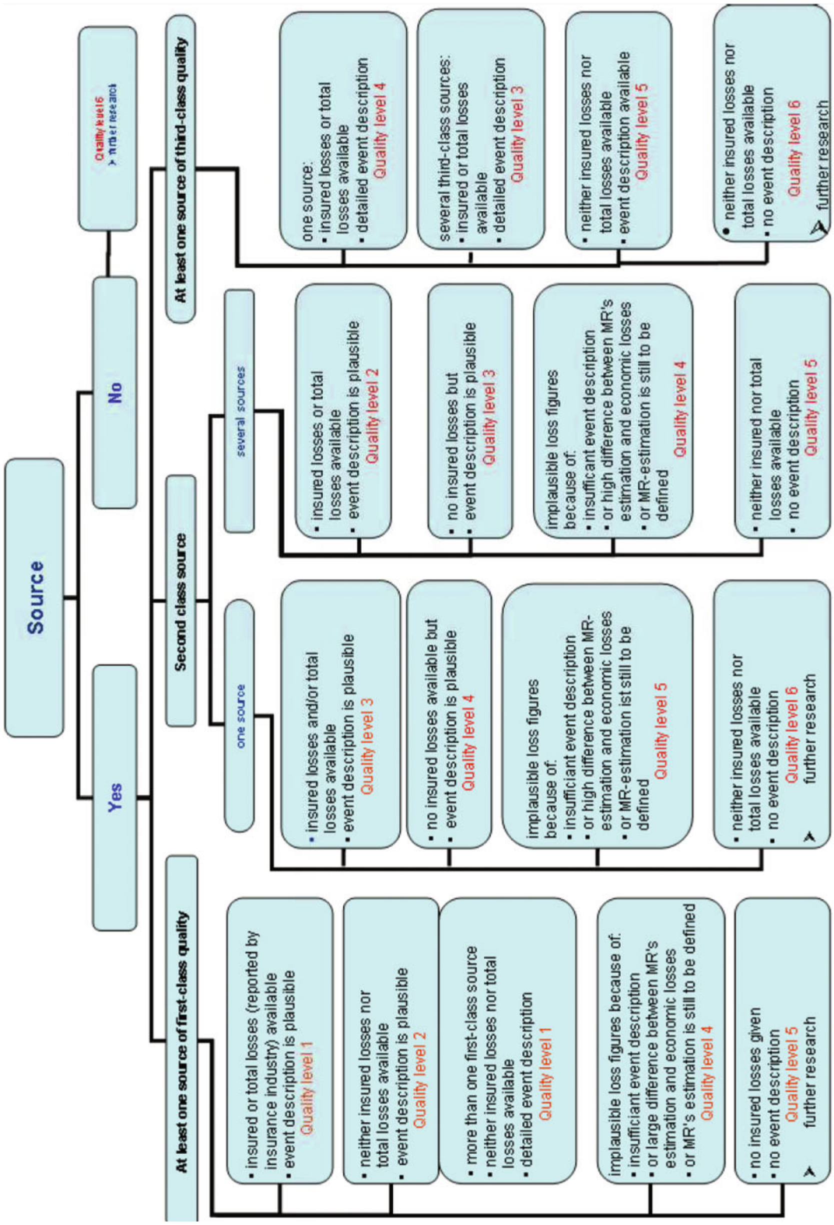


Fig. 3.8. Classification of data quality (Munich Re, 2007)

3.3.1 Event Analysis by Disaster Type

Figures 3.9 and 3.10 show the events partition, in terms of frequency of the same type of disaster, for both databases. According to EM-DAT, the most common natural disasters in Europe are floods, followed by storms. This trend is reversed in NatCat, although the difference in percentages is rather small.

This slight difference can be explained by the way events are classified in the two databases. For example, the events that affected France, Italy and Austria in the summer of 2003 have been classified as “storm surge” in NatCat and as “floods” in EM-DAT. This kind of “misclassification” between floods and some types of landslides is quite frequent.

Given the rather different threat posed by flash floods with respect to slow river floods, in terms of expected damages and management procedures, a distinction between the two has been made using the data of the two databases. As shown in Fig. 3.11, flash floods represent only a minor fraction of the total number of reported floods in both EM-DAT and NatCat. The disparity with national databases probably reflects the scarce attention of global databases to local events, even though, in this context, NatCat seems more accurate than EM-DAT.

According to both databases, the most destructive flood of the last 50 years in Europe occurred in 2002 along the Danube and the Elbe rivers. In Table 3.5 the records extracted for this event from the two databases are shown: a quite

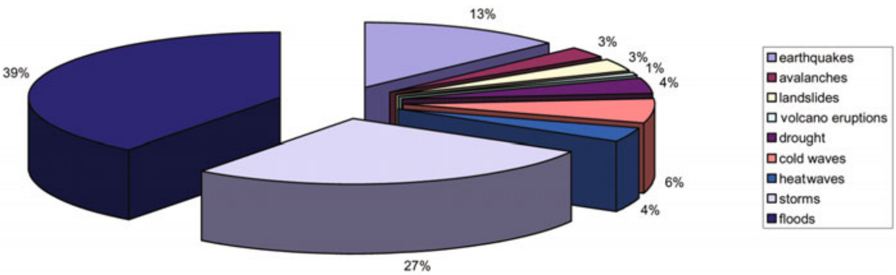


Fig. 3.9. Number of events per disaster type (source: EM-DAT 1950–2006)

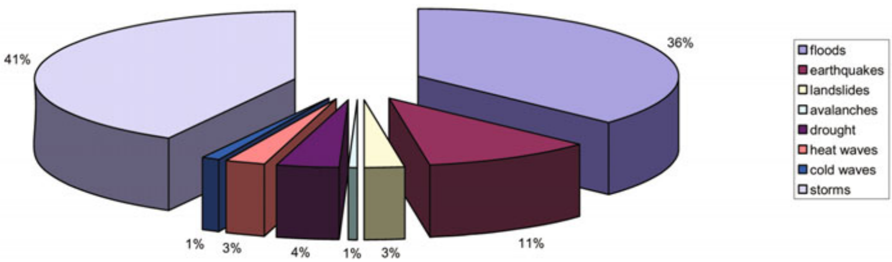


Fig. 3.10. Number of events per disaster type (source: NatCat 1950–2006)

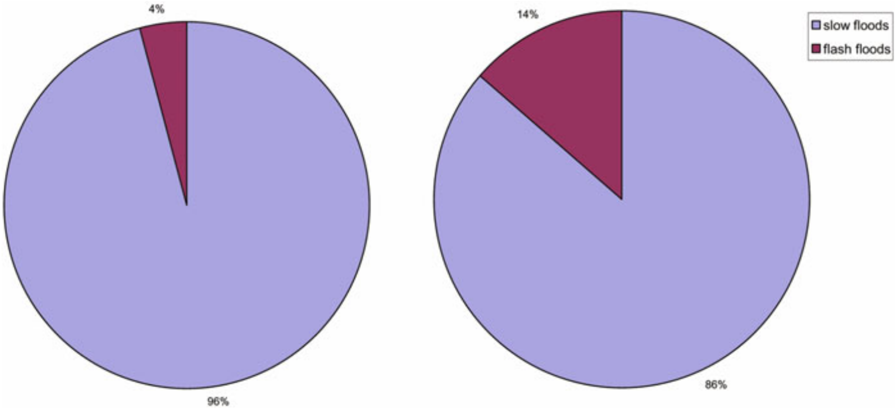


Fig. 3.11. Sharing between floods and flash foods (EM-DAT on the left, NatCat on the right)

Table 3.5. Comparison of the EM-DAT and NatCat database records related to the flash flood in 2002 along the Danube and Elbe rivers

Database	*Affected countries*	*Victims*	*Damages (millions $)*
EM-DAT	Germany, Czech Republic, Hungary, Slovakia, France, Austria, Romania, Bulgaria,	60	13,683,227
NatCat	Germany, Austria, Italy, Czech Republic, Hungary, Moldova, Switzerland, Bulgaria, Slovakia	233	21,533

relevant difference can be seen in the numbers provided. According to the data used by the Scenario research team to depict the Elbe disaster (see Chapter 4), the total economic losses amount to 18.5 bn (of which 3 bn were insured).

In Figs. 3.12 and 3.13 the partition of recorded events by damages caused by the same type of disaster is represented, showing a good agreement between the two series. Damages due to floods and storms are the largest, as those events are the most frequent; nevertheless, losses due to earthquakes are not negligible. The latter in fact provoke direct physical damages to buildings and infrastructures and several induced damages due to triggered hazards, such as tsunami, landslides and na-techs.

According to both EM-DAT and NatCat the most severe earthquake that hit Europe was the one striking the Irpinia area in Italy in 1980. Table 3.6 shows the records extracted from the two databases. Also in this case, quite an important different between the data can be seen. According to data provided by Pappalardo (1994), who carried out a thorough investigation on the Irpinia disaster using official sources of the Ministero del Bilancio (Ministry for Economic Affairs), 2700 people died and 9000 were injured, while total damage

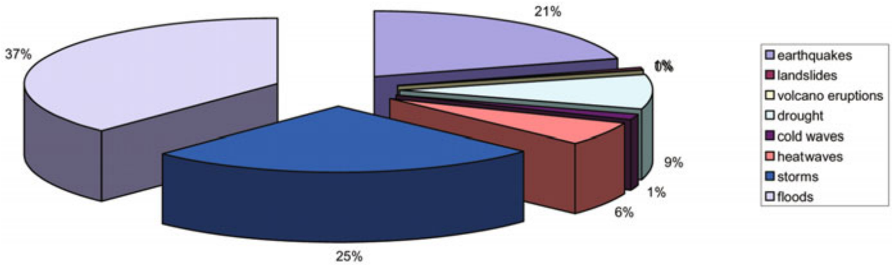


Fig. 3.12. Damages per disaster type (source: EM-DAT 1950–2006)

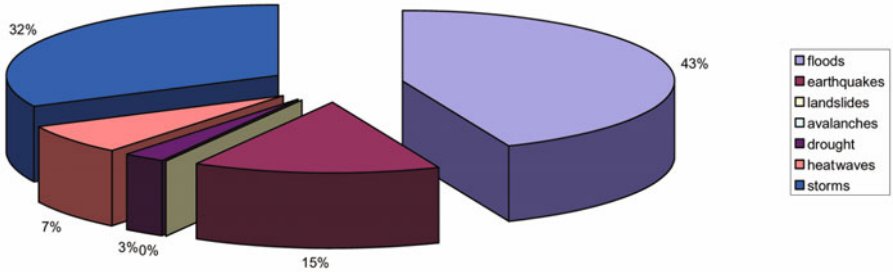


Fig. 3.13. Damages per disaster type (source: NatCat 1950–2006)

Table 3.6. Comparison of EM-DAT and NatCat databases related to the Irpinia earthquake in Italy

Database	*Affected regions*	*Victims*	*Damages (millions $)*
EM-DAT	Avellino, Potenza, Caserta, Naples	4689	20000
NatCat	Irpinia	2914	11800

amount to 21224 Billion Liras of 1980. In this case, the NatCat source seems to be more reliable.

Finally, the percentage of victims per disaster type, for both databases, is shown in Figs. 3.14 and 3.15, again showing good agreement. Looking at absolute numbers, heatwaves provoked the highest death toll in Europe; nevertheless, it should be pointed out that 95% of the total victims have to be attributed to the summer 2003 heatwave. Except for this event, the number of victims follow the disaster damage levels. (see Figs. 3.16 and 3.17), the largest part of which have been provoked by earthquakes.

Given the dramatic impact that the 2003 heatwave on the entire Europe, in terms of victims and damages, a specific search has been made to compare the two databases, which show rather significant discrepancies.

It is not an easy task to estimate the total number of deaths due to the heatwave with respect to those that would have occurred in any other normal

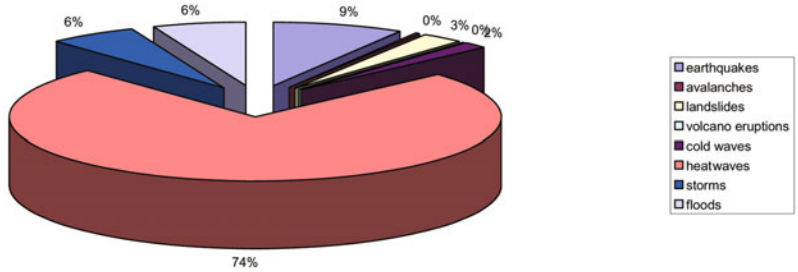


Fig. 3.14. Victims per disaster type (source: EM-DAT 1950–2006)

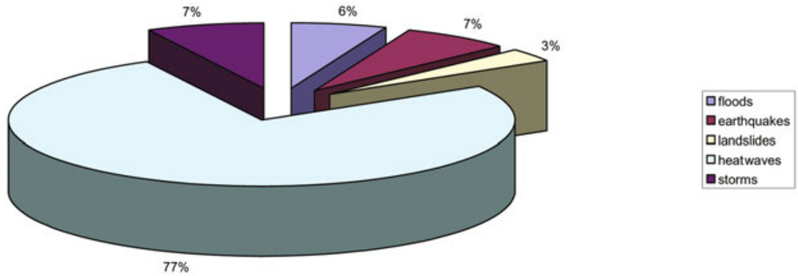


Fig. 3.15. Victims per disaster type (source: NatCat 1950–2006)

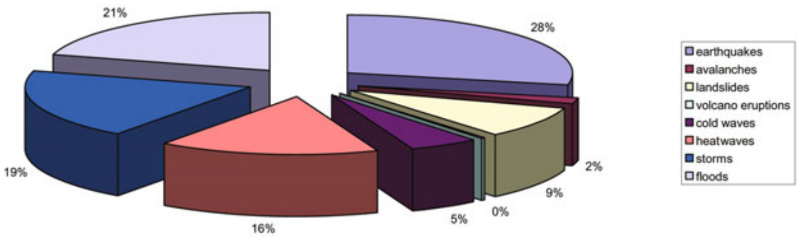


Fig. 3.16. Victims per disaster type, not considering 2003 heat wave (source: EM-DAT 1950–2006)

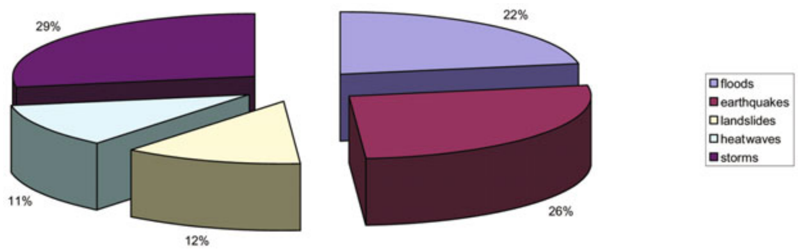


Fig. 3.17. Victims per disaster type, not considering 2003 heat wave (source: Nat-Cat 1950–2006)

Table 3.7. Comparison of data related to the heat wave in 2003

Database	*Affected Countries*	*Victims*	*Damages $ (millions $)*
EM-DAT	Netherlands, Belgium, UK, Germany, Italy, Luxemburg, Czech Rep, Portugal, Slovakia, France, Austria, Slovenia, Spain, Hungary	70383	11940
NatCat	Austria, Bulgaria, France, Germany, Italy, Netherlands, Spain, Poland, Portugal, United Kingdom, Slovakia, Slovenia, Switzerland, Hungary (Belgium, Czech Rep., Luxemburg)	50025	13000

year. For this reason the European Commission has mandated studies in order to understand what the "real" impact of this disaster was. It must be remembered that this impact can be explained not only on the basis of the natural meteorological adverse circumstances, but also (or mainly?) as a consequence of severe deficiencies in preparedness and mitigation. According to Robine et al. (2003): "In total, more than 80,000 additional deaths were recorded in 2003 in the twelve countries concerned by excess mortality compared to the 1998–2002 period. Whereas 70,000 of these additional deaths occurred during the summer, still over 7,000 occurred afterwards. Nearly 45,000 additional deaths were recorded in August alone, as well as more than 11,000 in June, more than 10,000 in July and nearly 5,000 in September. The mortality crisis of early August extended over the two weeks between August 3rd and 16th. 15,000 additional deaths were recorded in the first week and nearly 24,000 in the second. The excess mortality in this second week reached the exceptional value of 96.5% in France and over 40% in Portugal, Italy, Spain and Luxembourg. Excess mortality exceeded 20% in Germany, Switzerland and Belgium and 10% in all the other countries."

3.3.2 Disasters Are Increasing

Given the discrepancy in the number of events reported by the two databases, historical trends have been analysed rendering data dimensionless, by dividing reported data by the sum of the respective series. Figure 3.18 displays historical trends for disaster occurrence, showing a good agreement in the linear trends, despite apparent differences in absolute numbers between the two databases. Time series related to damages and victims, however, overlap considerably (see Figs. 3.19 and 3.20).

Those trends show a general increase in the occurrence of and economic damages due to natural hazards in the last 50 years, while the number of victims seems steady. If the 2003 heatwave data are removed, a slight decrease in the number of victims comes out (see Fig. 3.21).

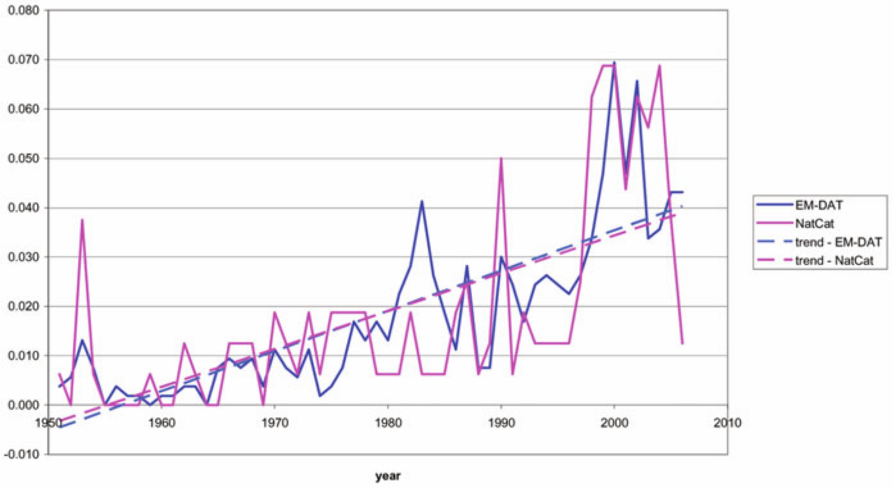


Fig. 3.18. Events per year (sources: NatCat, EM-DAT 1950–2006)

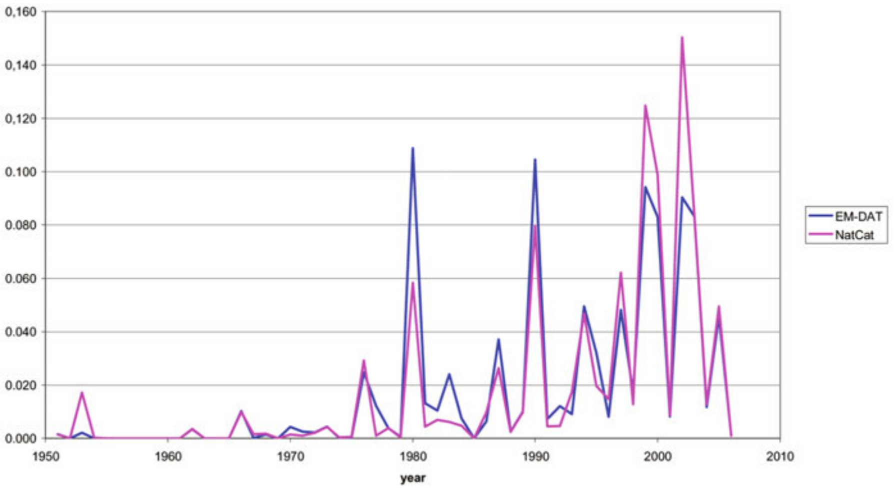


Fig. 3.19. Damages per year (sources: NatCat, EM-DAT 1950–2006)

As suggested in other parts of this book, this increase in trends can be explained by the significant development cities and regions of Europe have experienced since the Second World War, worsening exposure and vulnerability conditions to natural extremes. On the other hand, the observed decrease in number of victims can be explained by improvements in civil protection's capability to manage emergencies and in early warning systems.

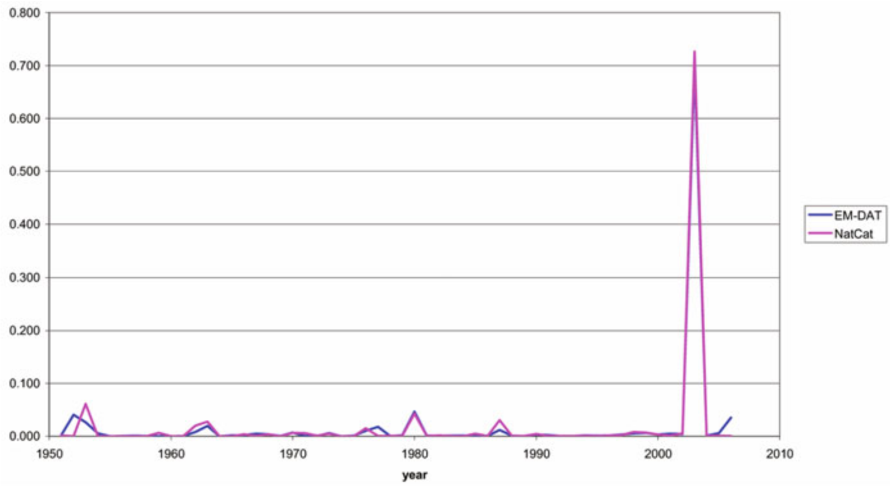


Fig. 3.20. Victims per year (sources: NatCat, EM-DAT 1950–2006)

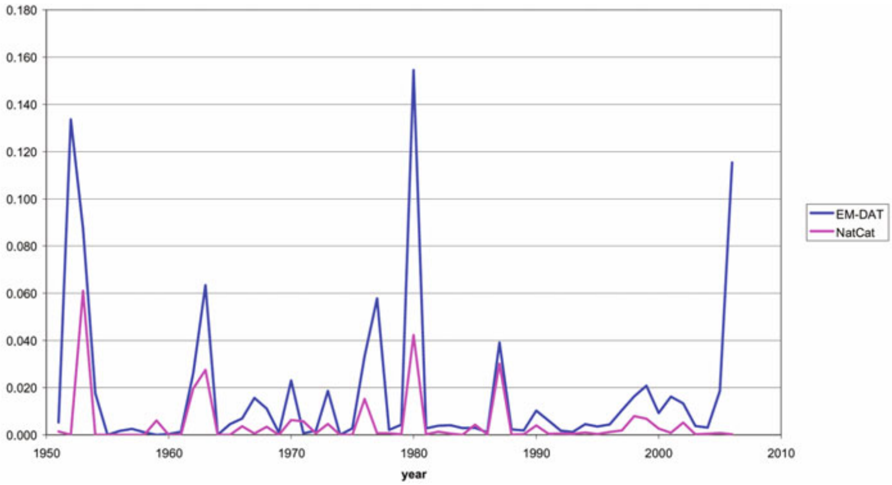


Fig. 3.21. Victims per year, not considering 2003 heatwave (sources: NatCat, EM-DAT 1950–2006)

3.3.3 Where Disasters Hit

Data analysis with respect to affected countries was limited to disaster occurrence. In fact, in both databases it is not always possible to disaggregate victims and damage data by country for events affecting more than one country.

Both databases identify France, Italy, Germany and the United Kingdom as the most frequently affected countries, although with different rankings (Fig. 3.22). There is also a good agreement in the partition by event type: while

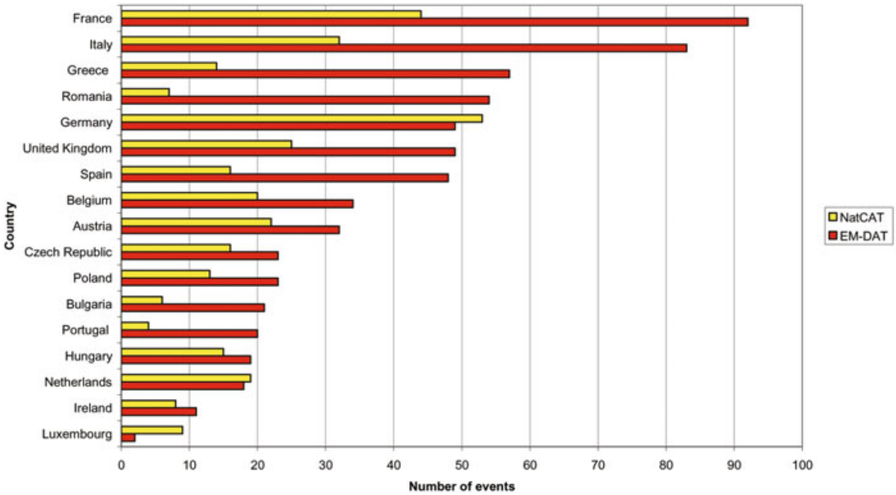


Fig. 3.22. Events per country (sources: NatCat, EM-DAT 1950–2006)

northern countries have mainly experienced meteorological, hydrogeological risks (floods, storms, heat/cold waves and landslides), Italy has been equally stricken by hydrogeological disasters (floods and landslides, mostly) and earthquakes.

A relevant disagreement arises, however, with respect to Greece and Romania. In fact, whilst in accordance with EM-DAT they are listed among the most affected countries, NatCat ranks Greece low in the list of the 10 most hit countries, while Romania is not even in that list. Furthermore Greece's exposure to seismic risk appears to be minor in the NatCat register, contrary to evidence. This discrepancy can be explained on the basis of the following reasons: the larger number of events recorded in EM-DAT, the fact minor events are better registered in EM-DAT than in NatCat and, finally, because countries affected by the same event are not always equally registered in the two databases.

3.4 Defining Damage and Losses: Different Perspectives and Interpretations

A disaster can be defined as a serious disruption of a community's normal life, due to widespread human, material, economic or environmental losses which exceed its capacity to cope using its own resources (EEA, 2008).

An attempt aimed to distinguish adverse effects due to disasters was carried out by the US National Research Council (NRC, 1999). It adopts the term **impacts** for both market- and non-market-based effects. **Losses** represent market-based negative economic impacts. Within this definition, another distinction is made between direct and indirect losses. The former result from the physical destruction of buildings, crops and natural resources, while indirect losses represent the consequences of that destruction, such as temporary unemployment and business interruption.

Costs of disasters represent cash payouts by insurers and governments to reimburse some (and in certain cases all) of the losses suffered by individual and businesses.

Finally, the NRC committee defines **damages** as physical destruction, measured by indicators, such as the numbers of deaths and injuries or the number of buildings destroyed.

Mileti (1999) for example emphasises how the word "damage" is used interchangeably with "loss". The term "direct damage" means any loss that is attributable to the destruction of buildings, machinery or public infrastructure, whereas "indirect losses" remains a somewhat vague concept. In some cases, indirect consequences of a disaster may even turn into positive outcomes for the local and regional economy, thanks to money and resources pouring in for reconstruction (negative losses).

These ambiguities may explain the reason why systematic efforts to collect data on indirect damage has begun only recently.

Another ambiguity, not much investigated, stands between a "catastrophe" and a "disaster", especially in terms of social impacts. The two terms are used sometimes interchangeably, sometimes to address different magnitudes of extreme events. Fritz (1961), for example, defines a disaster as "an event that concentrates in time and space, in which a society or a relatively self-sufficient sub-division of society, undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfillment of all or some of the essential functions of the society is prevented".

Quarantelli (2000) has devoted much attention to define what a disaster is, having in mind potential repercussions in planning and managing actions. Hence, severe aspects of a catastrophe compared to a disaster are stressed in terms of:

a) entity of community built structure heavily impacted
b) possibility of local officials to undertake their usual work
c) sharp and simultaneous interruption of everyday community functions
d) possibility to receive help from nearby community.

Impacts from disasters may be different according to the typology of the disaster itself. Some of the most frequent economic and social effects, depending on the type of natural disaster, are shown in Table 3.8 (Cuny, 1983).

A more exhaustive view of the consequences of an extreme flood is provided by Damm (2007) (Fig. 3.23). It is worth highlighting the possibility of "positive" as well as "long-term" impacts. In this regard, potential impacts on human health have rarely been investigated.

Table 3.8. Main impacts produced by different typologies of disasters (Otero and Marti, 1995) (Adapted from Frederick C. Cuny, *Disasters and development,* Oxford University Press, New York, 1983)

Disaster type / ***Impacts***	*Earthquake*	*Cyclone*	*Flood*	*Tsunami*	*Volcanic eruption*	*Fire*	*Drought/ famine*
Short-term migrations			x		x	x	x
Permanent migration							x
Loss of housing	x	x	x	x	x	x	
Loss of industrial production	x	x	x	x		x	
Loss of business production	x	x	x	x		x	
Loss of crops		x	x	x	x	x	x
Damage to infrastructure	x	x	x	x		x	
Disruption of marketing systems	x	x			x		
Disruption of transport systems	x		x				
Disruption of communications	x	x	x	x		x	
Panic						x	
Breakdown of social order	x	x				x	

A more systemic approach for classifying disaster impacts has been adopted by the World Bank Institute: "in the event of natural disaster, humanitarian, economic and ecological impacts and effects may occur. Humanitarian effects include loss of life, affected people and psychological post-disaster effects; ecological effects comprise the loss of arable land, forests and damage to ecosystems. Economic effects are usually grouped into three categories: direct, indirect and macroeconomic[4] effects" (Mechler, 2003, pp. 35–36).

With respect to human losses, other discrepancies can be found in definitions: "fatalities" is usually used as equivalent to "deaths", but in some cases it is used to identify "involved/affected people", including also injured and missing people. Moreover, it is widely accepted that nowadays there is no universal definition for what is meant by "affected", although it varies enormously from disaster to disaster and between reporting sources (CRED, 2006).

[4] Macroeconomic effects are also classed as secondary effects.

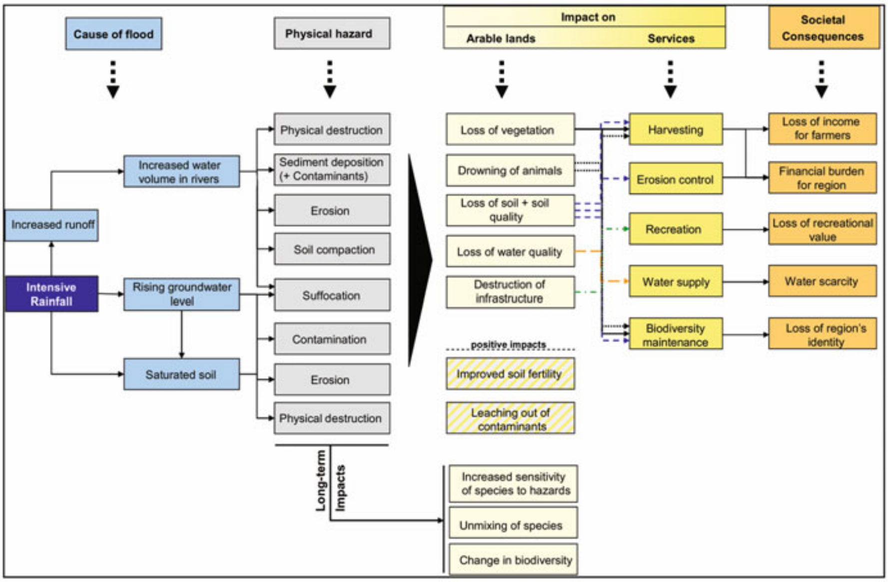


Fig. 3.23. Impact chain derived by flood (Damm, 2007)

Ecological effects, such as the destruction of rich forest ecosystems and the affects on rare plant and animal species caused by forest fire or the removal of the biotic stock caused by landslides and snow avalanche are also rarely considered in the damage assessment. Certainly those are difficult to represent in monetary terms.

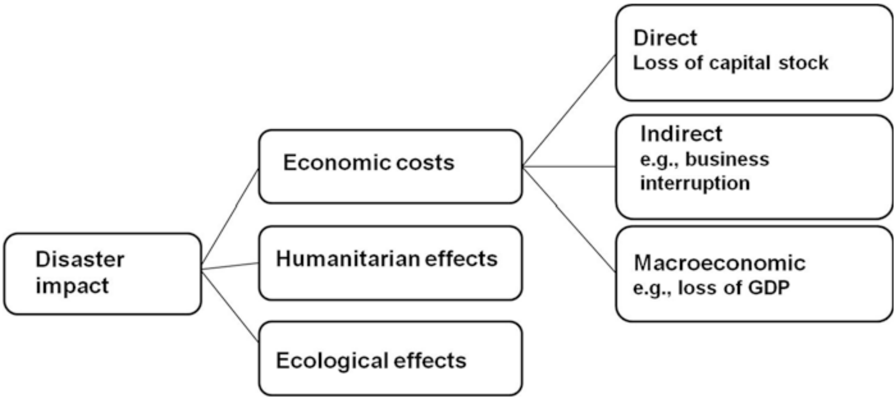


Fig. 3.24. Impacts from disasters according the World Bank approach (Mechler, 2003)

In contrast to available studies addressing ecological and human impacts, a wide literature about economic effects has been developed (White, 1964; Howe and Cochrane, 1993; OECD, 1994; ECLAC/IDNDR, 1999; Freeman, 2002; Benson, 2002).

Economic effects are grouped into three categories: direct, indirect and macroeconomic effects (Mechler, 2003). Significant differences can be found though in the way those effects are defined. In Table 3.9 interpretations and views held by individual researchers and by a number of international institutions involved in risk mitigation and management are represented.

In the framework provided by Benson (2002), consultant for the World Bank, the economic costs of disasters can be broken down into three types:

- Direct costs relate to the capital cost of assets (such as buildings, other physical infrastructure, raw materials and the like) destroyed or damaged in a disaster. Crop losses are often included in such calculations.
- Indirect costs refer to the damage to the flow of goods and services. They include, for example, lower output from factories that have been destroyed or damaged; loss of sales income due to damaged infrastructure such as roads and ports; and the costs associated with having to purchase more expensive materials or other inputs where normal – cheaper – sources of supply are affected. They also include the costs of medical expenses and lost productivity arising from increased disease, injury and death.
- Macroeconomic or secondary effects concern short- and long-term impacts of a disaster on the overall economic performance. These may include a deterioration in external trade and government budget balances, the reallocation of planned government spending and increased indebtedness. Disasters can also affect the pattern of income distribution or the scale and incidence of poverty.

As observed by Otero and Marti (1995, p. 16), because macroeconomic effects reflect indirect damage as well as relief and restoration efforts, these effects cannot be simply added up without causing duplication.

Direct damages occur at the disaster onset or within a few hours, while indirect and secondary ones may occur over a much longer period of time, as much as five years or even more, depending on the magnitude of the impact. In fact, the time period to be considered in estimating indirect losses is equal to that required to return to the pre-event normal conditions (ECLAC, 2003).

Estimated costs are based on "direct" physical losses, while "indirect" and "secondary" effects on economic activity go unreported even though they may be substantially higher than direct damages. In fact, as reported in a paper prepared by Environmental Resources Management on behalf of DFID (2005) "most assessment of disaster impacts only focus on quantifying immediate direct damages and only in financial terms. The economic costs consist mainly of immediate damage assessment in order to provide governments and aid donors with estimates of the amount of funds required to address emergency and reconstruction needs, as well by insurance companies. Long-term indirect

Table 3.9. Summary of definitions of direct, indirect and secondary damages

Author	*Direct damage*	*Indirect damage*	*Secondary damage*
ECLAC (1999)	damage to properties distinguishes between: – damage to public goods – damage to private owners and between: – repair costs – replacement costs – damage to machinery – damage to stocks	effects of flows of goods and services examples: – unpaid fees (gas, electricity …) – decreased taxes from damaged areas – increased transport costs	effects on main macroeconomic variables examples: – effects on GNP (local more than national) – import balance – national debt – investment capacity – public resources
Van der Veen (2003)	loss of capital and stocks	* primary indirect damage interruption of economic flows	* secondary indirect damage amplification effects due to interaction between different services
Rose (2002)	damage to capital and flows are the same effect as they both produce a decrease in production and in future income		
Cochrane (1997)	damage to capital and objects	damage to activities connected to those physically damaged	
International agencies (IIASA, World Bank, United Nations)	damage to physical structures * buidings * lifelines * industrial facilities * stocks of goods and materials	damage to flows of goods and services: * decreased production in damaged plants * decreased revenue as a consequence of "context damage" (marketing, "image") * damage to transportation networks * increased costs of energy resources as a consequence of loss of more economic ones	

costs in the flows of goods and services, reduced levels of production and non market impacts such as environmental damage and psychosocial effects are frequently omitted from such assessments". The World Bank has implemented a "**macro-economic method**" to estimate losses, supported by IIASA, UN and other development organisations in order to assess whether a disaster may hinder macroeconomic performances of developing countries. This method adds the secondary effects concept to the disaster cost/loss estimation method but this is susceptible to producing the aforementioned duplication effects.

The World Bank approach is not widely accepted. Van der Veen et al. (2003) for example criticises the "secondary effects" category, stating that "the World Bank aims at modelling the recovery phase of an economy after a disaster". According to them, only the two categories of direct and indirect costs should be considered.

Direct costs related to:

- Physical damage to capital assets, including building, infrastructure, industrial plants, and inventories of finished, intermediate and raw materials destroyed or damaged by the actual impact of a disaster. In particular:
  - Property owned by households and government is measured as changes in stocks;
  - Business interruption is estimated as a flow for the duration of the flood.
- Non-monetary impacts on households.
- Indirect costs, instead, are describe by Cochrane (1997) as a
  "result of dislocation suffered by economic sectors not sustaining direct damage. Activities that are either forward-linked (rely on regional markets for their output) or backwardlinked (rely on regional sources of supply) could experience interruptions in their operations."
  According to Cochrane (see Fig. 3.25), if factory B is flooded, suppliers of goods and services are affected as well as firms that purchase gooods from B.

Accepting to limit the analysis to direct and indirect damages, discrepancies can be found with respect to the exact definition of direct and indirect as well as to how stocks and flows enter into the assessment. Cochrane, for example, also includes in direct damages the induced physical effects provoked by the disaster. Parker et al. (1987) differentiate between primary and secondary indirect costs. According to their view, direct costs relate to loss of land, capital and machinery, and thus to stocks, while primary indirect costs refer to business interruption. On the other hand, secondary indirect costs refer to flow interruptions and the associated ripple effects in the economy. The authors also state that the two categories cannot be simply added together. According to Rose and Lim (2002), however, business interruption should be considered as a direct cost within a national accounting method. In fact, both business interruption and loss of stocks imply a halt to production and a reduction in future income.

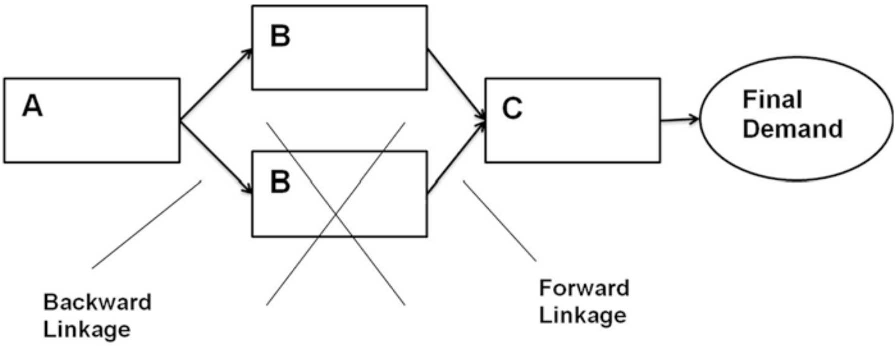


Fig. 3.25. Forward and backward linkages in an economy, when Factory B is damaged

Difficulties connected with impact analysis methodologies emerge from the presented review. To ambiguity related to what is intended for direct and indirect costs, Okuyama et al. (1999) adds other specific and sectorial factors:

- Dynamic adjustment of production process: recovery process, resiliency, influence of network infrastructure disruptions, interregional substitution, inventory adjustment
- Change in labour supply: number of refugees, commuting problems
- Data availability: the scales of timeline and spatial size of damage by unscheduled events are much shorter and smaller than the usual published statistic data
- Change in final demand: a massive amount of relief goods, retrofit investment of public and private capital.

Summarising this overview of damage definitions, a significant level of disagreement arises among methodologies for assessing disaster losses. Very few of the refined distinctions that have been discussed above appear in global databases; very few are available at national or lower levels. The possibility to include indirect, secondary damages into disaster accounting is therefore still a challenge to be met should a European disaster information system be created to address the shortcomings and the needs highlighted in this chapter.

Rose (2004) recognises the improvement of the empirical and theoretical basis of damage estimation as a priority of future research, implying:

- the establishment of protocols for defining and collecting data comparable across disasters and impacted regions
- testing major hypotheses regarding determinant of losses, strength of resiliency, and effectiveness of public policy
- incorporating these advances into hazard loss estimation models.

3.5 A Look ahead toward the Development of a Global Database at the European Level

In order to assess potentialities and limits of current global disaster databases, a SWOT analysis has been carried out (Fig. 3.26). SWOT, an acronym standing for Strengths, Weaknesses, Opportunity and Threats, was created as a decision support system for business strategies in contexts characterised by lack of certainty and strong competitiveness. In the specific instance, for analogy, competitors could be represented by the different existing datasets.

STRENGTH	WEAKNESS
✓ Standard definitions and common methodologies ✓ Public access ✓ No thresholds for an entry ✓ Completeness in data records referring to both natural and technological disasters ✓ Accuracy in disaster picture ✓ Adequate resolution and observation level ✓ Different searching options ✓ Geo-referencing ✓ Well-calibrated techniques of capturing human, economical and ecological losses ✓ Data validation and continuous update ✓ Wide advertise of results	✓ Lack of standardised practises for collecting data (definition, methodologies) ✓ Private access ✓ Entries depending on thresholds ✓ Field filling not complete ✓ Lack of a unique disaster-related codex ✓ Global observation level ✓ Difficulties in reporting trans-boundary effects ✓ Difficulties in reporting "disaster cascades" ✓ Low accuracy in reporting indirect losses ✓ Discrepancy in data due to different sources
OPPORTUNITY	**THREATS**
✓ Interoperability ✓ Reliable scientific source in terms of characteristics of disasters ✓ Inventory of losses for estimating disaster impacts on development ✓ Guide for relief and recovery activities ✓ Tool of measurement for assessing effectiveness of mitigation actions ✓ Provider of outcomes and vulnerability data for risk assessment ✓ Monetary value of a good data collection	✓ Impossibility to compare data across different databases ✓ Misleading trends ✓ Small scale event kept hidden under the main ones ✓ Transboundary effects neglected ✓ Impacts related to triggered phenomena underestimated ✓ Indirect losses underestimated ✓ Arbitrariness in results depending on chosen source

Fig. 3.26. A SWOT analysis to define an ideal disaster database significant from a global perspective

Within a SWOT approach, strengths and weaknesses are endogenous factors that can be subjected to modifications, whereas opportunities and threats depend on external factors that cannot be controlled or influenced.

Interactions among the S-W-O-T factors are mutual and usually more complex but, in this context, an "N" reading pattern will be privileged, examining how weaknesses can turn into threats when an external use is made and how, on the contrary, these threats can become opportunities for improvements.

A low standardisation level, in terms of definitions and methodologies for collecting data, has been observed in current global databases as well as in the literature in general. This factor, together with restricted access to records and to the absence of a unique number to identify individual occurrences, make data comparison rather difficult.

Shared definitions and common methodologies to gather data are needed to guarantee interoperability among databases, for example between local/ national and global ones. Data sharing could be limited by a non-open-source access: publicly available databases are clearly preferable and the internet provides the adequate solution as an open repository.

Disaster trends have been recognised as one of the most important outputs provided by a database in terms of risk assessment. The threat is represented by the processing of misleading trends because of missing values in records or inaccuracy in reporting transboundary or secondary effects. In this regard, completeness in records should be strongly recommended, including also secondary and cascade effects, such as na-techs.

Misleading trends could also be a consequence of low accuracy in reporting losses, and in particular indirect losses, which are often larger than direct ones. In these terms, there is a need for research that develops techniques to represent human and economic losses as well as ecological ones.

"Traditional" fields (e.g. disaster type, location, date, human and economic losses) could be complemented by technical information (e.g. magnitude, return period) as well as by qualitative information provided in a narrative-descriptive format. The latter should be structured according to a predetermined framework, following for instance the temporal disaster phases: impact, response and recovery. The record could also be integrated with photos and visual systems.

In a "global" database, a global observation level can make small-scale events invisible. This aspect represents another threat in terms of output because the resulting country profile may appear incomplete or neglect important phenomena. As mentioned above, interoperability between global and local databases should be looked for.

The SWOT analysis proposed in this paragraph is meant to support the creation of a European database, aimed at recording and providing reliable data to support risk mitigation policies and also to enable researchers to improve current images of Europe at risk as well as support attempts to depict future scenarios.

4

Current Mitigation Practices in the EU

J.F. Esteban, B. Izquierdo, J. Lopez, D. Molinari, S. Menoni, A. De Roo, H. Deeming, G. Walker, G. Eftichidis[1]

4.1 Introduction to Mitigation Measures

Mitigation measures are those aimed at reducing the potential harm to people and damage to the built and natural environments resulting from natural extremes. Various actions, ranging from hazard mapping to structural and non-structural measures, to insurance and legislation have been proposed as components of risk mitigation.

Those actions can be grouped in three main categories:

- The first relates to risk assessment methods, ranging from hazards analysis to exposure and vulnerability appraisal to their representation in different forms including mapping. This category has been treated in other chapters of this book, with a specific focus on Europe.
- A second category can be more appropriately referred to as "risk mitigation". It comprises policies and interventions to be taken in order to lessen or minimise the impact of natural extremes on societies and assets. Such measures should be based on risk assessment in order to address the problems at stake in the best possible way. For a number of years though, some scholars have been questioning the utility of many research products in actually feeding mitigation (see Weichselgartner and Obersteiner, 2002; Lindell, 1997). Clearly this is a very crucial point for the Scenario project and will be thoroughly discussed in Chapter 7. Here, however, the current situation as far as mitigation practices are concerned will be addressed.
- The third category of tools is aimed at implementing adopted mitigation policies, for turning them into practical interventions and actions. The latter must be taken by the multiplicity of actors who have been recognised as key players for risk reduction (see Lindell, 1997). In this chapter, two basic implementation tools will be considered: legislation and insurance. In both cases first the situation at the European political level will be con-

[1] The contribution of D. Lumbroso and S. Wade in providing information and input to this chapter is acknowledged

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

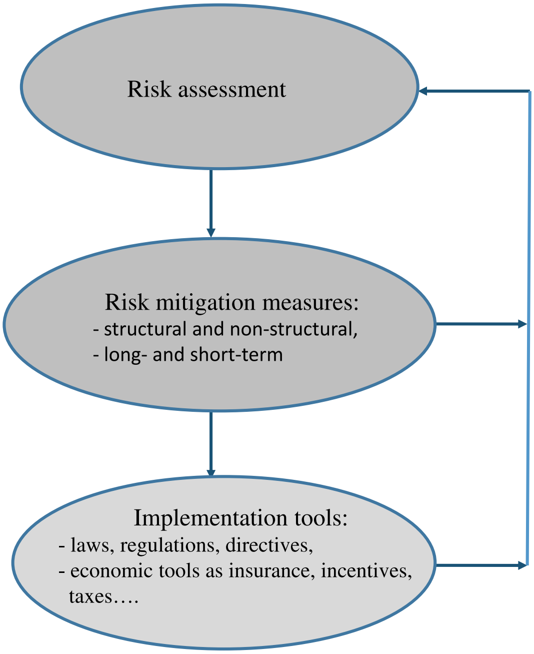


Fig. 4.1. The different components of risk mitigation

sidered, then at the country level, pointing out examples that are deemed relevant for the entire Union.

The chapter is completed by the summary of an extensive review of the results of the Nedies project, constituting a unique source for revising lessons learnt in a large variety of cases encompassing all natural hazards in the EU.

According to Lindell (1997)

> “risk adjustment can be defined as those actions that intentionally or unintentionally reduce risk from extreme events in the natural environment. These adjustements can be classified according to their time of implementation in relation to the time of physical impact of the hazard agent. The best known and most widely utilized adjustments are the post impact adjustments of emergency response and disaster recovery. [...] By contrast, emergency preparedness and hazard mitigation activities take place before disaster impact. Emergency preparedness activities such as developing plans and inventory response resources are undertaken to improve community’s capacity to respond in a timely and effective manner during disaster impact. Hazard mitigation actions such as reducing the occupancy of vulnerable areas or strengthening structures are directed toward eliminating the causes of a disaster, reducing the likelihood of its occurrence, or limiting the magnitude of its impacts if it does occur” (p. 328).

While it is considered important to address both emergency preparedness and risk mitigation (we prefer risk mitigation as a term to hazard mitigation) as parts of a comprehensive policy aimed at reducing and preventing the negative impact of a natural disaster, it seems important to enrich the number and quality of criteria used to classify risk mitigation as a whole. In fact, as Neal (1997) has observed, an overemphasis on the disaster phases, pre-impact, impact, emergency, recovery and reconstruction, overshadows the fundamental cyclic character of most (all?) natural hazards and the dynamic processes involved in the move from one phase to another, which is dependent on several political and social variables and cannot be assumed as being automatic or "natural".

In this regard, recovery and reconstruction should be considered a pre-impact mitigation as well, evidently not with respect to the event that has just happened but to the one that is likely to occur sometime in a probable future.

This way of considering disaster cycles and dynamic features responds well also to other critiques that have been raised for example by Roux Dufort (2007), according to whom more prepared and effective organisations should move from an event-focused approach to a more process-oriented thinking and taking decisions about risk management. His argument concerns crisis management, but several of his observations can be clearly extended to risk management in general and actually have been proposed by other authors (see Quarantelli, 1998b), who refused to consider the disaster as an exceptional event and favoured instead a vision of the event as just an accelerator, a facilitator of processes that were already developing in the stricken community. In this respect, vulnerability is clearly an important variable to be considered, as an intrinsic feature of a society and a territory that determines the way they react to an "external" stress (Hewitt, 1997).

Therefore in this chapter another distinction with respect to time will be proposed, between short- and long term strategies, considering as a discriminating factor the time needed to see first positive results in terms of risk reduction. Long-term measures have a longer time horizon and require time to develop their efficacy. An example is certainly land use planning, particularly when transformation of existing settlements is at stake. The second can be considered "short term" in that they address preparation for a potential emergency, increasing the coping capacity of a given community and territory. Those should be considered as part of mitigation for several reasons. First because to be able to cope correctly and efficiently to an extreme, a previous planning and preparedness process must have been developed. Second because such measures will always be required, even in the fortunate case where residual risk is brought close to zero. One should never assume emergencies will not occur in the future, as surprises are going to be crucial challenges in the future, as suggested by many authors. Third, because despite the general belief that organisational capacities in Western countries are strong enough to deal with such surprises and crises, many cases show

	STRUCTURAL		NON-STRUCTURAL			
	decreasing HAZARDS	**reducing EXPOSURE**	**reducing VULNERABILITY**			
			physical	**social and economic**	**built environment**	**natural environment**
long-term mitigation measures	- building consolidation	- land use planning to avoid the most hazardous zones	- building codes	- preparedness programs	- land use planning	- preserving diversity in agricultural activities
	- levees, outlets, etc.	- relocation from the most critical areas	- building retrofit codes	- education, training of various public sectors	- locational decisions regarding public services and infrastructures	- tailoring agricoltural practices to the type of soil/terrain
	- avalanche defence - landslide consolidation	- insurance integrated to land use planning	- norms to secure public facilities, factories etc.	- development of programs with the media		- protection of marsh areas, humid zones, shoreline dunes
	- reduction of gas emissions			- adaptation to reduce the impact of climate change		
short-term mitigation measures	- lava flows diversion	- evacuation	- building usability checks	- improvement of civil protection organisational capabilities	- accessibility to services and to potentially damaged areas	- sustainable practices in lava, water flow diversion
	- sandbags and barriers to inundating waters		- temporary repairs particularly for lifelines	- business continuity plans also for the public sector		
	- fire control			- use of the media to dispatch emergency messages		

Fig. 4.2. Short- and long term mitigation measures addressing different risk components

exactly the opposite and call for stronger coordination among the various search and rescue and civil protection forces, more international cooperation and more guidance by the European Union in the specific case of Europe. There is room for improvement also in the field of emergency preparedness, not to mention the fact that good crisis management is the fundamental basis of any rapid and positive recovery.

However, classifying risk mitigation measures would require aspects other than time to be taken into account in order to provide a satisfactory picture.

As shown in Fig. 4.2, two other key criteria are proposed, on the one hand distinguishing between structural and non-structural measures, and on the other according to the risk component they are designed to reduce (hazard, exposure, vulnerability or a mix of the latter).

Structural measures consist mostly in engineering works that are designed to modify the physical phenomena that represent a hazard for a given community. Examples are landslide consolidation, avalanche defences, levees, etc. Strengthening exposed buildings and infrastructures can be also considered a structural measure to reduce their physical vulnerability. Such measures can be very effective against hazards such as earthquakes, storms, hurricanes.

Non-structural measures consist instead in social, economic and managerial adjustments, aimed at making communities and settlements more resilient to various types of threats. A large variety of measures can be considered, pertaining basically to two main categories: land use planning and facilities location on the one hand and organisational and social strengthening through training, preparedness and risk awareness programs on the other.

Finally it is important to understand what component is addressed by the selected structural or non-structural measure, as suggested in Fig. 4.2. This way a more refined distinction can be proposed among:

- Structural measures aimed at reducing the hazard potential and/or frequency
- Structural measures aimed at reducing physical vulnerability of exposed settlements and infrastructures
- Non-structural measures aimed at reducing the exposure and vulnerability of communities and settlements.

Structural measures aimed at mitigating hazards have certainly received the most attention until very recently, to the point that they have sometimes contributed paradoxically to increase the overall level of risk. In this regard, various examples can be quoted, like the vicious cycle of levees, urban development, flood, levee upgrade, new development, more catastrophic flood. This cycle is not unique to floods; one can well recall other cases, for example, avalanche defences or landslide consolidation.

Structural measures to reduce buildings' physical vulnerability have been strongly promoted for seismic risk, where there exists a rather long tradition of vulnerability assessment and a variety of tools to retrofit existing structures. Particular attention has been devoted in some countries, like Italy, to the historic heritage, developing a wide range of instruments, both analytical and in design to help improving seismic performance of traditional masonry, wooden and other types of structures.

Vulnerability reduction measures have been proposed also for other hazards. For example it has been prescribed to elevate buildings in floodplain areas or recur to specific design features to make buildings and blocks more resistant to avalanches. According to Burby (2001), one and perhaps the most meaningful result of the Nfip (National Flood Insurance Program) program in the US has been the reduction of buildings' vulnerability in floodplain areas.

In the same vein is the recently approved Flood Directive (2007/60/EC), which most importantly will constitute a fundamental step towards a more comprehensive European policy addressing flood risk mitigation considering not only structural measures aimed at hazard control but also vulnerability reduction. The Directive, which is the first significant European act directly addressing the issue of natural risk prevention, constitutes a unique occasion also for enhancing non-structural measures aimed at both the short and long terms. In particular, in article 7.3 it is written: “Flood risk management plans shall address all aspects of flood risk management focusing on prevention, protection, preparedness, including forecasts and early warning systems and taking into account the characteristics of the particular river basin or sub-basin. Flood risk management plans may also include the promotion of sustainable land use practices, improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event”.

Land use planning has gained attention in more recent years and has been increasingly included in discourses regarding risk conditions and risk avoidance. It has become evident how planning decisions may create, exacerbate or reduce risks as no other policy, because they set the characteristics of the built environment for long periods of time, much longer than the life of each individual building or infrastructure that are part of a new or transformed settlement.

4.2 Long-term Risk Mitigation Measures

4.2.1 Structural Defence Measures

Structural defences are not sufficient to eliminate risk on their own but continue to be important and relevant for mitigation. For example, major potential flood disasters in Europe (such as along the east coast of England in November 2007) have been prevented through the protection provided by structural defences. Examples of unsustainable structural defences can be found around Europe, at least as far as their impacts on the landscape and on ecosystems are concerned, for example when concrete works are used to stabilise landslides and slopes.

Similarly, a positive mix of traditional soil maintenance practices and bioengineering interventions can be also found in mountain river basins and slopes.

An issue that has to be considered is the economic sustainability of defence measures. Sometimes structural measures appear to be sensible and cost effective when adopting a local perspective, but may look expensive and incapable of solving the problem when a wider perspective is taken and multiple localised hazard sites are considered at a larger scale. For this reason in the “image of Europe at risk” (see Chapter 2) a third category of stresses, multi-site, has been identified. Even though a landslide or an avalanche may be regarded as a single phenomenon, when looking at a larger scale and discovering that very large areas are all affected by similar local hazards, the question of what the best mitigation priorities should be can shift and a variety of different measures may become necessary. In a more integrated framework it is necessary to consider the full breadth of costs and benefits involved, and to compare between alternative approaches that could be adopted.

4.2.2 Structural Measures Addressing Vulnerability: Building and Infrastructure Construction

Making buildings, public facilities and lifelines more resistant to various external stresses can be considered a structural measure, though in this case the goal is to reduce exposed systems' vulnerability rather than intervene with the hazard itself. There is much evidence that good construction and state-of-the-art consolidation techniques, which are not necessarily sophisticated or new, can save thousands of lives and limit the severity of damage, especially for some hazards such as earthquakes.

Reinforcing and retrofitting buildings has proven to be extremely efficient in preserving lives and properties. In fact, it must be borne in mind that any new code will be enforced in future developments, whilst leaving unprotected large parts of settlements built before its introduction. For this reason, it is crucial that facing any type of natural hazard, not only new structures are taken into consideration, but also old ones, in order to reduce their vulnerability.

Furthermore, in a multi-risk perspective, when a territory is exposed to a variety of threats, it is necessary to analyse the various mitigation measures in a comprehensive fashion and make sure that they do not conflict with each other. This is to avoid a situation where a mitigation measure taken to reduce one risk augments the vulnerability to another threat. It may be the case, for example, for elevated houses which can be more resistant to floods but in the meantime more vulnerable to ground shaking.

Similar considerations can be drawn for public facilities and lifelines. These have only gained interest recently; therefore, studies are less advanced than in the case of ordinary buildings. In both cases, but especially for lifelines, everyday activity seems more important than occasional strengthening projects. Because lifelines are extensively spread over very large areas, their retrofitting solely for safety purposes is rather unlikely. More promising are those initiatives aimed at including safety among design and maintenance criteria, so as to achieve substantial results in ten or twenty years. Particularly interesting in this regard is the experience of California, where managers of utility services (e.g. water and electricity supply) and transport networks have been educated in seismic engineering (Taylor et al. 1998). This has allowed the gradual inclusion and enforcement of seismic prevention measures into standard programmes; both for new infrastructure and during the replacement and renovation of old stock and plant.

4.2.3 Non-structural Measures: Land Use Planning and Management

Land use planners and city managers play a key role in influencing patterns of exposure and vulnerability, as they substantially contribute to shape the relation between buildings, people and critical infrastructure location and areas potentially affected by particular hazards. Planning may even contribute to change the course and severity of hazard events – these include flooding where development can change the drainage and response patterns of a catchment and na-tech situations where the siting of hazardous installations can be crucial in determining the potential for interaction between natural and technological hazards. It is relatively easy to illustrate how sustainability may be coupled to risk mitigation in sound land-use planning, especially in those cases where poor planning decisions may lead to increased hazard, exposure and vulnerability. Furthermore, because planning is a systemic activity that must take into account multiple issues, it may create positive connections between risk prevention and eco-compatible choices for urban and rural settlements. Seeking to integrate wider environmental objectives within those of risk mitigation and even to find ways of "turning hazards into resources" (for example, in the management of coastal flooding) should be a priority for land management strategies.

However, research has enlightened many problems with integrating hazard and risk concerns effectively into land-use planning across Europe (Fleischhauer et al. 2006). Despite the growing concern for land-use planning expressed by various scholars, there is no comprehensive European policy or act directly addressing the connection between planning and risk prevention. Such a provision existed in the first version of the US Stafford Act (Public Law 93-288) and with less emphasis in the amended version of 2000. For example, in section 405 regarding the repair of federal facilities, it is written: "In implementing this section, Federal agencies shall evaluate the natural hazards to which these facilities are exposed and shall take appropriate action to mitigate such hazards, including safe land-use and construction practices".

The low level of attention gained by land-use planning as a preventive tool in Europe, an issue clearly raised by the Armonia project (Fleischhauer et al. 2006), is rather puzzling considering the longer and more pervasive tradition of urban planning in Europe with respect to the USA.

One of the main conclusions of the state of the art developed within the Armonia project regarding the role of planning in mitigation is the fragmentation and sectoralisation of policies, in such a way that even when land uses and facilities' location are at stake, limitations and regulations are set by sectoral instruments (for example river basin plans) that must be implemented by planners but are not the result of an interaction of planners, different stakeholders and experts in natural hazards. Limitations and rules addressing risks are considered as "technical" input to plans, the intimate meaning of which is often misunderstood by those who should actually apply them at the local scale. Even the most advanced tool that can be found in Europe, the *plan de prevention des risques* in France, does not escape this general fate of being a document external to the land use mainstream production of plans and programs, with the result that there are examples of overriding the preventative requirement instead of attempting a less efficient, but more fruitful integration of technical and negotiation aspects related to the future asset of built areas.

4.2.4 Non-structural Measures: Public Education and Communication

Communication and education can play a vital part in contributing to the development of community and individual preparedness and resilience. People or communities that are poorly prepared for hazards will respond less effectively during and after particular events, with the consequence that impacts will be more severe and last longer. For smaller events, effective communication and good preparedness can be particularly important in achieving the goal of greater resilience (Covington and Simpson, 2006; King, 2000). Communication in the context of preparedness has an important role to play in enhancing capacity for mitigation and developing community resilience to coping with and recovering from natural hazards.

There are many examples of how being informed, aware and prepared, before events occur, has enhanced the capacity of members of the public potentially at risk to cope and to reduce losses. For example, Covington and Simpson (2006) refer to people taking preparatory actions such as storing food, clean water, cash and equipment, securing heavy furniture to walls and developing household emergency plans in order to reduce the affects of hazard occurrences. In the UK awareness programmes recommend various levels of preventative action to householders at risk from flooding. These include learning how to switch off utility supplies and barricade doorways with sandbags in an emergency, to considering long-term flood-resilient countermeasures such as replacing wood flooring with concrete and raising electrical sockets above the potential flood level (ODPM, 2003).

Mileti et al. (2004) argue that being aware of risks and taking preparatory actions can "prime" people for response in the future (for example, going to evacuation centres), enhancing therefore the effectiveness of warning systems that communicate before and during hazardous events. In simple terms, if people do not know in clear terms what to do in response to a warning being issued (in the form of a siren, media message or local door-knocking), then that warning is less likely to be responded to effectively. Therefore there needs to be a close coordination and integration between the different pre-, during and post-event phases of communication.

There have been many initiatives in European countries and elsewhere to inform and communicate to the public of existing risks and possible self-help mitigation measures. Such programmes have met with mixed success and have been limited in their impact. There are a number of reasons for this. First, the lack of continuity of most communication initiatives. These are often initiated in the aftermath of a large event, rarely repeated in following years, and easily forgotten as the traces of the event fade away. This lack of continuity can be recognised not only in community experiments but also in schools initiatives. Risk mitigation is rarely considered a permanent part of the education curriculum integrated into young peoples' cultural development, but rather an additional and occasional special feature.

Second, educational and information programmes are often designed without any direct contact with target communities, thus neglecting knowledge and experience that they already have and which should form the basis upon which to ground further educational efforts. Generic programmes are particularly unhelpful in areas that are exposed to severe or frequent threats of which inhabitants may sometimes have a better understanding than external experts. The local information needs of communities, therefore, should be studied before new programmes are proposed. In other words communication for sustainable risk mitigation needs to be a two-way process, in which both experts and the public have to learn from and teach each other, especially when important matters involving uncertainties and vulnerabilities must be tackled and discussed.

4.3 Short-term Risk Mitigation Measures

Short-term measures can be defined as those aimed at improving the response during, and the recovery in the aftermath of, an extreme event, so as to minimise its impacts on the affected community. The attention of governments has long been focused predominantly on the latter, at the expense of longer-term measures. It may be suggested that a good balance between the two should be kept, as an event requiring an emergency response could always occur. Some national laws in Europe (for example the Sarno law in Italy, n. 267/1998) explicitly recognise that below a certain threshold the risky situation cannot be prevented, therefore contingency plans must be prepared for the population which accepts the implications of living with the level of risk that cannot be further lowered. Despite the large efforts invested in these types of measures, there is still a lot to improve, both from an organisational point of view and to meet the expectations of the public (see Schneider, 1995).

4.3.1 Prediction and Warning

In a review of current practices in Europe regarding early warning systems, Handmer (2002) found that a lot has still to be done in order to attain the level of other western countries such as Australia. He encounters problems at several levels, ranging from the insufficient application of existing technology, especially regarding the integration of various systems pertaining to different and sometimes conflicting agencies, to the almost complete absence of communities from the design process of alert messages and procedures. This lack of consideration of people for which alarms are supposed to be designed clearly constitutes a significant obstacle to the implementation of a complete chain of alert, connecting the technical monitoring to the elaboration of messages to their dissemination and the decision to take action by potentially affected citizens.

In their evaluation of flood forecasting systems in the European Union, Parker and Fordham (1996), proposed a framework based on a set of criteria, ranging from "dominance of forecasting vs. warning" to "methods of disseminating flood warning" and "organisational culture". Early warning systems were then ranked by five development stages from "rudimentary" to "advanced". Using their words "cross-country comparison must be undertaken with caution because of the different physical, historic-cultural and institutional backgrounds of the countries, and variations in levels of economic development. The results indicate two broad levels of flood forecasting, warning and response systems development. France, Germany, the Netherlands and England and Wales appear to have reached the third or fourth stage of development upon many criteria, whilst Portugal, Scotland and Northern Ireland appear to have reached a slightly lower level of development. However in the latter recognition of the limitations is relatively high and improvements are being pursued". It would be useful to use the framework to assess the performance of other countries that were not included in the study as well as update findings going back to 1996 or earlier. Another aspect the authors have considered relates to transboundary warning systems, where problems were identified for example between Portugal and Spain for the Tago river and between Belgium and the Netherlands for the Mose.

As far as other hazards are concerned, a rather well developed monitoring system exists for volcanic risk, particularly in Italy. A question that still remains open regards the extension of an equal level of alert on all volcanoes and not only on the main or the most active ones. Moreover, the actual link between the monitoring and alerting system to the prompt response of civil protection and information dissemination to the potentially affected population has to be also investigated. An issue, as mentioned earlier, that was found to be relevant for the entire Europe.

The tsunami catastrophe in South-Eastern Asia in December 2005 gave new impetus to the research and development of improved early warning systems, including in Europe (see the platform for early warning created by the United Nation Strategy for Disaster Reduction – SDR – based in Geneva). Hazards that are considered in this book can be divided in two types as far as early warning is concerned: some leave enough time to take protective action (typically most but not all hydrological and meteorological hazards) while others do not (earthquakes). Nevertheless it should be remembered that even in the latter case induced hazards, for example landslides triggered by earthquakes as well as na-tech events, can be forecasted in advance or at least communicated to the public so that preventive actions can be taken. In this regard, more advanced warning systems should not limit their attention to the initial event, but should rather encompass the induced events and accidents that may be triggered by the first one.

Box 4.1
ICT and early warning systems

ICT are critical to produce **risk alerts**. Alerts require a network of sensors that ensures the quality of the information. Due to the current status of the sensor technology, in some cases it is difficult to assess such quality. In this case different sources of information must be combined and analysed. ICT constitutes the first part of any early warning system. A number of projects and activities run by a variety of institutions have addressed this topic, in the attempt to improve the data quality and the reliability of forecasts. Some examples are reported below.

The Global Disaster Alert and Coordination System (GDACS)

GDACS is an initiative of the United Nations; it provides near real-time alerts about natural disasters around the world and tools to facilitate response coordination, including media monitoring, map catalogues and Virtual On-Site Operations Coordination Centre.

European Flood Alert System (EFAS)

The European Flood Alert System (EFAS) is a research activity of the DG Joint Research Centre of the European Commission (De Roo et al., 2003). The aim of the EFAS project is to develop a prototype of a Pan-European Early Flood Alert System. The development of EFAS started in 2002.

German Indonesian Tsunami Early Warning System (GITEWS)

GITEWS is a project of the German Government aimed at developing a tsunami early warning system for the Indian Ocean which can later be extended to the Mediterranean and the Atlantic Ocean. The conception integrates terrestrial observation networks of seismology and geodesy with marine measuring processes and satellite observation.

Data and readings from the individual components of the early warning system for the Indian Ocean are to form a chain from the recording of an earthquake to its analysis, its evaluation and finally a warning.

After the implementation of the technical part by 2008, a second phase was initiated, aimed at building capacity within Indonesian institutions.

SAFER – Seismic Early Warning for Europe

SAFER is an international project to develop tools that can be used by disaster management authorities for effective earthquake early warning in Europe and, in particular, the densely populated cities. The project was funded under the VI Framework Programme of the European Union and involved 23 institutions from 14 different countries.

DEWS – Distant Early Warning System

The DEWS project started in 2007, in order to build up an interoperable tsunami early warning system for the entire Indian Ocean region, beginning with Indonesia, Thailand, Sri Lanka and New Zealand. DEWS will develop an innovative platform and services for the disaster management cycle between GITEWS hazard detection and warning/alarm. DEWS software will include models for tsunami wave spreading, assessment of vulnerabilities/consequences of natural disasters and systems for monitoring and crisis management, including information and decision support.

Water Risk Management in Europe (WARMER)

WARMER's general objective is to create a real-time system for risk management through water monitoring, integrating mixed technologies including remote sensing and ICT technology.

4.3.2 Preparedness and Emergency Response

Problems in emergency response can be divided in two: more "traditional" problems, that have not been fully solved yet, and newer challenges posed by the impact on modern complex societies of emerging and new threats. As for the former, findings on the response of European countries to chemical accidents after the introduction of the Seveso Directive (see De Marchi, 1996) can be easily extended to any type of emergency.

Those findings highlighted the lack of coordination among the several bodies that together contribute to the complex civil protection function, lack of specific technical training and the lack of information regarding where to find the needed resources. The latter are often present in sufficient quantities; what is often lacking is the needed timely information regarding who holds the resource and where it can be found.

Schneider (1995) adds as a crucial point: the widening gap between what is perceived by authorities as a correct response and what is expected by affected citizens. The reasons for such an extending gap are many: among them the lack of confidence in authorities and the lack of transparency in the passing of information regarding the actual consequences of some events (particularly those involving public health). Ways to reduce the gaps lie in better information and communication strategies, in overcoming the obstacles to satisfactory performance that have just been mentioned and in the recognition that if safety is a public good then it must not only be guaranteed by authorities but citizens must also take their share of responsibility.

Finally new and emerging threats cannot be neglected, especially by those who are in charge of rescue and civil protection activities. What challenges will climate change and related worsened hazards pose to firemen and other organisations in charge of first aid to victims? Are those organisations aware and prepared for such events? In an enlightening book, Guilhou and Lagadec (2002) propose that organisations will be faced with extreme, unexpected surprises that will characterise future severe emergencies. In order to be better able to cope with them new strategies will be required, including the extended use of scenarios and simulations to prepare for them.

In the aftermath of an extreme event, significant challenges must be met. First responders are faced with inevitable demands and challenges, to which they may sometimes react without considering a sufficiently wide perspective. Undue damage to the environment may be provoked by actions taken to protect goods from imminent threats. In this regard two major concerns should be considered as far as sustainable practices are concerned: on the one hand the avoidance of temporary solutions that will create even further damages and problems or that will just move the risk from one place to another; on the other, promote solutions to safeguard fragile ecosystems and cultural heritage.

Examples of what has been stated above are the intervention after the accident at the Sandoz factory in Basel in 1986 (Scanlon, 2001) that led to the contamination of the Rhine as a consequence of the discharge of water used to extinguish the fire; and the techniques adopted to temporarily consolidate churches and historical monuments in the aftermath of earthquakes in Italy in the 1960s and the 1970s. In some instances, like the Friuli earthquake, historic buildings were destroyed on purpose out of fear or to substitute them with newer structures. In this regard a new form of expertise has grown in Italy and elsewhere to ensure that historic buildings will not be unduly destroyed while preserving the safety of inhabitants and passers by.

4.4 The Contribution of ICT to Risk Management

The improvement of European capabilities towards the risk and disaster management requires multidisciplinary research in several areas: sensor networks, data fusion, automated analyses of temporal and spatial changes, etc. The main objective is twofold: the increase of prevention capabilities (risk assessment, early detection of potential threats) and the improvement of response activities (response time, efficiency and efficacy of actions, avoidance of domino effects).

This involves the acquisition, processing, storage, retrieval, fusion and communication of large amounts of information at different temporal and spatial scales, with the challenges of covering wide areas with the maximum possible resolution, combining airborne and satellite data with terrestrial data, combining basic information (infrastructures, topography) with detailed and more rapidly changing information (temperature, motion) or obtaining critical indicators on time, among others.

Such information is produced and owned by a wide range of organisations, which need the necessary IT framework to achieve interoperability (successful exchange and use of information), while guaranteeing security and business requirements (i.e. ensure that the right information is delivered to the right person/institution for a specific use, and for a given price). This section describes the characteristics of such an IT framework, as well as the specific research topics necessary to develop it and the current projects financed by the European Commission in order to improve the current situation.

The stakeholders involved in risk assessment have to face a situation where the information is extremely distributed and it comes from different and heterogeneous sources.

The characteristics of the systems used by them are summarised in the following points:

- For the risk management activities, the systems do not have to deal with the problem of the real-time information but the data used should be updated regularly. This update depends on the type of information and could be performed yearly, monthly and in some concrete cases daily (i.e. weather information).
- There is a mix of spatial and non-spatial information and in many cases the access to this information is restricted due to technical constraints and also to privacy issues.
- Most of the information used is retrieved locally or regionally and in many cases it is duplicated because of administrative issues. Often the change from the regional scale to the local one is not feasible due to the impossibility to integrate local data into the regional information. The main reason of this problem is the use of different data formats and systems by the local and regional administrations.

In summary the main problems for risk management in relation to information systems are the lack of technical interoperability and accessibility, and availability of data, information and software.

In order to address the issue of interoperability between systems and information in the geographical information domain, the European Commission has decided to convert the INSPIRE initiative into a European Directive (2007/2/EC).

INSPIRE is based on infrastructures for spatial information established and operated by the Member States. The components of those infrastructures shall include metadata, spatial data sets (described in three Annexes of the proposal), spatial data services; network services and technologies; agreements on sharing, access and use; co-ordination and monitoring mechanisms, process and procedures.

The Inspire Directive requires the Member States to implement various measures, some directly, and others requiring further implementation rules to be provided by the European Commission.

In recent years, the European Commission, European Space Agency and national institutions have been investing heavily in new technologies and methodologies to improve the state of the art in disaster management. As a result of those efforts more than 200 Research and Technological Development (RTD) projects have generated prototypes and partial solutions. However the conclusions of these projects were that it is necessary to develop an info-structure for risk management.

To reach this ambitious objective the EC has invested in recent years in the following projects and initiatives.

Projects financed under the Sixth Framework Program dealing with the creation of an Info-Structure for Risk and Disaster Management are briefly described below.

The ORCHESTRA project's starting point is the recognition of the need to be able to consolidate information from disparate systems to support citizen protection and security, disaster management, criminal justice and other missions, crossing pan-European agency boundaries and extending into national, state and local government areas. One of the most urgent and important challenges currently facing governments is to get these systems to interoperate and share information. ORCHESTRA is responding to this challenge. The overall goal of ORCHESTRA was to design and implement an open service-oriented software architecture to improve the technical interoperability between systems for multi-risk management. Some of the results of ORCHESTRA served as an input to the INSPIRE and GMES initiatives.

In order to realise this vision:

- The project has designed an open service-oriented architecture for disaster risk management. Special attention was paid to an integrated service and data approach including their spatial, temporal and thematic characteristics.
- It has developed the software infrastructure for enabling disaster risk management services.
- It has developed services that are useful for different thematic disaster risk management applications (for instance forest fires or floods, man-made risks).
- It has provided software standards for disaster risk management applications, the details of which have been made available in a book.
- Finally the prototype has been applied in some transboundary areas chosen as test cases.

Box 4.2
Towards the Harmonisation and Protocols for Information Exchange in Europe: The GMES Initiative

Global Monitoring for Environment and Security (GMES) is a European initiative for the implementation of information services dealing with environment and security. GMES is the European participation in the worldwide monitoring and management of planet Earth and the European contribution to the Group on Earth Observation (GEO) and to GEOSS. GMES will be based on observation data received from Earth observation satellites and ground-based information. These data will be coordinated, analysed and prepared for end-users. GMES will monitor the state of our environment and its short-, medium- and long-term evolution to support policy decisions or investments. GMES is being developed gradually: it started with a pilot phase which targets the availability of a first set of operational GMES services by 2008 followed by the development of a wide range of services which meet user requirements.

Examples of services are:

– Oil spill/discharge detection & monitoring;
– Land cover/land use for policy making and services to farmers;
– Support to civil protection – rapid mapping;
– Environment and health services – ozone monitoring and UV exposure.

The services provided by GMES can be classified in three major categories:

– **Mapping**, including topography or road maps but also land-use and harvest, forestry monitoring, mineral and water resources that do contribute to short- and long-term management of territories and natural resources. Services pertaining to this group generally require exhaustive coverage of the Earth surface, archiving and periodic updating of data.
– **Support** for emergency management in case of natural hazards and particularly civil protection institutions. This category concentrates on the provision of the latest possible data before intervening.
– **Forecasting** is applied for marine zones, air quality or crop yields. This type services provides data on extended areas systematically, permitting the prediction of short-, medium- or long-term events, including their modelling and evolution.

The widespread and regular availability of technical data within GMES will allow a more efficient use of the infrastructures and human resources and is expected to improve not just risk reduction activities, but also better management of land and resources.

The WIN project was intended to provide risk management actors (data providers, decision makers, support agencies, on field actors . . .) with a flexible solution allowing to set-up thematic sub-networks in line with practices, favouring data sharing and collaborative working: on the thematic sub-networks, generic services provided by WIN and application services proposed by service providers are available to end-users; associated with the thematic sub-network, several charters (technical interoperability, business, ...) allow the management of technical and business issues related to the sub-network deployment and follow-up.

The main goals of WIN were:

- to define, in relation to other GMES projects, an open and flexible service-oriented architecture that can be deployed at several levels (European, national, regional) in order to favour sharing of data and co-operative working between actors
- to propose an organisational model facilitating the deployment of WIN
- to study in a few thematic domains how a first version of this general solution can be effectively deployed and customised in line with thematic domain practices
- to develop and release this initial set of services and tools in line with the priorities identified on thematic domains involved in WIN definition
- to demonstrate the added value of WIN, on the first real-size deployment involving end-users and key actors.

The OASIS project aimed to facilitate the cooperation between the information systems used by civil protection organisations, in a local or international environment. It took advantage of the wide experience of the different OASIS partners both in the Civil Protection domain as well as in the Military domain. For example, a major achievement would be to allow responders from different countries to exchange information, even if they do not speak the same language, as can be done between armies from different countries, due to the work performed in the NATO environment.

The main goals of OASIS were:

- to provide an IT framework which can be used at the different levels of the civil protection organisations in Europe, compliant with existing standards
- to provide, within this framework, an initial set of applications that will cover the main needs that are identified by the end-users who help to define OASIS
- the capability to replace one component developed for OASIS by an existing component which follows the OASIS-defined standards
- the capability to benefit from the services offered by the OASIS framework in order to add new components inside this framework.

An important project financed and developed under the ESA programme is the Service Support Environment for earth observation (EO) and Geographic Information Services. The efforts for the development of a “Service Support Environment” have been focusing on two high-level requirements which are:

- Provide an environment:
  - with common approach for online and offline services (i.e. those requiring the tasking of the satellite and therefore a response time variable from hours to days)
  - improving cost efficiency
  - reducing time to provide / demonstrate new services
  - neutrally managed
- Empower Service Providers in:
  - orchestrating EO and Geographic Information Services from own and partner service elements
  - maintaining full control over own infrastructure and intellectual property rights.

SSE will support service providers in setting up services, through a new set of interactions necessary mainly to empower the co-operation relationships among service providers. This will facilitate and automate the steps traditionally executed on the basis of personal (human) interactions, which are beneficial in an early definition of the service, but which may become a burden when the service becomes operational and the same tasks have to be repeated tens or hundreds of times.

4.5 Implementation Tools: Insurance

In principle a variety of economic tools could be used to attain desired levels of protection towards natural and na-tech hazards, as is the case for environmental policies at large. In reality, such a variety of tools has not been widely developed, with the exception of insurance. Insurance against natural calamities has grown in importance in some countries, like the US, France and the UK, though with different coverage as far as different hazards are concerned and to the extent to which it has penetrated the market. A large literature exists on strengths and weaknesses of insurance policies (Burby, 2001; Kunreuther, 2004; Kunreuther and Roth, 1998); they are claimed to be very important for guaranteeing fast and efficient recovery in the aftermath of an event, thanks to the possibility to transfer the burden of damage estimates, controls and payment to a private market institution. Furthermore it has been demonstrated that even for poor countries, the utility of insurance is large, in guaranteeing that funds for rebuilding and reconstructing will be available without having to lessen other public expense chapters and without heavy consequences for the stability of economic growth (see Linnerooth-Bayer et al. 2003).

It is perhaps one of the few cases where insurers are not so keen on covering such risks, because of many reasons, synthetically described for example in CEA (2007). The latter range from expected difficulties in covering future losses, should climate change modify the present trend of natural hazards in the world, to the increase in damages registered in the 1990s, with the most expensive disasters occurring in developed countries, where a relatively large insurance coverage existed.

Insurance coverage across Europe is highly uneven and the insurance systems in place are sensitive to affordability to different degrees. In relation to flooding in particular, across Europe there are three principal systems of insurance and compensation in operation (Bouwer et al. 2007).

- Traditional insurance systems set up and operated by private companies
- Insurance or pooling systems in which the government has a considerable role in managing the pool through the financing of them by way of *ex ante* taxes (e.g. Belgium, Denmark)
- Government-administered systems of *ex post* compensation of losses, whereby losses are funded directly from the public purse rather than through any form of *ex ante* premium (the Netherlands).

Taking a picture of flood insurance and compensation provision in 19 European countries, Bouwer et al. (2007) found that a country's operational insurance system is currently most dominantly determined by that country's surface area and its population size. Additionally, they reported that the market penetration of flood insurance has been high (>50%) in only 7 countries, even though private flood insurance systems prevailed in 15 out of the 19 countries considered (Fig. 4.3). The explanation for this is given as being that the highest market penetration is observed in the countries that operate systems whereby flood premiums are bundled into policies alongside premiums for other risks (e.g. fire).

The Netherlands is in a unique position, as, since 1998, the system in place has taken the form of government-funded *ex post* compensation for all. In this country the potential consequences of a significant flood are judged as being so high that structural measures have been viewed as being, unavoidably, the hazard mitigation measure of choice. This has resulted in the validation of defence systems with an up to 0.01% (1:10.000 year) standard of protection and a resultantly very low probability of residual effects. However, this concentration on structural measures is being increasingly challenged in light of the projections for climate change and sea-level rise (Ten Brinke and Bannink, 2004) and there is a growing acknowledgement that other measures (e.g. land-use planning) will need to be applied more effectively if the potential for unsustainable future strain on the tax system is to be reduced.

Bouwer et al. (2007) suggest that in order to increase the market penetration of private flood insurance its mandatory inclusion will be necessary in all insurance policies (regardless of individual risk). Furthermore, a harmonisation of insurance services regulation across Member States is seen as being important, so that losses can be more easily shared between countries of varying sizes and risk levels. The CEA (2008) go even further by suggesting that climate change presents such a potential driver of increasing risk levels that agreements should be made to share these risks with nations outside the EU.

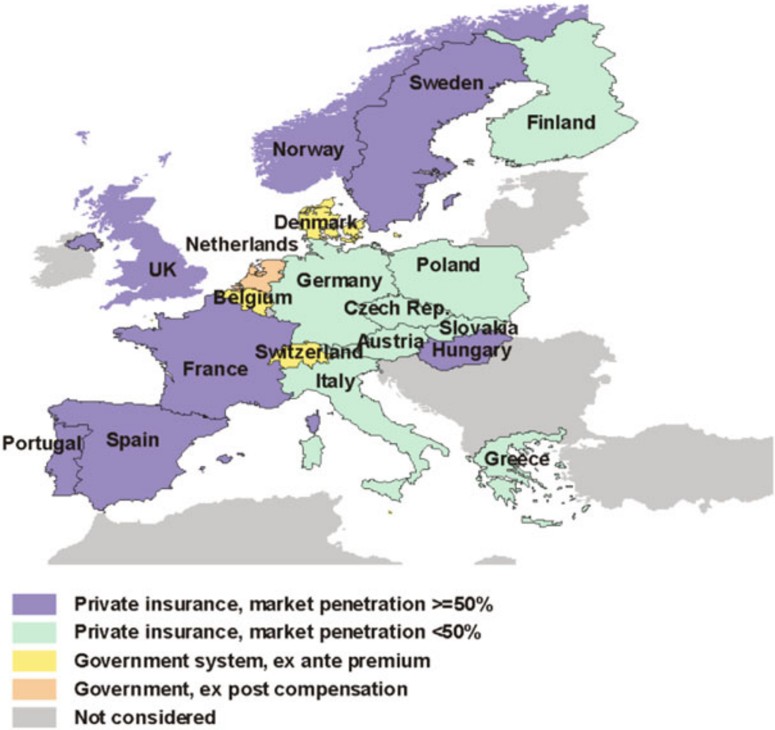


Fig. 4.3. Overview of selected national flood insurance and compensation systems in Europe (source: Bouwer, L.M., D. Huitema and J.C.J.H. Aerts (2007)). Adaptive flood management: the role of insurance and compensation in Europe. Deliverable D 1.2.4 of the NeWater project, Institute for Environmental Studies, Vrije Universiteit Amsterdam

However, even if greater market penetration is achieved, in countries operating a private or tax-based insurance system there will inevitably be a potentially sizeable fraction of the population who remain uninsured or underinsured due to pricing or availability limitations (Priest et al. 2005).

The situation in Europe is rather diversified, as can be seen in Fig. 4.4. In the majority of states, optional or non-existing coverage is the rule, with the important exceptions of France, Belgium and Switzerland. The French CatNat (Catastrophe risques Naturelles) system represents a significant model, as opposed to the United States Nfip (National flood insurance program) one. It is a compulsory coverage, that is calculated as a percentage of the insurance coverage against fires for buildings and cars. This is made so as to extend as much as possible the pooling among the insured, basically creating a sort of solidarity framework, where those at risk and those living in safe areas are equally paying the same price. The Nfip system, instead, is voluntary and differentiated according to risk levels, thus contributing to mitigation

	Austria	Belgium	Czech Republic	Denmark	Finland	France	Germany	Greece	Italy	Netherlands	Norway	Poland	Portugal	Spain	Sweden	Switzerland	Turkey	United Kingdom
Storm	O	C[1]	O	O	O	C	O	S	N	O	P	O	O	P	O	C	O	O
Cyclone/hurricane	O	C[1]	N	O	O	C	O	S	N	O	P	N	O	P	O	C	O	O
Floods	O	C[1]	O	N	O	C	S	S	O	N	P	O	O	P	O	C	O	O
Hail	O	O	O	O	O	O	O	S	O	O	S	O	C[2]	O	O	C	S	O
Landslides	O	C[1]	O	O	O	C	S	S	O	S	P	O	O	S	O	C	O	O
Snow	O	O	O	O	O	O	S	S	O	O	N	O	N	O	O	C	O	O
Frost	O	O	O	O	N	O	O	S	O	O	O	O	N	O	O	O	N	O
Avalanche	O	N	O	N	O	C	S	N	O	N	P	O	N	O	O	C	N	N
Drought	O	N	S	N	N	C	N	N	N	N	N	N	N	S	O	N	N	N
Subsidence	O	C[0]	O	N	N	C	S	S	N	N	N	O	O	S	O	N	O	O
Earthquakes	N	C[1]	O			C	O	O	N	N	P	O	O	P	O	O	C	O
Forest fires	S	N	N	O	O	S	O	S	N	O	O	O	O	S	O	N	S	N
Volcanic eruption	N	N	O			C	O	O	N	N	P	O	O	P	O			N
Lightning	O	O	O		O	O	O	O	O	O	O			O	O		O	O

1 for simple retail risks only
2 only if hail results from a storm

Type of insurance cover

C = Compulsory cover by law
P = Obligatory pool
O = Optional cover
S = Cover offered but not widely taken
N = Non-existent

Rate of penetration of cover

orange = > 75%
blue = 25-75%
green = 10-25%
yellow = < 10%
white = not known

Fig. 4.4. Insurance coverage and penetration rate for different natural catastrophes across Europe (source: CEA, 2007)

strategies. Premiums are raised or reduced on the basis of risk levels attained in a given community.

Both models have shown over time their positive and negative aspects. Clearly compulsory coverage provides a more certain and controlled pooling of premiums and claims, therefore insurers certainly prefer this alternative; corroborating this is the large number of publications devoted in the US to analysing the motivation for buying, or not, insurance, and to the rather negative consequence of particularly catastrophic events, affecting a large proportion of the uninsured population, as was the case with the 1993 flood. In that event's aftermath, a process of critical revision of the Nfip system has been initiated, to the point that Burby (2001) came to the conclusion that federal policies had substantially subsidised risks rather than discouraging people from settling in hazardous areas.

On the other hand, the French system has been also criticised because it poorly (if at all) motivates people to reduce the risks they are exposed to, allowing for coverage and assistance in any place at the same price.

Another important point to be stressed referring to insurance against natural hazards is the fact that it is very rarely a purely market system. Not only insurers will look for reinsurance in the larger market, but in the majority of cases (certainly for the Nfip in the US and for the CatNat in France) the State is the ultimate reinsurer, in case of losses that go beyond the repayment capacity of companies. In other words, in the field of natural hazards a private–public partnership is the rule rather than the exception.

After the 2002 Elbe flood and the institution of the European Union Solidarity Fund, proposals for a more extensive and general insurance policy have been raised in the political agenda. The CEA (Comité Européen des Assurence) has expressed some concerns regarding the process that has taken place with respect to this delicate issue, particularly relevant to their associates.

Two fundamental aspects have been put forward in the quoted document by the CEA: the need for a stronger public–private partnership to counteract the potential effects of climate change *per se* and as trigger of hydrogeological and metereological hazards on the one hand, and on the other the importance of limiting exposure and vulnerability in hazardous areas, through careful land-use planning.

4.6 Implementation Tools: Legislation

Platt (1999) proposes a general scheme to assess the evolution of the US Federal mitigation policies in the field of natural hazards that can be considered of general validity. Mainly the scheme stresses the co-evolution of understanding hazards and associated risks, developments and changes in the built environment and in the legislative and political processes for mitigating and reducing losses and harm to society. In this context legislation can be considered an implementation tool, as it sets the norms and the regulations that must be complied to within distinct areas relevant for social and economic life. It can be also said that legislation generally records the cultural level of awareness and understanding regarding a given issue. The relatively recent approval of most norms and laws both at the European and the individual countries levels reflects the fact that risk mitigation has reached a given maturity rather late with respect to other topics, like public health or safety in the workplace.

4.6.1 Legislation at the EU Level

At the European level, legislation related to natural and na-tech risks is quite complete, although a comprehensive framework directive does not exist.

Indeed, some kinds of risk are handled within a more general ambit rather than in specific laws. As an example, seismic risk prevention is considered in different fields, like building codes, but there is not a specific legislation for

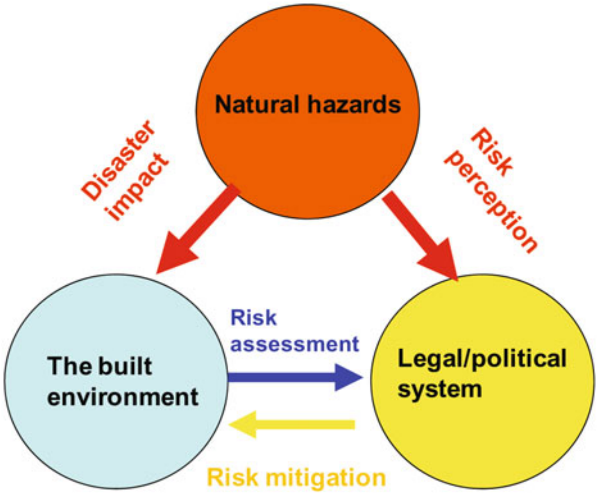


Fig. 4.5. Risk governance aspects according to Platt (1999)

seismic mitigation addressing all relevant topics and levels of concern (including for example urban planning).

In the field of natural hazards, generally the EU has legislated in a rather sectoral fashion, addressing individual risks; in more recent times, a stronger emphasis on integration and comprehensive framework has been pursued, as can be clearly seen in the Flood Directive. The latter in fact aims at integrating in the same policy.

Forest Fires

Regulation (EC) No 2152/2003 of the European Parliament and of the Council of 17 November 2003 (Forest Focus) was, until now, the Community scheme for harmonised, broad-based, comprehensive and long-term monitoring of European forest ecosystems. It concentrates in particular on protecting forests against air pollution and fire, emphasising the concept of sustainable forest management. In more detail, the following measures have been implemented:

- Monitoring and collection of data on forest fires through the continuation and the further development of the database known as "common core database" (currently managed in a centralised way by the Joint Research Centre of Ispra)
- Protection from forest fires carried out through the co-financing of "intellectual" prevention measures (public awareness-raising campaigns, specialised training) and some "field" prevention measures of infrastructural nature (realisation of firebreaks, water points, etc.) complementary to those established according to the rural development regulation

- Realisation of some studies, both by Member States and the Commission, connected to the prevention of fires (including developing indicators and methodologies for risk assessment) and having a relevant added value at EU level.

To achieve Forest Focus objectives, two-year national programmes have been drawn up by the Member States. Forest Focus expired at the end of 2006, although the programmes funded by the Regulation remained active until 2009.

The new instrument that will take over many of the forest fire prevention measures is the European Union Forest Action Plan (COM(2006) 302). The action plan provides a coherent framework for forest-related initiatives at the Union level. It also serves as an instrument for coordinating Community initiatives with the Member States' forest policies. The action plan is centred around four objectives: improving the long-term competitiveness of the forestry sector, protecting the environment, improving the quality of life and fostering intersectoral coordination and communication. In order to achieve this, 18 key actions have been recommended, to be implemented over five years (2007–11). In particular, key action 8 is about working towards a European Forest Monitoring System, following completion of the Forest Focus monitoring scheme.

In addition, Member States may – with the support of the European Agricultural Fund for Rural Development (EAFRD) and the financial instrument LIFE+ – promote measures in favour of forests, support restoration of forests damaged by natural disasters and fire, and support studies on the causes of forest fires, awareness-raising campaigns, training and demonstration projects.

Floods

In 2000, the Directive 2000/60/EC (Water Framework Directive – WFD) was adopted. The WFD is an operational tool, setting the objectives for water protection for the future. By means of this Directive, the EU provides for the management of inland surface waters, groundwater, transitional waters and coastal waters in order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of floods and droughts. Indeed, although the main topic of the legislation is water quality, water quantity – and thus floods – is also addressed. The WFD requires the establishment of River Basin Management Plans, which should contain a detailed account of how the objectives set for the river basin (ecological status, quantitative status, chemical status and protected area objectives) are to be reached within the timescale required.

More specifically on floods, and closely linked to the WFD, the Commission passed a new Directive on the assessment and management of flood risks (2007/60/EC). The directive was proposed in order to prevent and limit floods and their damaging effects on human health, the environment, infrastructure and property.

The new Directive requires that Member States take a long-term planning approach to reducing flood risks in three stages:

- Member States will by 2011 undertake a preliminary flood risk assessment of their river basins and associated coastal zones
- Where real risks of flood damage exist, they must by 2013 develop flood hazard maps and flood risk maps
- Finally, by 2015 Flood Risk Management Plans must be drawn up for these zones.

These plans are to include measures to reduce the probability of flooding and its potential consequences. They must address all phases of the flood risk management cycle but focus particularly on prevention (i.e. preventing damage caused by floods by avoiding construction of residential and industrial settlements in present and future flood-prone areas or by adapting future developments to the risk of flooding), protection (by taking measures to reduce the likelihood of floods and/or the impact of floods in a specific location such as restoring flood plains and wetlands) and preparedness (e.g. providing instructions to the public on what to do in the event of flooding).

Droughts and Water Scarcity

Concern about drought events and water scarcity situations has risen among European Member States due to an increasing frequency of drought events in recent years. This led in 2003 to the emergence of a working group set up by the European Water Directors, in charge of preparing a technical document on drought events and long-term imbalance issues. Although droughts are not specifically addressed, the Water Framework Directive implementation helps address issues of water scarcity, through the implementation of the water management plans and associated programmes of measures. Furthermore, the WFD is an opportunity to make demand-side measures a priority. The Commission is currently finalising a Communication to address water scarcity and droughts.

Landslides

In 2006, the European Commission adopted a comprehensive EU strategy specifically dedicated to soil protection. The Thematic Strategy for Soil Protection consists of a Communication from the Commission to the other European Institutions, a proposal for a framework Directive and an Impact Assessment. The Communication (COM(2006) 231) sets the frame. It explains why further action is needed to ensure a high level of soil protection, sets the overall objective of the Strategy and explains what kind of measures must be taken. It establishes a ten-year work programme for the European Commission.

The proposal for a framework Directive (COM(2006) 232) sets out common principles for protecting soils across the EU. Within this common framework, the EU Member States will be in a position to decide how best to protect soil and how to use it in a sustainable way on their own territory. It identifies the main eight threats to which soils in the EU are confronted. Amongst these are soil erosion and landslides. The key components of the proposed Directive are:

- Identification of areas at risk of erosion, organic matter decline, salinisation, compaction and landslides, and establishment of programmes of measures
- Setting up an inventory of contaminated sites, a mechanism for funding the remediation of orphan sites, a land status report and establishing a national strategy for remediation of the contaminated sites identified.

Earthquakes

The European policy on prevention, mitigation and response on earthquakes is based essentially on the EUROCODE 8. In 1975, the Commission of the European Community decided on an action programme in the field of construction. The structural design codes were called EUROCODES. EUROCODES intend to provide a set of rules for the design of buildings and civil engineering works. Eurocode 8 (EC8) indicates the design provisions for earthquake resistance of structural construction works. It concerns the following aspects.

- General rules, seismic actions and rules for buildings
- Bridges
- Towers, masts and chimneys
- Silos, tanks and pipelines
- Foundations, retaining structures
- Geotechnical aspects.

Furthermore, seismic risk is contemplated in the above-mentioned Thematic Strategy for Soil Protection which includes seismic risk as a potential trigger of landslides.

Coastal Erosion

On account of the importance of coastal zones to Europe, the EU recommends that the Member States take a strategic approach (Integrated Coastal Zone Management) to their management (Recommendation 2002/413/EC of the European Parliament and of the Council of 30 May 2002). This must be based on the protection of the coastal environment, recognition of the threat posed by climate change, the implementation of coastal protection measures (including protection of coastal settlements and their cultural heritage) and the sustainable development of coastal zones.

On the matter of instruments, in developing their strategies the Member States should consider the advantages of:

- national strategic plans for ensuring the control of any additional land-use planning and the exploitation of non-urban areas which should respect the natural characteristics of the coastal environment
- land purchase mechanisms and declarations of public domain to ensure public access to recreational areas without prejudice to the protection of sensitive areas
- contractual or voluntary agreements with coastal zone users
- harnessing economic and fiscal incentives
- applying regional development mechanisms.

For 2006 the recommendation provides that the Member States must present to the Commission a report with, among other things, the results of the national stocktaking exercise, the national strategy, a summary of the actions taken and an evaluation. During 2006 and the beginning of 2007 the Commission reviewed the experience with the implementation of the EU ICZM Recommendation. The Commission Communication of 7 June 2007 (COM(2007)308) presents the conclusions of this evaluation exercise and sets out the main policy directions for further promotion on ICZM in Europe.

Climate Change

Following the launch of the European Climate Change Program (ECCP) (COM(2000) 88), the EU is taking various actions in order to reduce greenhouse gas emissions. Moreover, with the second European Climate Change Program (ECCP II), the EU climate change policy includes also an adaptation policy. Making decisions about adaptation policy involves risk assessments and assessments of costs and benefits. The main goal of such policies is to ensure that decisions we make today do not compromise the resilience of the European Union in the future.

The impacts of climatic changes will hit locally and regionally in different ways. The majority of adaptation actions will therefore need to be decided and to be undertaken at the local, regional and national levels. The European Commission is therefore exploring its role and the scope for a policy strategy to adapt to the impacts of unavoidable climate change and how best to assist local, regional and national efforts. As part of exploring options to improve Europe's resilience to climate change effects and defining the European Union role in climate change adaptation, the European Commission is undertaking the following activities:

- ECCP II working group on Impacts and Adaptation:
  - Impacts on water cycle and water resources management and prediction of extreme events
  - Marine resources and coastal zones and tourism
  - Human health
  - Agriculture and forestry
  - Biodiversity

  - Regional planning, built environment, public and energy infrastructure, structural funds
  - Urban planning and construction
  - Development cooperation
  - Role of insurance industry
  - Building national strategies for adaptation (country reports)
- Developing the Green Paper on "Adapting to climate change in Europe – options for EU action"
- Undertaking an extensive research project into adaptation and mitigation options
- Hosting a conference on climate change adaptation.

Na-tech Disasters

Generally speaking, despite the evidence that na-tech disasters are increasing, there are no sectoral and comprehensive laws on na-techs either at the EU level or in individual countries. Nevertheless, at the EU level there are several legal acts that indirectly address na-tech risk, through rules governing industrial establishments housing hazardous materials, landfill sites and waste treatment plants. Requirements governing prevention of chemical accidents at industrial establishments at the EC level appear in the Seveso II Directive (98/82/EC) and its amendments contained in the 2003/105/EC Directive. Although the Seveso II and III Directive does not specifically discuss requirements for na-tech risk management, it is addressed obliquely in several ways. Indeed, the Directive provides for an analysis of "external events" (Section IV of Annex II) which may lead to a chemical accident, implying the consideration of the potential threat of natural hazards in the hazard analysis, the carrying out of preventive measures to reduce the likelihood of a na-tech and the establishment of preparedness measures in case a na-tech does occur. Moreover, na-tech disasters are addressed in Article 8, concerning domino effects, and Article 12, related to the prevention of chemical accidents through land-use policies. Furthermore, the European Commission has published a set of Guidelines, (see Papadakis and Amendola, 1997; Mitchison and Porter, 1998; Christou and Porter, 1999) to help Member States fulfil the requirements of the Seveso II Directive, which specifically recommend analysing the potential effects of natural hazards (e.g. floods, earthquakes, extreme temperature changes, winds) in the hazard analysis for chemical accidents. There are then a number of other EC Directives that indirectly address na-tech risk. As examples, the Water Framework Directive explicitly calls for the adoption of measures to prevent or reduce the likelihood of, or to reduce the impact of, accidental pollution incidents while the Council Directive on the landfill of waste (Council Directive 1999/31/EC of 26 April 1999) requires that landfills be located taking into consideration the potential for flooding, land subsidence, landslides or avalanches on the site.

Civil Protection

The Council Decision of 23 October 2001 (2001/792/EC) established the Community Mechanism for Civil Protection, intended to facilitate reinforced co-operation in civil protection assistance interventions. A later Commission Decision of 29 December 2003 (2004/277/EC) laid down the rules for the implementation of the Community Mechanism, defining its duties and the functioning of the various tools making it part of the Mechanism. When natural or manmade disasters strike a country, both inside and outside the European Union, it is possible to mobilise the necessary operational resources to assist and provide prompt response.

The Civil Protection Mechanism was improved through the Commission Communication of 20 April 2005 (COM/2005/0137). Among others it proposes structural reforms of the Mechanism, aimed at developing a more robust civil protection capability that enables the Union to react more rapidly and effectively to any type of disaster in the future. The recast of the Mechanism was adopted by Council on 12 June 2007.

Actually, the Community Mechanism has a number of tools intended to facilitate both adequate preparedness and effective response to disasters at a community level.

The Monitoring and Information Centre (MIC) is the operational heart of the Mechanism. It is operated by DG Environment of the European Commission and is accessible 24 hours a day. It gives countries access to a platform, to a one-stop-shop of civil protection means available amongst all the participating states. Any country inside or outside the Union affected by a major disaster can make an appeal for assistance through the MIC. It acts as a communication hub at headquarters level between participating states, the affected country and despatched field experts. It also provides useful and updated information on the actual status of an ongoing emergency. Last but not least, the MIC plays a co-ordination role by matching offers of assistance put forward by participating states to the needs of the disaster-stricken country.

The Common Emergency and Information System (CECIS) is a reliable web-based alert and notification application created with the intention of facilitating emergency communication among the participating states. It provides an integrated platform to send and receive alerts, details of assistance required, to make offers of help and to view the development of the ongoing emergency as they happen in an online logbook.

A training programme has also been set up with a view to improving the co-ordination of civil protection assistance interventions by ensuring compatibility and complementarity between the intervention teams from the participating states. It also enhances the skills of experts involved in civil protection assistance operations through the sharing of best practices. This programme involves training courses, the organisation of joint exercises and a system of exchange of experts of the participating states.

Until 2006, the Civil Protection Action Program (1999/847/EC) provided funding, in the form of grants, for activities aimed at preventive action, preparedness and response.

Actually, the EU has established an instrument to finance the preparation and implementation of civil protection measures (Council Decision 2007/162/EC). The Decision establishes an instrument to finance rapid response and preparedness measures for major emergencies, whether these result from natural, industrial and technological disasters or terrorist acts. The objective is to contribute to the effectiveness of national systems for preparedness and response to risk situations for people, the environment or property either by improving the capacity of such systems or by encouraging coordination. Eligible actions are specified in the Decision and include demonstration projects, awareness and dissemination measures, training and exercises, sending and deploying experts or the release at short notice of adequate means and equipment. Among selection criteria, actions must for example allow the assessment of needs and the establishment of adequate means and equipment, ensure the availability of these, allow their transfer to States, promote sharing of expertise and experience between national services, etc.

Last but not least the newly approved Communication from the Commission to the European Parliament and the Council on Reinforcing the Union's Disaster Response Capacity further strengthens the process under way aimed at promoting coordination between national civil protection agencies and creating a more identifiable Union force able to intervene both inside Europe and in international arenas. The annex to the Communication related to forest fires hints at the fact that lessons learnt in the summer of 2007 have been quickly translated into a policy effort.

4.6.2 National Laws

In the annex to this chapter the laws regulating natural risk prevention in the UK, Greece, France, Germany, Italy and Spain are synthetically described in a structured table. From a cross-comparison, some interesting aspects stand out. Some countries, like Greece and Italy, manifest a rather dispersed and segmented picture, with a rather large number of laws addressing different, specific natural hazards. On the other hand, countries like France and the UK propend towards a more comprehensive approach, in which all natural hazards are considered unitarily within an environmental legislative scheme. In the field of land-use planning, as already mentioned, the French legislation is probably the most advanced. It is grounded in almost twenty years of experience and was amended in 2003, to include in the risk policy both natural and technological threats. Besides the Plan de prevention de risques, other aspects should be considered, like the population's right to know, which extends to natural hazards as well, and the connection of risk mitigation to the CatNat insurance system (see section 4.5).

A similar comprehensive and holistic approach has been taken by the UK Planning Policy Statement 25, “Development and Flood Risk”, designed to bridge the gap between sustainable development and risk mitigation. In general terms it may be said that most laws are rather recent, either as new or amended texts. The picture resulting from this comparison of norms regulating natural and na-tech risks in Europe is therefore new and not so easy to judge as far as successful or unsuccessful results, which must be allowed to mature in the coming years. Nevertheless it can be said that, similarly to what has been noted for the European level, there is a tendency towards more comprehensive policies, integrating risk mitigation with other strategies of environmental protection, and to address increasingly not only the hazard component, but also exposure and vulnerability. The Framework Plan of the German Federal State of Schleswig-Holstein can be considered as particularly relevant in this respect as it explicitly requires any decision on new coastal development to be made according to a risk estimation based on hazards and vulnerability of settlements.

4.7 Lessons Learnt from Natural Disasters in Europe

The project NEDIES (Lessons Learnt from Natural Disasters) (http://nedies.jrc.it) has been set up at JRC to support EU policies, mainly those of the Civil Protection and Environmental Emergencies Unit of DG Environment, in the area of prevention, mitigation and management of natural risks and technological accidents.

One fundamental aspect of the Nedies project has been the possibility to collect and analyse lessons learnt from small to large disasters that have affected the European Union in the last twenty years. The important added value of the documents and material produced within Nedies is the possibility for analysts to assess and compare not only countries’ experiences but also challenges posed by different hazards. Such an analysis is extremely helpful to distinguish between specific challenges posed by different hazards and more general issues that have been identified as critical aspects in all emergencies, independently from the triggering event. Furthermore, by providing the picture of events through the lens of various actors and stakeholders that have been interviewed, a window is opened on the stock of experience and knowledge that has been developed within various agencies and countries.

Comparison is made even easier by the general framework that has been set for all cases, which is illustrated in different steps: first the description of the general event, then providing insight into the shortcomings of prevention, preparedness and recovery, and finally a summary of the most crucial elements that emerge from each case.

The lessons that can be learnt from the Nedies project can be grouped into two main categories: first those that are specific to each hazard, and the second those that are more general, cutting across various cases independently from the specific event at stake.

As for the first, some lessons stand out with respect to the specific preparation and resilience (or lack of) in the face of the specific stressors that are involved in each particular hazard. Clearly the type of resistance required by buildings in the case of earthquakes is different from that required for floods or storms.

The second class of lessons addresses more general aspects regarding the response capacity of hit systems, their resilience (or lack of) as systems and not as individual objects, more related to social, economic and territorial vulnerabilities rather than hazard specific. As can be seen from Table 4.1, the large majority of lessons learnt that can be extrapolated from the Nedies project pertain to this second category. They refer to deficiencies in setting up preventative measures that could have avoided or significantly lessened the impact of extremes, in terms of both human lives and material losses.

Looking more closely at the various reports, the following lessons can be learnt, ranked by "relevancy", according to the number of cases where the lesson is mentioned and analysed.

- Lack of implementation of structural measures, particularly for reducing vulnerability to specific hazards, like seismic hazards.
- Scarce implementation of measures aimed at reducing exposure in particularly critical areas (an interesting exception, at least in terms of juridical tools available to public administrations is provided by the French norm addressing relocation).
- Weak role of planning as a non-structural measure in deciding location of facilities considering existing hazards and their level of frequency and severity. Lack of inclusion of mitigation in planning is mentioned as a fundamental cause of damage, particularly for some hazards, like floods.
- Scarce development of non-structural measures addressing social vulnerabilities, which can be subdivided in various claims:
  - need for a closer relationship with the media, both for disseminating information about mitigation strategies and for correct dispatch of news in the case of an emergency. Various reports point out the fact that even civil protection authorities are often strongly influenced by the media in their first reaction to the crisis, thus risking acting according to a perspective of the disaster that is relevant for journalists but not necessarily to event responders
  - room for much improvement in preparedness and in raising awareness with two distinct goals: make restrictions for mitigation purposes more acceptable, particularly when they affect important rights like land ownership, and spread consciousness about the importance of actions that can be taken individually and significantly contribute to lessen the hazard or its impact. In this regard, cleaning and maintenance of river banks are called for as well as forest fire prevention and control

Table 4.1. Structural and non-structural mitigation measures

	Structural		Non-structural			
	decreasing HAZARDS	reducing EXPOSURE	reducing VULNERABILITY			
			physical	social and economic	built environment	natural environment
long-term mitigation measures			- specific requirements to control building vulnerability to various types of hazards (particularly seismic, but also avalanches and landlsides)	- improve citizens' involvement in risk management: - accepting building and land-use restrictions; - environmental maintenance activities (forests, rivers) - in accepting for example building restrictions; - in "environment maintenance" activities (rivers, forests)	- need for stronger floodplain regulation and building permit control	- monocultural agricultural practices should be avoided in areas prone to flooding and forest fires
short-term mitigation measures	- understimation of flood levels in different events (excluded possibility of overcoming "historic" catastrophies) - poor monitoring systems (particularly floods) in Eastern countries and Greece - ICT should be more carefully and extensively used to deal with the emergency	- difficulties in evacuating people in temporary settlements a long way from their original homes		- plans should include feedback analysis and procedures to update the plan according to lessons learnt - plans are often too generic - plans should consider the possibility of multi-site events that will put significant pressure on civil protection - plans should be based on accurate scenarios - improve planning for crisis, including the need to plan for long emergencies		
	- need of local forecasts for some hazards (fires, floods, landslides)			- need to be prepared not only in traditionally "hot" periods regarding given risks (fires) - improve relationship with the media to be able to disseminate messages during emergencies and guarantee "correct" information to the public		
	- need of local forecasts for some hazards (fires, floods, landslides)			- creating better coordination among civil protection forces - creating better coordination with critical infrastructure providers		
				- business continuity plans also for the public sector		
				- improving people's preparedness to face emergencies		
				- need to provide stronger role to the EU Civil Protection		

- need to improve population response to crises, adopting life-saving actions and behaviours that do not hinder efforts of civil protection and search and rescue teams
- need to improve coordination between search and rescue and civil protection agencies involved in emergency management, overcoming corporate barriers to face at best crises. In a number of reports a stronger role of the European Commission is called for, particularly in the case of multi-site or transboundary regional events
- need to improve the coordination and the interaction between public agencies coordinating emergency management and critical infrastructure managing companies.

Box 4.3
The Elbe Flood in August 2002

Fig. 4.6. Affected area of the Elbe flood 2002 (source: Munich Re 2004)

There were record-breaking rainfall amounts and intensities during the first half of August 2002 in the Elbe/Danube catchment. They produced flash floods in small rivers in the Erz Mountains, the Bohemian Forest and in Lower Austria followed by record-breaking floods in the Elbe and Danube and its larger tributaries. The reason for this millenium flood was a so-called Vb weather pattern, a cyclone track passing Genoa and the Po valley before approaching Hungary, Austria and Poland. These cyclones are common in fall and spring, but in summer they are feared because, due to the warm weather, they are transporting a huge amount of humidity. Several flood events have been caused by such weather patterns, e.g. the Odra River flood (1997), the alpine floods in 2005 and the Elbe River flood in 2002. For the 2002 flood the total economic losses amounted to 18.5 bn (insured 3 bn). In Germany the total loss amounts to approx 11.6 bn (Thieken et al. 2005). The affected area was distributed over various countries (cf. Fig. 4.6).

In Dresden, Germany a gauge level of 9.40 m was measured on 17 August 2002. This was the highest level since 1275. A total of 312 mm of rain within 24 hours was reported for the time period between 0600 GMT on 12 August and 0600 GMT on 13 August. This is about three times the mean precipitation for August at Zinnwald, Germany, and the highest amount of daily precipitation ever measured in Germany (Deutscher Wetterdienst, 2002). The consequences of this flood as well as the disaster response mechanisms were analysed in detail in the aftermath. A lot of lessons were learnt. In particular that disastrous consequences are an indication of an unsustainable situation, a severe lack of coping capacity of exposed territories. Many watercourses in the flooded region are almost completely channelled. The banks are consolidated in areas of settlement and partly consolidated outside these.

Dams, bridges and other structures along the channels reduce the discharge capacity considerably, i.e. they are bottlenecks where the available

Fig. 4.7. Impressions of the Elbe catchment 2002: A) 27,000 soldiers were helpers in need, nevertheless there was much solidarity (Wittenberg, Saxony-Anhalt), B) Central Station Dresden, Saxony, C) destroyed road between Bitterfeld and Eilenburg (Saxony), C) damage in Weesenstein, Saxony, D) Oil pollution

discharge profile is reduced. So it was proven that some river profiles were too small to cope with the huge amount of run-off. Other strategies identified as mandatory are the construction of flood retention areas and adequate river basin management. Emergency planning is also imperative for operative flood protection. Municipalities must implement detailed flood alert plans and ensure that their fire brigades are prepared and ready for action. To some extent also the competences of legal entities must be clarified and structured more adequately in order to avoid mismanagement.

Already in advance and also in the aftermath of the Elbe flood in Germany several research programmes and projects have been implemented, e.g. SCALING 2005, RIMAX 2007, making clear the relevance of flood risk management for the German government.

4.8 Looking at the Future: Needs in Risk Mitigation

The rather large review of instruments used in the European Union for mitigating and responding to natural and na-tech risks demonstrates the importance that this issue has gained, particularly in more recent times. There is still much room for improvement, both in individual sectors and in the search for a more comprehensive and global approach. In the following paragraphs, two main points will be raised: the need for a more satisfactory treatment of uncertainties on the one hand and for a stronger European lead in the field of prevention on the other.

4.8.1 The Treatment of Uncertainty

Risk issues are inherently uncertain, therefore it may seem too obvious that decisions on how to manage them must face a certain level of uncertainty. The question is that until recently it was supposed that such uncertainty could be simply expressed through a probability, perhaps a Bayesian probability, thus denouncing the subjective judgements made in relation to the available information and the degree of belief put by the expert in the possibility that a given loss would occur with a given return period. This way of considering risks is rather familiar to natural hazards experts, while it encountered a number of difficulties in other risk analysis fields, ranging from technological threats to risks associated to the manipulation of food or organisms.

Larger concerns have been raised in the latter regarding the possibility to encapsulate uncertainty associated to risk assessment and the derived set of decisions that were opened to stakeholders using probabilities only. For example Stirling (2007) suggests that there are at least three main areas of concern for assessors: one is related to the more traditional uncertainty, represented in probabilistic terms, the second to ambiguity, whenever the negative outcomes of a given event or activity cannot be fully envisaged, and the third to ignorance, when both probabilities and outcomes are hard to appraise. Ranging from what Stirling defines as uncertainty to ignorance, a vast array of methods are available to support the decision-making process, under what have been realised as hard decision-making environments (see Van der Sluijs et al. 2004).

From a regulatory standpoint, the precautionary principle has been introduced in areas where lack of data and/or knowledge should not be considered as a justification not to take action or to continue developing a potentially dangerous technology or activity. The principle introduced in the Maastricht Treaty (Title XVI, Environment, article 130r/2) and further explained in a Communication of the European Commission in 2000, according to Funtowicz et al. (2000) “provides few guidelines for policy makers, and fails to constitute a rigorous analytical framework”.

The introduction of the principle is explained by the need to put complementary attention to the “contextual aspects of the complex systems in which hazards arise and within which social significance and acceptability must be appraised” (Funtowicz et al. 2000).

Very similar considerations are brought about by the European Commission document titled “Taking European knowledge society seriously” (EC, 2007), calling for a “more balanced and explicit articulations of technical “facts” and “uncertainties” with wider social values, interests and imaginations around science and technology, that we can build more robust decisions and commitments relating to “risk” and what this encompasses” (p. 32).

Until now, most studies and reflections related to the precautionary principle have been addressing technological risks or risks associated to manipulation of food and organisms. One may question why such a concept has not been considered also for natural hazards. An answer is provided by the distinction made between the two concepts of prevention and precaution (see Godard, 1997), the first being associated with the management of well known and largely predictable events, the latter with the management of risks for which ambiguity and ignorance prevail.

Despite those considerations which certainly capture an important part of the issue, one may nevertheless ask whether or not this is more a matter of interpretation than the actual diversity of the two fields of concern.

Oreskes et al. (1994) have convincingly demonstrated that in earth sciences the terms validation, calibration and verification could by no means be associated to the definite proof of a theory regarding the predictability and behaviour of given phenomena, because of the intrinsically open nature of earth systems, which introduces several layers of uncertainty in every step of the model development and application.

Among the examples provided by recent literature, two will be briefly illustrated here, one related to flood forecasting and the second to the field of earthquake engineering.

In their short summary of the many aspects that make rainfall-runoff modelling uncertain, Maskey et al. (2004) include:

"1. model uncertainty
2. input uncertainty (due to imperfect forecast of future precipitation, evaporation, etc.)
3. parameter uncertainty
4. natural and operational uncertainty (due to unforeseen causes, malfunctioning of system components, erroneous and missing data, human errors and mistakes . . .)".

Surprisingly rather similar arguments are brought by Wen et al. (2003) regarding the prediction of the "behaviour and performance of complex engineered systems, provided that the demands on the systems and the capacity of the system to withstand these demands are known. However, numerous sources of uncertainty arise in this analysis and assessment process and accordingly impact the ensuing technical, economic and social decisions. Some of those uncertainties stem from factors that are inherently random (or aleatory) at the scale of understanding or customary resolution in engineering or scientific analysis. Others arise from a lack of knowledge, ignorance, or modelling (epistemic) and are dependent on the model selected" (p. 6).

The fact that a stronger connection than generally supposed can be envisaged between all risks does mean perhaps that the call for the precautionary principle would be needed for a variety of risks, whenever complex decisions related for example to where to develop an urban area or build a new infrastructure must be made. In this regard Dubreuil (2001) notes that the compartmentalised character of public administrations and agencies dealing with complex issues such as risk and environmental problems is "confronted to growing difficulties", "whereas a complex problem can be addressed by several categories of administrations, none of them are in the position to solve it". Similar conclusions were drawn also by the Armonia project in the field of land-use planning in hazardous areas.

In summary, there seems to be an increasing recognition of the need to acknowledge various levels of uncertainty and in the meantime create more contextual knowledge frameworks, to combine scientific and value appraisals that cannot be easily separated in most risk arenas.

As stated by Wen et al. (2003): "integrated approaches to uncertainty modelling and public or private decision making, applied at country or regional scale, have rarely been attempted. The state of the art in decision-theoretic methods and computational platforms now has advanced to the point where such integrated approaches can be contemplated". The point is to verify to what extent those approaches can become part of ordinary practices in risk governance.

4.8.2 Risk Mitigation in the Context of the European Territorial Agenda

According to some Authors (see in particular McCormick, 2001), "the European Union still does not have an environmental policy. Instead, it has a series of policies relating to specific environmental aspects such as air pollution, chemicals or waste management" (Peltonen, 2006). The same lack of a comprehensive policy can be recognised in the review of initiatives and legislations regarding risks and hazards both at the European and national levels.

This is particularly evident for countries exposed to a variety of hazards (like Southern European countries): competences are fragmented between civil protection, ministry of environment and interior, various regional offices and agencies. This way the fundamental need for policies that encompass all natural hazards (including na-tech) and provide mitigation strategies to be tailored for the specific situation remains unanswered. Such strategies should not be too hazard specific, though they should consider the possibility to offer responses to specific threats, taking into account the kind of stress imposed on structures, environments and communities by a given hazard.

On the other hand, they should be oriented towards multirisk approaches whenever those are relevant for the geographical area of interest. At present only civil protection agencies, including the European Civil Protection Agency, have a multirisk perspective, but mostly focused on post-disaster response, while such a perspective is essential for long-term measures as well. Furthermore, the proposed connection to sustainability calls for stronger integration not only among strategies aimed at reducing various types of risks, but also between environmental protection and reduction of damages due to natural hazards.

It has been noted (Peltonen, 2006) that policies addressing technological risks are far more developed than those relating to natural hazards, thanks to the Seveso Directive apparatus. One reason for this could be the ubiquitous presence of hazmat installations throughout the European Union, whilst a rather diverse geographical distribution of natural hazard can be recognised, as discussed in Chapter 2. This is perhaps the reason why the call for territorial cohesion has been seen as an important drive for promoting a European action in the field of risk management.

In the Territorial Agenda for the EU approved in the informal ministerial meeting in Leipzig on May 2007, the promotion of a trans-European risk management is strongly advocated in articles 23 and 24.

> "(23) Territorial cooperation is to be further developed and intensified in order to create common approaches and strategies to prevent, mitigate or adapt to climate change as well as other shared technological and natural risks.

(24) In order to improve the efficiency of risk management and to guide development appropriately, integrated trans-European territorial development policies (e.g. Integrated Coastal Zone Management) are to be adopted and new forms of transnational risk governance are to be developed especially in multi-hazard areas like coastal zones, lakesides, maritime and river basins and mountainous areas."

According to Faludi (2006), the call for more cohesive policies for risk reduction are part of a more general reframing of the European Spatial Development Perspective in the name of solidarity (cohesion in the social realm) and sustainability (cohesion in the environmental sphere). It has still to be seen to what extent such a process can be initiated without any statutory affirmation of the territorial cohesion principle, as could be achieved by being included in a ratified European constitution. From a practical perspective, the call for a more comprehensive and long-term risk mitigation has to be grounded in a mix of tools such as those described in the previous sections, deriving from a variety of instruments tailored to specific political and environmental conditions. In the absence of a strong European commitment in this field, national differences will continue to prevail, generating rather scattered situations. In fact, there must be a strong action in some fundamental aspects, should risk mitigation achieve more substantial results, for example in the following areas:

- control of land use and land ownership regimes, to avoid further urbanisation and re-urbanisation of the most hazardous zones
- connection between various levels of government (horizontally and vertically) to achieve shared goals
- attention to how general objectives can be reached locally, an issue that is certainly relevant for risks (as will be shown in the examples of scenarios provided in Chapter 6).

4.9 Appendix: Cross-national Comparison of National Laws

Field	Type of legislation	Contents	Central authorities' involvement	Local authorities' involvement	Aspects relevant at EU level (best practice/lessons learnt)
UK					
Flood risk	Acts of the UK parliament: Environmental Act 1995 Water Resources Act 1991 Coast Protection Act 1949 Land Drainage Act 1991	Parliament Acts identify authorities involved in flood defence and risk management as far as their roles, powers and duties.	- Defra (Department for Environment, Food and Rural Affairs) has overall policy responsibility. It funds operating authorities and publishes advice and guidance. - EA (Environment Agency) is the executive agency, empowered to manage flood risk, flood forecasting and flood warning dissemination.	- Regional and local Flood Defence Committees have powers to raise revenue to fund flood defence works and can carry out works for defence, maintenance and longer-term protection. - Local authorities and internal drainage boards have powers to undertake flood defence works.	Defra's program includes Catchment Flood Management Plans (CFMPs). CFMPs support the River Basin Management Plans (RBMPs), required under the EU Water Framework Directive.
	Planning Policy Statement 25 (PPS 25): "Development and flood risk"	It is aimed to ensure that flood risk is taken into account in the planning process and encourages admini-strations to act on a precautionary basis, considering climate change scenarios.		The policy requires that regional planning bodies (RPBs) and local planning authorities (LPAs) prepare and implement strategies to appraise, manage and reduce flood risks.	The shift from structural defences to a more strategic and holistic approach to catchment management, based on an ecosystems perspective, is coherent with European sustainable development vision.

Climate Change	UK Climate Change Programme 2006	It is the UK's key strategy for its work on tackling climate change. It sets out the policies and measures which the UK is using to cut its emissions of greenhouse gases and main adaptation measures to the impacts of climate change.	Government, through Defra, has policy responsibility. It produces programmes and guidelines.	Local governments have a vital part to play in combatting climate change, promoting renewable energy, greater energy efficiency and adaptation strategies through their roles in local planning, transport, housing and education.	The government established the UK Climate Impacts Programme (UKCIP), which provides scenarios that show how the climate might change in the UK. The first scenarios were produced in 2002 and will be updated by 2008.
	Planning Policy Statement: 'Planning and Climate Change'	It sets out how local planning should create lower carbon emissions settlements and be more resilient to climate change.		Policies on planning and climate change should be taken into account by regional and local planning bodies' documents.	The government's intention is to move towards a common methodology for all regions.
Civil Protection	Civil Contingencies Act 2004	It formalises duties of local authorities, and other organisations involved in responding to any emergency.	There are provisions for government coordination, through the Cabinet Office Civil Contingencies Secretariat.	Local responders are seen as fundamental; the Act divides them into categories, basen on their responsibilities.	
Sustainable development	Securing the future; and strategic framework, 2005	The two documents set up the national strategy on sustainable development.	The government supports local action with suitable tools.	The strategic framework will be supported by separate strategies for each administration.	The strategy introduces a set of indicators to give an overview of sustainable development in the UK. Sustainable communities are among the goals of the policy.

Greece					
Seismic risk	Earthquake Design Code	It includes earthquake safety regulation for structures, and provides all the relevant information required for incorporating seismic safety considerations into housing, urban and regional planning.	The Earthquake Planning and Protection Organization (E.P.P.O.) is in charge of seismic risk prevention.		
Flood risk	Law 3199/9-12-2003 on "water protection and the sustainable management of the water resources"	The law establishes long-term protection of water resources and also addresses the mitigation of floods and drought effects.	The National Water Agency is the governmental authority with the overall responsibility for establishing water policy.	The legislation provides a detailed identification of 13 River Basin Districts and their respective responsibilities in water management in Greece.	The Law translates the EU Water Framework Directive into the national legislation, introducing an innovative approach to water management.
Coastal erosion	Framework for Spatial Planning, Sustainable Development in Coastal Areas	It addresses issues, such as the delimitation of the boundaries of the coastal zones and the identification of the management zones.			An Action Plan is also included, to be implemented between 1993 and 2018. It introduces the idea of Integrated Coastal Management.

Drought risk	-National Action Plan (NAP) for combating desertification -Common Ministerial Decision (CMD) no. 99605/3719	The CMD contains guidelines for the creation of the required agencies and the application of policies and measures described in the NAP, mainly based on sustainable development.			Within the NAP, the following documents were produced: - Greece Desertification Vulnerability Map; - Greece Soil Associations Map, providing information on soil type and quality, desertification vulnerability, sustainable agronomic uses, restrictions for non-agronomic uses.
Civil protection	Law N. 3013	It upgrades the role of civil protection in Greece, emphasising the importance of citizen protection and assigning roles to local authorities.	There are two main bodies: - SDO: interministerial body; - the General Secretariat for Civil Protection.	Each region and prefecture must develop emergency plans. The prefect, as the local government representative, grants assistance.	It provides for the community mechanism involvement.
Forest fire risk	Articles 24 and 117 of the Greek Constitution				Inclusion in the constitution has proved to be a good practice for protecting forests from land use changes.
	Legislative Decree 86/1969	Establishes compulsory reforestation of burnt areas to be carried out by local authorities.	Ministry of Internal Affaires monitors the law's application.	Local authorities have to submit the reforestation plan to regional (forest) authorities.	

Forest fire risk	Law 998/1979 (Forest code)	Defines the role and responsibilities concerning forest fire management and the obligation to declare burned areas as protected for reforestation.	Forest Service, Fire Service, police, army, Ministry of Environment and Public Works	Forest offices, fire offices, local authorities, regional authorities, local land planning authorities.	
	Circular on Fire Danger Mapping (issued annually)	Anticipate issuing daily a national fire danger map.	General Secretariat of Civil Protection produces the map between May and October, sends it to authorities and publishes it on the official web site of the GSCP.	Local and regional authorities have to arrange their activity during the "fire season" according to the issued fire danger maps.	Fire Service is also provided with maps produced by the European Forest Fire Information System in JRC Ispra. However, fire brigades criticized these maps as non-operational.
	Law 1892/1990	Defines the obligation of the local and regional suthorities regarding fire suppression and other fire issues (Articles 115-119).	Ministry of Internal Affairs	Local and regional suthorities have to participate in fire suppression activity, providing resources and organizing fire shifts during the summer period.	
	Law 3208/2003	Refers to the protection of forest ecosystems and the creation of the forests cadastre.	Ministry of Environment and Public Works	Forest offices monitor the application of the law and issue binding land use declaration.	Greece is still (since 1976) in the process of developing the national cadastre of forests.

Sustainable develop-ment	National Strategy for Sustainable Development (NSSD)	It provides directions for achieving environ-mental sustainable policies, establishing a framework for an Action Programme.		On the basis of the principle "think global-ly, act locally", the strategy provides guid-ance to local authorities.	
Climate change	Greek Action Plan **(GAP)**	The GAP coordinates policies and measures to curtail predicted CO2 emissions in Greece.			No adaptation measures are foreseen for potential increase of climate change driven disasters.
France					
All risks	Act of 2 February 1995	It provides for a "10-year program for the prevention of major natural risk".	The Ministry of Ecology and Sustainable Develo-pment is responsible for preventing natural risks.	It calls for the involvement of local authorities at different levels.	
	Law 2003-699 addressing natural and industrial risks	The Environmental code sets up the natural risk prevention policy in France.	Plans for the prevention of foreseeable natural disasters (RPP) have implications for relevant risk zoning.	Following a public enquiry and consultation with municipal councils, the RPP is approved by a ruling of the préfecture.	Among mitigation mea-sures, the French legislation envisages compulsory in-surance linked to the PPR. The latter is a good example of using the same frame-work for all risks.
	Right to be informed about risk exposure (1987)	It introduces an informational risk zoning.		"Departmental dossier of major risk", "municipal synthetic dossier" "municipal dossier on	DICRIMs place an obligation (also enforced in the Environmental Code-Book I-Title II) on the

All risks				information about major risks (DICRIM)" must be prepared and made public.	elected persons to inform the public about major risks, both technological and natural.
Civil Protection	Law of 22 July 1987		The Directorate of Public Defence and Safety (DDSC) within the Ministry of Interior holds responsibility at the national level.	At the regional level, six CIRCOSC (Inter-Regional Emergency Control Centre) are in charge of the co-ordination of all civil protection agencies.	
Climate change	The Climate Plan	It is an action plan operational in 2010 to tighten and accelerate emissions reduction in all sectors.			
Sustain-able develop-ment	National Strategy for Sustainable Development (NSSD).	The main objective of the strategy is promoting Agenda 21 implementation.		The strategy recommends, on a voluntary basis, the setting-up of 'local Agenda 21', aiming at local design and implementation of the global programme.	

Germany					
Land-slide/ Ava-lanche risk	Plan for the Bavarian Alps	The aim is to prevent intensive tourist development within highly sensitive alpine zones. It distinguishes between three spatial zones with different binding rules.		Federal authorities are in charge of the development of the plan.	Only the Bavaria Region is prone to this kind of hazard. So there is not a legal national basis for dealing with it, but regulations are mainly at the Federal State (local) level.
	Information Service for Alpine Natural Hazards	It provides for early warning information and a landslide activity map.		It is a joint programme of the Federal Water Management Administration and the geological survey and forest authority.	
Seismic risk	DIN 4149	It defines common technical building standards (in accordance with Eurocode8) with regard to 3 hazard zones.	Responsiblity of the German Institute for Structural Engineering.		
Forest fire risk	National Forest Program	It is a comprehensive forest policy framework for achieving sustainable forest management.	Developed by the Fed. Ministry of Food, Agriculture and Forestry.		The Federal Agency for Agriculture and Food publishes annual report and statistics on forest fires. Anyway, they covers only the hazard component but not attention is paid to vulnerability.
	Federal State Forest Acts	They lay down specific designations related to forest fires.		Sectoral federal authorities are in charge of Forest Acts Development.	

Storm surge risk	German National ICZM Strategy	Storm surge risk is integrated in coastal protection activities. The report defines the strategy as a voluntary approach towards sustainable development of coastal areas.	The Federal Environmental Agency is formally responsible for the development of the German National ICZM Strategy.		As an example of good practices, the Schleswig-Holstein Framework Plan for Coastal Protection can be considered. It is an integrated, flexible instrument for coastal zone management, taking into account all relevant spatial functions of these areas as well as risk management perspective. As a consequence, further development of coastal areas has to be planned taking into account a risk estimation based on both hazard and vulnerability. The plan was elaborated with the participation of all relevant actors, including the public.
	Federal legal acts	They define programmes in the field of coastal protection, overcoming the limited approach based on structural measures (dikes) only.		Water management authorities provide for Acts.	
	Federal State Spatial Planning Acts	In general, they only show the structural mitigation measures planned and to be implemented by sectoral planning.		Coastal *Länder* authorities	
Flood risk	VII Amendment of the Fed. Water Act (2002)	It lays down basic principles for the designation of flood zones.	The Fed. Min. for the Env., Nature Con. and Nuclear Safety.	Water management authorities are in charge of flood hazard assessment.	Flood zones can be viewed as hazard maps. No attention is paid to vulnerability.
	Flood Control Act	It designates homogeneous principles for flood protection as well as standards for flood zones,	It was issued at national level by different ministers.	Regional planning assumes responsibility for all land-use related risk management activities.	Under the new Act, the Länder must designate more areas than before as flood plains, with the requirement

Flood risk		strengthening the role of regional planning.			to also inform the general public.
	Flood action plan	They are a programmatic basis for water management authorities and planning authorities.		Federal water management authorities are in charge of the implementation. In case of large river basins (e.g. Elbe, Danube, etc.) special international commission were created.	They try to overcome the weakness of flood zones, providing for flood prone areas, based also on economic damage potential. The risk management at river basin scale represents a good practice.
Civil protection	Each state has its own emergency legislation			The mayor is generally considered the local civil protection authority	
Sustainable development	Perspectives for Germany	It is the national sustainability strategy.	The State Secretaries' Committee on Sustainable Development is in charge of sustainability policy..		Among priority fields of action, “sustainable human settlement development” is mentioned.
Climate change	The National Climate Protection Programme 2005	It contains a comprehensive catalogue of measures to reduce greenhouse gas emissions. Nevertheless, adaptation measures are not explicitly foreseen	Developed by Fed. Min. for the Env., Nature Conservation and Nuclear Safety		Good practices can be found at state level, such as the Bavarian Water Law, adding 15% to the national design flood value in order to explicitly consider climate change.

Italy					
Flood/ Land-slide risk	Law 183/1989	It is a general policy law which aims to protect water and soil. It is aimed at dealing with hydro-geological risks at the river basin scale.		It sets up local River Basin Authorities, which must develop River Basin Plans, which entail binding limitation on land use planning.	It shifts the focus from point-shaped interventions to the river basin scale. It was an innovative law, preceding the Water and the Flood Directives
	Law 493/93	It enables River Basin Authorities to create different River Basin Plans (Piani Stralcio) for different problems (e.g. pollution control, flood protection, etc.).			On one hand, the law highlights the problems faced in developing a unique comprehensive plan. On the other hand, it allows the different authorities to take action based on their own river priorities.
	Law 267/98 (Legge Sarno)	The law requires identification of the areas exposed to the highest levels of hazard and risk. In those areas, special contingency plans must be prepared and relocation programs are to be considered.			The law does not give any indications on how to determine the areas more at risk, leading to a situation in which each river basin authority adopted its own criteria. Furthermore, up to the present, relocation has very rarely been applied.
Seismic risk	D.M. 14/1/2008	It establishes the new building code for seismic areas, in line with the Eurocode 8.			

	Ordinance 3274/03	It approves the national criteria for seismic zoning.		Regions must define seismic zones within their own territory.	
	Regional regulations, special disposition	Several regional regulations have been issued concerning planning adaptation to seismic risk, particularly during reconstruction.			
Forest fire risk	Law 353/2000	It is a general framework law that aims at protecting and preserving the Italian territory from forest fires.	The Department of Civil Protection coordinates airforce activity during emergencies.	Regions must develop regional plans for both forest fire prevention and prediction.	Among prevention measures, training and awareness programmes are foreseen; as well as building limitations in burnt areas.
	Prime Minister decree, 20 December 2001	It provides guidelines for the development of regional plans.			The organisational framework proposed in the decree is based on the use of the most advanced information systems and ICT tools.
Volcanic risk	Campania Region decision n.2139, 20.06.2003	It formalises the Regional Programme for the mitigation of Vesuvio volcanic risk.		Local authorities must develop emergency plans and take action to encourage relocation.	The Regional Programme couples risk prevention with the preservation of the biodiversity and the natural habitats in the Vesuvio area.
Civil Protection	Law 225/92 Decree 112/98	The law establishes the National Service of Civil Protection. The decree empowers local authorities on civil protection activities.	The Prime Minister is responsible for civil protection and operates by means of the Department	Several authorities are responsible at different scales; overlapping may be found at the provincial level	

			of Civil Protection. The Department is in charge of developing prevention and emergency plans at the national level.	where provinces and prefectures coexist. The latter, however, have the actual power to coordinate forces such as fire depts. or police.	
Sustainable development	National strategy for sustainable development – 2002	It establishes the environmental strategy to be adopted by Italy in the next ten years in order to support sustainable development.	The government supports the strategy implementation by providing suitable laws and funding.	Local authorities must implement the strategy adopting specific processes like Agenda 21 and suitable tools (like EIA, SEA).	
Climate change	Law 120/02 and National plan to reduce greenhouse gases 2003-2010	It ratifies the Kyoto-protocol. The plan establishes fields of actions, policies and priorities, and establishes a funding timetable.	The government must develop the national programme for planning the reduction of greenhouse gases.		
Spain					
Flood risk	Law 62/2003 – Art. 129	It modifies the existing Water Law in order to incorporate the EU Water Framework Directive into Spanish legislation. It acts on sections regarding hydrologic planning. Also, it establishes basin plan content and objectives.	The government approves Basin Hydrological Plans.	The law introduces River Basin Authorities (Consejos del Agua) which are in charge of Basin Hydrologic Plans, public information and participation in planning activity.	The law also introduces the National Hydrologic Plan with the aim of facing discrepancies among Basin Plans, providing a national perspective. It must be developed by local authorities and must foresee public participation.

	Directriz Básica de Planificación de Protección Civil ante el Riesgo de Inundaciones (1995)	The aim is to establish minimal requirements for Flood Special Plans according to the more general framework provided by the Directriz Básica to guarantee the coordinated activity of all authorities involved in emergency response.			It provides risk maps at the river basin scale (based on hazard, exposure and vulnerability assessment). Moreover it requires assessment of the impact of any asset that can increase the flood impact or create domino effects.
Drought risk	No law has been issued.		The Environment Ministry set up the National Observatory on Drought.		
Forest fire risk	Directriz Básica de Plan. de Protección Civil por incendios forestales (1993)	The aim is establishing minimum requirements for Forest Fires Special Plans, to guarantee the coordinated action of all authorities involved in emergency response.			It provides risk maps at local scale (based on assessments of hazard, exposure and vulnerability). Neverthelessm criteria for defining local risk indexes are not provided.
	Forest Law No. 43 of 2003	It establishes the national forest policy, including forest fires management.		Local authorities are in charge of forest fire protection, including prevention, training and development of awareness programmes.	Special attention is given to the root causes of intentional fires; and to the construction of transportation networks across forests.

Seismic risk	Directriz Básica de Plan. de Protección Civil ante el Riesgo Sismico (1995)	The aim is the establishment of minimum requirements for Seismic Special Plans to guarantee the coordinated action of all authorities involved in the seismic emergency response.			It provides for risk maps at local level (based on the assessment of hazard, exposure and vulnerability) in order to foresee different emergency strategies for different risk zones.
	Real Decreto 997/2002	It is the Spanish seismic building code. It distinguishes between three types of buildings: - moderate significance - normal significance - special significance.			Special significance buildings are strategic assets that may be vital for the emergency response
Volcanic eruption risk	Directriz básica de Plan. de protección civil ante el riesgo volcánico (1996)	The aim is to establish minimum requirements for Volcanic Special Plans to guarantee the coordinated action of all authorities involved in emergency response.		The directive is applied only in the Canary Islands, as it is the only region prone to volcanic hazard. Nevertheless, coordination with national emergency plans must be guaranteed.	The directive is mainly focused on forecasting activity rather than risk mapping.
Planning policy	Ley de Suelo (may, 2007)	It is the planning law that regulates land use in Spain.			It states that town planning cannot take place in high risk areas and that any future land use project requires a previous risk assessment report.

Climate change	Real Decreto 376/2001 Real Decreto 1334/2006	The decrees establish the General Direction on Climate Change (Dirección General de la Oficina Española de Cambio Climático).	The Direction, under the Environment Ministry, sets up the national policy on climate change.		
	Law 1/2005	It regulates the Spanish emission trade system.	A special commission was created.		
	Plan Nacional de Adaptación al Cambio Climático	It establishes the national adaptation strategy, and provides local authorities with data, scenarios, and guidelines.	Special commissions will ensure the implementation of the Plan.	Local authorities must develop adaptation policies based on the the content of the Plan.	Particular care must be given to public participation in developing adaptation plans.
Sustainable development			The Environment Ministry is in charge of promoting sustainable development policies also through special programmes and funding.	Local authorities must implement in their policies national guidelines.	
Civil protection	Legislation is fairly elaborate. Several provisions have been	The main areas of responsibility for the General Directorate include: risk analysis, prevention, emergency planning, intervention,	The General Directorate for Civil Protection depends on the Ministry of the Interior.	Each administration can organize and manage its civil protection system with complete autonomy but must guarantee solidarity in	The Spanish system is highly decentralized. It is build to favour cooperation between organisations possessing resources to cope with emergencies.

	issued since the 80s.	rehabilitation and information.		case of need.	
	Directriz básica: Basic Standards	It lays down the require-ments for civil protection plans distinguishing between two types of plans: *Territorial plans*: addressing emergencies at various scales. *Special plans*: addressing specific risks (like floods, earthquake, forest fires, etc.).	National government plans of national interest.	The local territorial and special plans are adopt-ed by each province to form the autonomous community plans. They are approved by the National Commission for Civil Protection, a consultative body made up of representatives of various administrations.	The Basic Standards are aimed at guaranteeing coordination between the many planning levels, which differ with regard to the size of their area and their agencies and organisations.

5

Risk Futures in Europe

J.P. Kropp, G. Walker, S. Menoni, M. Kallache, H. Deeming, A. De Roo, F. Atun, S. Kundak

5.1 Looking into the Future: The Increasingly Important Role of Scenarios in Risk Studies

In this section scenario as a concept and a tool will be discussed, tracing a path from the very general and theoretical to the more applied aspects. The notable chapter "The History of the Future", appearing in a book by Rescher (1991), will be taken as a starting reference. Rescher discusses the increasing importance of futurology in today's practical life, including policy and science (see also Oreskes, 2000). This focus on the future has become extremely important because of the rapid quantitative and qualitative changes experienced in modern life. It is also a consequence of the role played by science in society in supporting decision-making processes, particularly in the field of risks and environmental issues in general.

According to Rescher, three conceptual categories apply to discourses about the future: predictability, welcomability and tractability. The first and the third are clearly crucial for the kind of work that has been carried out in the Scenario project. As for predictability, getting to observations that are strongly supported also by Sarewitz et al. (2000), Rescher notes that since the entrance of stochastic and probabilistic tools to analyse natural processes, only "conditions or trends rather than specific development" (p. 206) can be actually predicted. Still, even "a world in which no particular future event is confidently predictable may yet be one whose future can be discerned in general terms" and even in "situations where we cannot predict the actual course of developments, we may be able to indicated a limited range of alternatives that maps out, in a rationally circumscribed way, a small number of plausible possibilities" (p. 207). Both natural risk and climate change scenarios are grounded on the belief that this can be done, that a number of alternative futures can be rationally mapped on the ground of our knowledge of the past and our understanding of underlying processes both in natural and manmade environments. With respect to welcomability, both communities share the idea

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

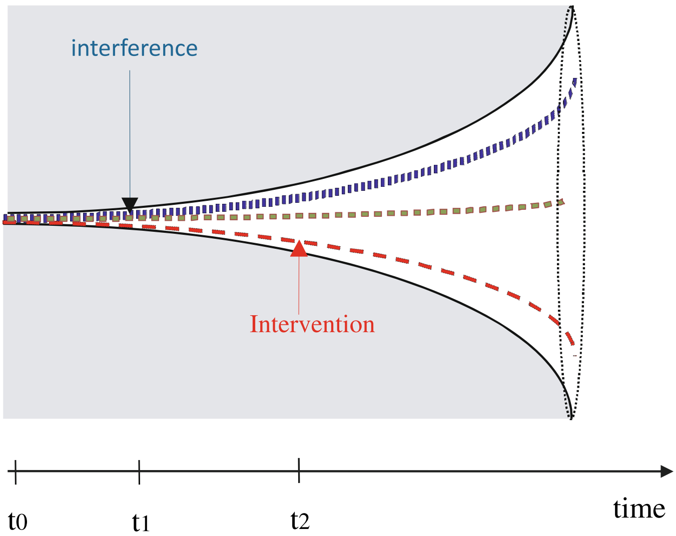


Fig. 5.1. Conceptual representation of scenarios (from Scholtz and Tietje (2002, p. 81))

that it is possible to intervene in order to change otherwise inevitable trends. Nevertheless, Rescher contradicts this positive vision by suggesting, regarding tractability, that "the relationship between human agency and its actual results is so complex that even a fore-knowledge of what people will try to do with the modificatory powers at their disposal would not enable us to foresee its actual ultimate effects" (p. 217). Despite this scepticism, Rescher recognises that "enhanced praxis enables us not merely as passive spectators but as active participants to produce future"(p. 215). Clearly scenarios in climate change, including political intervention and adaptation, rely on the fundamental faith in the possibility of humans to change future patterns (natural or social) they have perhaps significantly contributed to.

One distinctive methodological aspect of our research, clearly readable in the structure of the book, is the need to distinguish between what can be labelled as "descriptive scenarios", that is future developments that may occur if things are left as they are without any attempt to correct main fallacies, and "outcome oriented scenarios", deriving from the possible evolution of the current situation if corrective action is taken (see Scholtz and Tietje, 2002, Fig. 5.1).

The latter can be distinguished into two other approaches. The first, as introduced by Scholz and Tietje (2002), looks consequently forward, i.e. it permanently readjusts a strategy when a predefined target, which can change in time, is not fulfilled. The second approach (also known as inverse scenario, viability, or tolerable window approach, see Aubin, 1991; Petschel-Held et al., 1999) is looking back from the future and asks whether there exists at least one trajectory which can fulfill a set of predefined additional constraints at any time. This approach is increasingly used in environmental sciences in order

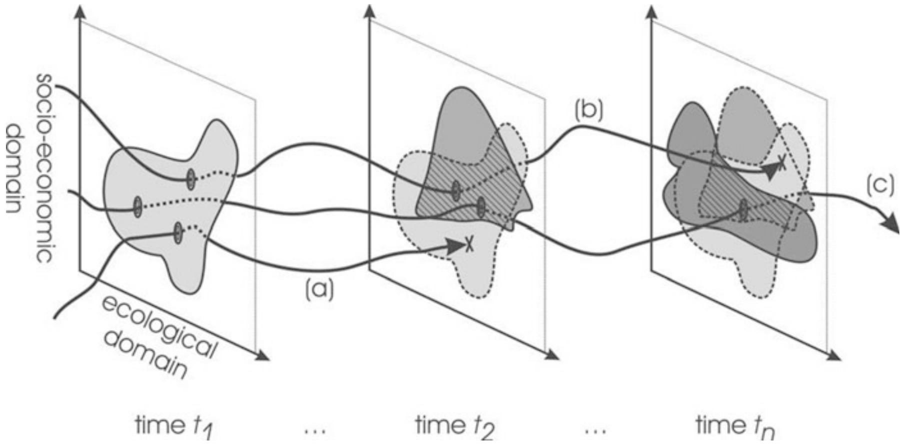


Fig. 5.2. Schematic representation of inverse scenario (viability) analysis, which can be considered as a filtering algorithm. At any given time (for example, time slices $t_1 - t_n$), it is checked whether a system stays within a defined domain indicated by the grey windows. Since the viability constraints may change, for example, due to changes in the economic situations, not all exemplary developments ((a) at t_2, (b) at t_n) fulfill the criteria. As indicated, the 'window of opportunities' shrinks in the future (hatched area), but with respect to actual management strategies it may also be possible that it is widened (from Kropp et al., 2006)

to assess whether sustainability targets in the future can be fulfilled under additional, e.g. economic or social, conditions for any time (Bruckner et al., 1999; Eisenack et al., 2006; Aubin & Saint Pierre, 2007). A prominent example for such an approach was the calculation of the 2 °C climate protection target (Bruckner et al. 1999).

In our opinion, it is of extreme importance both for the sake of methodological clarity and for providing the floor for conscious decision-making to be able to compare the possible development with and without intervention to prevent the most worrying consequences of the "business as usual" scenario. In climate change studies, such a distinction is fundamental, although not always proposed in such a clear-cut way; but also in the field of natural hazards, scenarios have been often presented with the objective of comparing costs and benefits of today's mitigation costs and future expected damages.

Working with scenarios does not entail a unique set of tools and products, rather it embraces a variety of possible approaches, ranging from the most quantitative to the totally qualitative. In the following sections a brief description of basic scenario approaches is presented, in order to provide a framework for the approach used in the Scenario project.

Scenarios as a deterministic input. In most scientific disciplines studying natural hazards, scenarios are equated with deterministic input, intended as the selection of one individual event from the range of all possible ones, in order to analyse its specific effects in a given environment. Thus the scenario approach contrasts with probabilistic risk assessment (PRA), where the intensity of damage provoked by any potential hazard, along with its estimated return period, is appraised. In general terms, PRA has been preferred by scientific disciplines, because of its completeness and the possibility to offer reference dimensions of damage in terms of average event, most frequent event, etc. Scenario approaches, however, have been dismissed and underused for a long time, because of the difficulties in demonstrating that the specific event chosen for analysis is more likely than others to occur and because of the many limitations that are forcefully implied in such a selection. For example, in the case of earthquakes, not only given magnitude and /or accelerations must be decided, but also epicentre area, which significantly changes the pattern of expected damages, with respect to another epicentre that is equally probable. In the nuclear industry approach, two kinds of seismic scenarios (e.g. design earthquake) were defined: the most credible and the most potential. In the first case, the selected scenario is referred to the most important event that has occurred in historical/archaeological times. The latter refers to the most potential identifiable event, according to the seismotectonic information available, evaluated through experts' judgement.

Despite its limitations, the scenario approach has gained some relevance in recent years, for two main reasons. First it has been adopted to investigate events that, though rather unlikely according to a PRA, may nevertheless significantly disrupt the environment. Lately, even insurance companies have paid more attention to the scenario approach (Linnerooth-Bayer et al., 2003) particularly for so-called "catastrophic risks". The reasons for this are the lack of historic records of extremely severe hazard occurrences on the one hand and on the other the differences in vulnerability patterns, which have only recently reached the present level level of complexity and density of people, functions and infrastructures.

Another reason for the increasing interest in scenario modelling derives from the so-called "end-users". PRA and scenarios should not be judged only on the basis of theoretical validity and completeness, but also on the grounds of what their results will be used for. For instance it has been recognised that contingency planning should be built on scenarios while probabilistic assessments convey a kind of information that is not as useful to prepare for emergencies and associated potential surprises.

Furthermore it should be kept in mind that scenarios, in scientific terms, tend to simplify the reality so as to simulate the evolution/behaviour of a limited set of variables that can be expressed in quantitative terms, for example, number or value of destroyed buildings. In the majority of cases such scenarios cannot grasp the complexity of a city or a regional area when other aspects like systemic interdependence among various components or the interface between societies and built and natural environments must be accounted for. Such complexity can be dealt with only mixing quantitative and qualitative scenarios, something that has been beyond the capacity and perhaps even the willingness of “hard sciences”, at least until now. The latter encounter significant problems in modelling even coupled hazards, for example, na-tech.

Quantitative scenarios rarely go beyond the estimation of direct physical damage due to the selected event; some interesting attempts have been carried out to model also indirect damage, particularly to lifeline systems (see Shinozouka et al., 1998).

Scenarios as storytelling. The word ‘scenario’, in the sense implied in this chapter, is due to Kahn in his work for the Rand Corporation (see Ringland, 1999). Asked to provide the US Army with an image of a likely future the day after a nuclear war, he attempted to fulfil such a futurology task by combining imagination with experience that was unfortunately already available from the two bombs of Hiroshima and Nagasaki in the Second World War. As Schwartz (1991) correctly puts it, “scenarios are not about predicting the future, rather they are about perceiving futures in the present” (p. 36) whose end result “is not an accurate picture of tomorrow, but better decisions about the future” (p. 9). Kahn labelled his exercise with the term scenario, which he preferred to others taken from theatre or cinema, because it provided a more general idea of imagination, blend of already known facts and jumps into the future. Interesting enough for present applications in the climate change community, is the ultimate aim of Kahn’s exercise: he wanted to show the disaster that may be expected as a consequence of a nuclear war, so as to discourage anybody from initiating such a tragic experiment.

This idea of scenario has since been implemented in many fields, ranging from economics (particularly market investigations and firms analysis, as Schwartz did for Shell) to civil protection. There have been some attempts to use qualitative scenarios as a complement to more quantitative risk assessments or scenario models, to forecast potential outcomes of floods or earthquakes (see Chatelain et al., 2000 for the case of a Quito earthquake scenario).

Use of accident scenarios in industrial risk analysis. Despite the definition “industrial risk assessment”, experts in hazardous plants analysis do not perform a probabilistic risk assessment as intended in the natural hazards field. What they actually do is identify a limited, though generally large, number of potential accident scenarios from the more trivial, common and easy to deal with to the more complex and potentially harmful, the so-called “top events”. The latter term refers to severe accidents, with implications that may cross the plant’s boundaries and involve the exterior environment, causing harm to natural and built systems as well as to the population. Although an event tree is not the only technical tool used in industrial risk analysis, or the most sophisticated, it can be viewed as the model conceptually underlying the whole process of scenario building. In fact any final accident, from the simplest to the toughest, results from a chain of minor, elementary failures which reverberate and amplify in complex systems, often in unexpected ways, because of the tightly coupled interconnections existing among systems and subsystems in particularly complex plants, like nuclear and chemical (Perrow, 1999).

What is extremely interesting in such analyses is that “top events” are not the linear, simple results of some mistake, a defective component or failure in an engine, rather it derives from a chain or cascade of failures where the human and technical components are often merged, overlap and contribute together to the dramatic outcome. In such a chain, the triggering physical factor initiating the chain as well as the many other failures that contribute to its creation do not entirely explain the accident. Rather the contribution of latent weaknesses in the system, either physical or human and organisational, are always essential. In other words, vulnerable elements in the systems are key factors in creating the accident, together with physical malfunctioning and sudden breaks.

Another interesting characteristic of industrial risk analysis which constitutes a link to other kinds of scenario models described above is the idea of an accident resulting from the combination of more than one individual event, thus opening the floor to multi-failure appraisal, something which is rather close to the concept of multi-hazard, intended as phenomena that may trigger one another under given circumstances.

What justifies the definition “risk analysis” is the fact that for each individual small failure and consequently to any large accident, there is an associated probability. Generally this probability is estimated as a conjoint probability, made up of the individual probabilities attached to each element of the chain. In other words, while most top accidents are (fortunately) too rare to provide a historic database on which to build expected frequencies (considering also the large variability of complex plants constituting each almost unique piece and the considerably fast evolution of technologies), the individual failures are much more common and therefore reliable statistical estimates do exist. Clearly though, the complex chain of events that must be imagined and the need to include human factors make those estimates rather questionable, or, rather, make it inevitable that a subjective rather than objective probability is assumed.

In analogy to what is generally done in industrial risk analysis, also in the field of natural hazards it has been proposed that the estimation of likelihood for each deterministic scenario could shorten the distance between PRA and scenario techniques (see Chang et al., 2000).

Design activities. Papanek (1997) defines design as “the conscious and intuitive effort to impose meaningful order”. Order in the environment, order in cities and settlements, order in the interiors of houses, factories and public facilities. Such a challenging activity has always required, more intuitively in the past, more consciously today, an effort to prolong into the future the vision of significant changes in the world: changes that may render obsolete the product that has been designed. Design in architecture, certainly in urban planning, has always been involved with some sort of “futurology”, posing relevant questions regarding how the place will look when the designed object or layout is realised, how people will use it, what the final cost will be and the ultimate benefits. In this sense, failure (see Fortune and Peters, 1995) is not to be intended only as the impossibility to fulfil the task or to implement the project, but also as more subtle outcomes, like the underuse of what was deemed to provide a mass service (Flyvbjerg, 2003), the extra costs that were not foreseen and challenge the cost-benefit analysis made at the beginning, and even changes in taste and preferences, which will make an outcome conceived only a few years early look unsatisfactory. Clearly the time span between the design phase and its actual realisation increases the risk of failure in the senses just described; nevertheless there are many examples of designs that proved to be time-resistant and manifest an extraordinary modernity even centuries after their conception (see for example the project conceived by Cerdà for the Ensanche in Barcelona in the 19th century). Architects and engineers have been always involved in the creation of the future, providing for many commonalities between the design activity and the development of scenarios. After all, both require a capacity to blend creative knowledge with the understanding of external processes that may lead to unexpected and/or undesirable outcomes.

Both require the capacity to select from past experience those elements that are particularly relevant for the problem at hand, reinterpreting them in the light of more recent advancements in science and technology. Architects more than engineers have been tempted in some historic periods to combine the design of the environment with the making of a specific societal model, embracing the "optimism" attitude that Rescher (1991) indicates for those who believe that the future can be crafted by human intervention.

5.2 Developing Scenarios to Depict Future Risks

Obviously it is not easy to depict future scenarios of risks in Europe; several aspects, factors and indicators should be blended together in order to achieve such a complex result. It might have been easier if scenarios were already available from past research. But little has been produced in this domain until recently, with the exception of the Espon project. Even though the latter clearly constitutes an important reference, for our purposes it seemed more useful to look more generally at scenario building efforts on the European scale and consider them as starting points to trace potential interesting paths to be explored by future research.

In the following section, a framework (Fig. 5.3) will be illustrated to explain more precisely how past scenario efforts were considered in the Scenario project.

Three levels of scenarios are represented. They are conceptually generated at different scales, even though they may be, in their turn, relevant at all scales. At the highest level, macro-scenarios have been identified: these are developed at the global scale, looking at the main drivers that are able, according to current understanding and imagination capacity, to significantly influence the

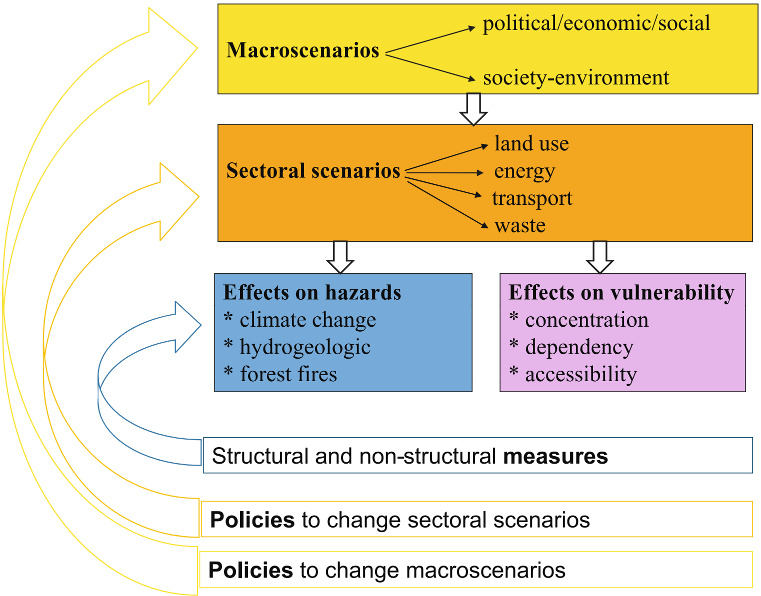


Fig. 5.3. Framework connecting different levels of scenarios

overall direction that humanity will take in the future, considering mainly political, social and technological aspects.

Those macro-scenarios consist of storytellings or storylines that have been developed by a multidisciplinary, multistakeholder team concerning possible futures unfolding in the global economy as a result of different political approaches and under pre-identified social and technological constraints. The relationship or the consequences of those unfolding behaviours and actions on the environment is considered only in some macro-scenarios.

Despite the many differences between the macro-scenarios that have been drawn in various studies (Gallopin and Raskin, 2002; IPCC, 2001), similarities can be found. Macro-scenarios can then be grouped into three main streams: baseline, market oriented and policy oriented. The first consists in the continuation of current policies and activities, in a world that does not undergo major changes from now on; present trends are then projected into the future.

The second is the result of free market driven mechanisms that generally exacerbate differences between the poor and the rich, and result in reduced solidarity and increased conflicts. The consequences for the environment may be very problematic, due to even stronger pressures than those experienced today.

In contrast, the third group includes stronger public governance, both national and international. imposes limitations to liberalism through legislation, international agreements, and voluntary and compulsory regulations. This macro-scenario results in a much more cooperative picture, with societies appreciating the benefits of the limitations to the totally free market economy, and providing a much more equal distribution of resources around the planet and within regions of the same state. The policy-oriented macro-scenario is clearly more beneficial for the environment in that pressures are reduced and a path towards sustainability designed and pursued.

Of course these are very rough representations of proposed scenarios, which provide also intermediate situations, in which the “free market world” attempts to reduce the impacts on the environment and mitigate the negative consequences of exaggerated extraction and abuse of resources. Other variations are proposed also at the other end, in a more compromise-oriented version of the relationship between public control and free market.

Within the Espon project (see project 3.2 in particular), three main macro-scenarios have been taken as the basis for projecting territorial developments: baseline, competitive and cohesive. They reflect the fundamental philosophy outlined above, putting strong emphasis on the influence European policies may exercise.

Those very general macro-scenarios are relevant for us only as far as they trigger consequences for the second-level scenarios, which have been labelled as “sectoral” in the framework. The latter are more directly connected to issues of risks, hazards and vulnerability.

Among the sectoral scenarios that can be found in the literature, four main categories have been mostly developed, also considering the rather wide and complete list provided by the EEA in one of its reports (EEA, 2007), which are as follows:

- Energy scenarios, depicting how energy will be produced, what will be the main sources, the leading technologies, the consequences on the environment and the economic costs. An eminent example of this category is provided by Shell 2050[1]
- Waste generation, recycling, final destination
- Transportation and infrastructures, meaning not only the modes of transport that will be preferred in the future, but also how projects designed for European train and highways networks are considered
- Land use, consisting of projections of land use changes in the future in Europe.

Those sectoral scenarios are relevant for their consequences on hazards and vulnerability.

With respect to hazards, all of them have direct or indirect consequences on climate change, which will be thoroughly discussed in Section 5.3. Climate change in its turn may influence the future of some risks, like forest fires and hydrogeological risks. It should be noted though that the latter may be also directly influenced by changes in land uses and transportation.

[1] See http://www.shell.com/home/content/aboutshell/our_strategy/shell_global_scenarios/dir_global_scenarios_07112006.html

The consequences of sectoral scenarios on vulnerability scenarios are even more evident when key categories like interdependence, concentration and accessibility factors addressed by several vulnerability indicators are considered.

Somehow, in between vulnerabilities and hazards, na-tech must be located, as they represent technological hazards originating in vulnerable systems and triggered by natural extremes.

In order to complete the framework, also the policies aimed at changing the potential "spontaneous", "without any intervention" scenario development must be considered. Again three families of interventions have been depicted: the larger one consists mainly of international policies, agreements and protocols. In the Espon project, the capacity of the European Union to mark a difference with individual countries and to set environmental, spatial and social common policies shared by member states defines the line demarcating the three identified scenarios.

At the second level, strategies aimed at changing the unwanted spontaneous unfolding of sectoral scenarios consist of, for example, land use regulations, and decisions concerning both the location and the process of development of critical infrastructures. Those strategies have also been indicated as having a direct impact on given risks. It may be suggested that non-structural, long-term mitigation measures, as defined in Chapter 4, are generally mainly oriented at producing an impact on categories like land use and infrastructure locations.

At the third level, long- and short-term measures, structural and non-structural have a direct impact on the potential evolution of hazards and vulnerabilities in the future. Here local projects aimed at reducing the severity and/or frequency of some hazards (hydrogeological for example) on the one hand, and the improvement of early warning systems on the other, can be mentioned as examples of, respectively, structural long-term measures and non-structural short-term measures. On the other hand, the introduction of insurance to protect from the loss of properties against natural hazards in the European Union can be considered as a long-term, non-structural measures. The latter though can be also considered in conjunction with policies aimed at implementing mitigation through correct land uses in dangerous zones.

There are some general problems that must be highlighted before moving towards a more detailed discussion of scenarios selected within our project.

The first refers to the overall framework as presented here: few if any attempts to follow the entire chain of "scenarios types" finalising with consequences in terms of hazards and vulnerability have been produced. This is rather comprehensible: there are already so many uncertainties and difficulties implied in each scenario setting, that combining more at different levels implies clearly even larger challenges. Nevertheless, as scenarios are a tool to unfold and make manifest uncertainties, such efforts should be considered at least to point out where our major comprehension deficiencies lie.

Some problems are due to the fact that for any component of those scenarios (like demography, economic development, land use, transportation, etc.) double, triple and even more entrances are possible in the chain: direct and indirect links among them arise at all levels, and efforts to make loops linear are generally ineffective.

Furthermore, it should be borne in mind that not necessarily everything is connected: there are many interrupted chains as well, with components potentially developing and changing also independently from each other. Therefore the chain must be followed as far as consequential effects can be foreseen, but also partially independent unfolding variables should be contemplated.

A second set of difficulties has been identified in downscaling problems: in the case of global scenarios, it is very difficult to move from global forecasts to specific consequences at the national not to mention the regional level. In the case of sectoral scenarios the same can be said for those that are designed for the global level; for those designed at regional level, the problem is both downscaling at lower level as well as reporting to the global one. Risk scenarios vary in the way they are designed, generally following the scale at which the feared phenomena is studied. In this case, downscaling or reporting to higher levels of concern is again the problem.

A third set of obstacles arises in the attempt to include weak and early signals, which may consistently change the overall trajectory of the entire scenario; this is due to the difficulties in separating changes from constant elements, which will remain unvaried until the pre-identified future materialises.

The above-mentioned constraints, including the intrinsic psychological ones related to any attempt to look into the future, explain why most scenarios are rather projecting trends from the past and the present into the future and only rarely imaginative jumps into a future of surprises and unknown.

Considering the discussed complexities, it has been decided to refer to the SRES scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) in the context of the Scenario project. Those scenarios serve as a reference for depicting likely futures of risk in Europe, considering as a time horizon the year 2050, at least for vulnerability and exposure aspects (as SRES have made projections until 2100).

We are not able to trace changes in all the aspects that contributed to define the present situation in Europe as far as natural risks and already detectable consequences of climate change are concerned, as was done in Chapter 2. A selected number of issues will be considered instead. On the one hand scenarios of climate change for Europe will be outlined, including the potential consequences of other hazards, like floods or forest fires. On the other hand, with respect to exposure and vulnerability, three main areas of concern will be investigated: changes in population patterns; land use practices with particular regard to urban sprawl, and critical infrastructures. Changes in those sectors will be assessed as far as the implications in terms of response capability to hazards are concerned.

5.2.1 Macro-Scenarios and Scenarios Developed in the Context of the Intergovernmental Panel on Climate Change (IPCC)

In 1992 the IPCC published six alternative development scenarios for greenhouse gas emissions (the so-called IS92a–f scenarios; see Leggett et al. 1992). They are mainly based on business as usual assumptions and do not include any kind of climate policies. The different worlds that the scenarios imply, in terms of economic, social and environmental conditions, vary widely and the resulting range of possible greenhouse gas futures spans almost one order of magnitude. The assumptions for the IS92 scenarios came mostly from the published forecasts of major international organisations or from published expert analyses. Although the IS92 scenarios were path-breaking (they were the first global scenarios to provide estimates of the full suite of greenhouse gases), much has changed in the period following the creation of the IS92 scenarios. For example, sulphur emissions have been recognised as an important radiative forcing factor and some regional control policies have been adopted. Restructuring in the states of Eastern Europe and the former Soviet Union has had far more powerful effects on economic activity and emissions than was foreseen in the IS92 scenarios. Further, the advent of integrated assessment (IA) models has made it possible to construct self-consistent emissions scenarios that jointly consider the interactions between energy, economy and land-use changes. Thus, the so-called SRES scenarios were developed. In the year 2000 the IPCC published a new set of scenarios for the Third Assessment Report (often mentioned as IPCC-SRES scenarios, IPCC, 2000). The SRES scenarios were developed between 1996 and 1999 and were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. They are based on the following three essentials:

- *Storyline*: a narrative description of a scenario (or a family of scenarios), highlighting the main scenario characteristics and dynamics, and the relationships between key driving forces
- *Scenario*: projections of a potential future, based on a clear logic and a quantified storyline
- *Scenario family*: one or more scenarios that have the same demographic, politico-societal, economic and technological storyline.

The SRES team defined four narrative storylines (see Fig. 5.4), labelled A1, A2, B1 and B2, describing the relationships between the forces driving greenhouse gas and aerosol emissions and their evolution during the 21st century for large world regions and globally. Each storyline represents different demographic, social, economic, technological and environmental developments that diverge in increasingly irreversible ways.

In simple terms, the four storylines combine two sets of divergent tendencies: one set varies between strong economic values and strong environmental values, the other set between increasing globalisation and increasing regionalisation (IPCC, 2000):

- **A1:** A future world of very rapid economic growth and successful economic development in which regional average incomes per capita converge and current distinctions between "poor" and "rich" countries could be dissolved; global population that peaks in mid-century and declines thereafter; rapid introduction of new and more efficient technologies; international mobility of people, ideas and technology.
- **A2:** A very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines. The A2 world "consolidates" into a series of economic regions. There is less emphasis on economic, social and cultural interactions between regions. Economic growth is uneven and the income gap between now-industrialised and developing parts of the world does not narrow.
- **B1:** A convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures towards a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies, i.e. environmental and social consciousness combined with a globally coherent approach to a more sustainable development.
- **B2:** A world in which the emphasis is on local solutions to economic, social and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development. International institutions decline in importance, with a shift toward local and regional decision-making structures and institutions. Human welfare, equality and environmental protection all have high priority, and they are addressed through community-based social solutions in addition to technical solutions, although implementation rates vary across regions.

The basic features of the four storylines include quantitative projections of major driving variables such as population and economic development taken from reputable international sources (e.g. United Nations, World Bank and IIASA, etc.; for details cf. SRES report, IPCC 2000). After determining them for each of the four storylines, the SRES team began to model and quantify them by the help of six so-called integrated assessment models (e.g. AIM, IMAGE or MARIA). This resulted in 40 scenarios, each constituting an alternative interpretation and quantification of a storyline. All the interpretations and quantifications associated with a single storyline are called a scenario "family" (cf. Fig. 5.4).

In the schematic illustration of the SRES scenarios (Fig. 5.4), four qualitative storylines yield four sets of scenarios called "families": A1, A2, B1 and B2. The set of scenarios consists of six scenario groups drawn from the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterising alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced) and A1T (predominantly non-fossil fuel). Within each family and group of scenarios, some of them have "harmonised"

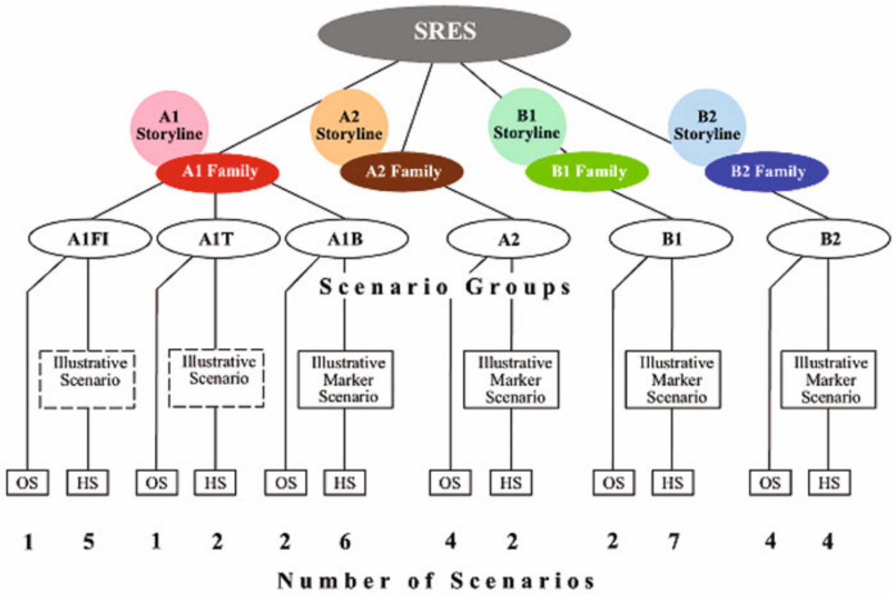


Fig. 5.4. Schematic illustration of SRES scenarios (IPCC SRES, 2000)

driving forces and share the same pre-specified population and gross world product. These are marked as "HS" for harmonised scenarios. "OS" denotes scenarios that explore uncertainties in driving forces beyond those of the harmonised scenarios. The number of scenarios developed within each category is shown (taken from IPCC SRES, 2000).

Several attempts have been made to evaluate the existing SRES storylines and if necessary to update some of these forcing scenarios (cf. e.g. van Vuuren and O'Neill, 2006). None of the scenarios can have an unlimited lifetime and additionally several researchers have claimed that the SRES approach is already off-track with respect to historical emission trends. Therefore new scenarios are under development and will be included in the AR5[2] (planned for 2014).

Nevertheless the SRES storylines are currently state of the art input in terms of GHG forcing for climate modelling purposes (they are translated into emission trajectories). For 23 global circulation models they are used as input. This allows comparison of the results for the future climate (e.g. temperature trajectories, etc.) for the same forcing scenario, e.g. B1 or A2, and different climate models. For this goal the IPCC has established the coupled model intercomparison project (CMIP; http://www-pcmdi.llnl.gov/projects/cmip/index.php), where the outputs of the different model runs based on the certain reference scenarios are accessible to the public.

[2] Fifth assessment report of the IPCC.

5.3 Futures of Climate Change

Climate scenarios are plausible representations of the future that are consistent with assumptions about future emissions of greenhouse gases and other pollutants and with our understanding of the effect of increased atmospheric concentrations of these gases on global climate. It is important to emphasise that climate scenarios are not predictions, like weather forecasts are. Scenarios are projections showing how climate might evolve when humankind develops in the directions described in the storylines.

In order to make clear the space of potential climate developments the Scenario project team decided to use the B1/A2 storylines as input forcing. This makes room for possible developments of the earth's climate. The B1 storyline in particular represents a more sustainable development that is compatible with the 2°C target, while A2 represents a more fragmented world with remaining North–South welfare gaps and an increasing population (cf. Fig. 5.5). The increase of temperature over the continent is significant in both scenarios, but with different intensity. The analysis of seasonal changes reveals that in summer the temperature increase in the Mediterranean is even larger. As shown in Fig. 5.6 also the annual sum of precipitation will undergo significant changes in some regions.

To date the assessment of potential impacts of climate change relies mainly on projections of Atmospheric-Ocean General Circulation Models (AOGCM or short GCM). Climate scenarios are based on the runs of these GCMs. However, for the majority of regional impact assessments, which address questions relevant for decision makers, their resolution is too coarse.

Examples for downscaling techniques are, e.g. weather generators and weather typing strategies, which are specifically used to provide typical future precipitation patterns. In general downscaling techniques involve statistical methods for data interpolation or local climate models. While the ability to include the orographic variability in such strategies may be improved, the accuracy of these regional climate scenarios depend on the (largely unknown) accuracy of the underlying GCM, the suitability of the statistical method used and the accuracy of representation of specific regional settings in the local climate models. The two main strategies used to provide regional climate change scenarios are model nesting (dynamical) and regression-based (statistical) downscaling.

By applying the so-called dynamical downscaling methods, the output of a GCM is fed into the regional climate model (RCM) and is used as a forcing element. Here some physical processes and orographic features must be represented explicitly, therefore these methods are computer-intensive. Local models are nested into GCMs, because their coarse resolution precludes the simulation of realistic extreme events and the detailed spatial structure of variables like temperature and precipitation over heterogeneous surfaces e.g. the Alps, the Mediterranean or Scandinavia.

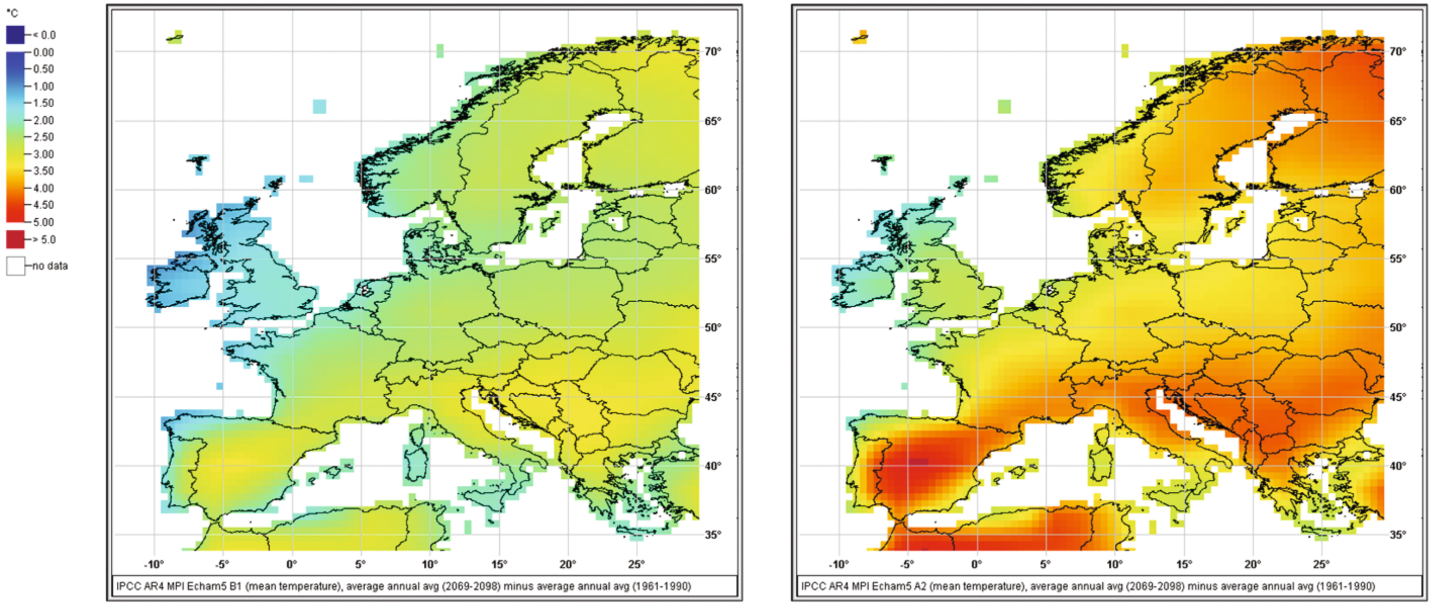


Fig. 5.5. Difference maps for the annual mean temperature for the reference period 1961–1990 and the end of the 21st century (2069–2098) based on AR4 runs performed by the ECHAM5 model (Roeckner et al. 2003) (downscaled to $0.5° \times 0.5°$) for the B1 forcing (left) and the A2 forcing (right)

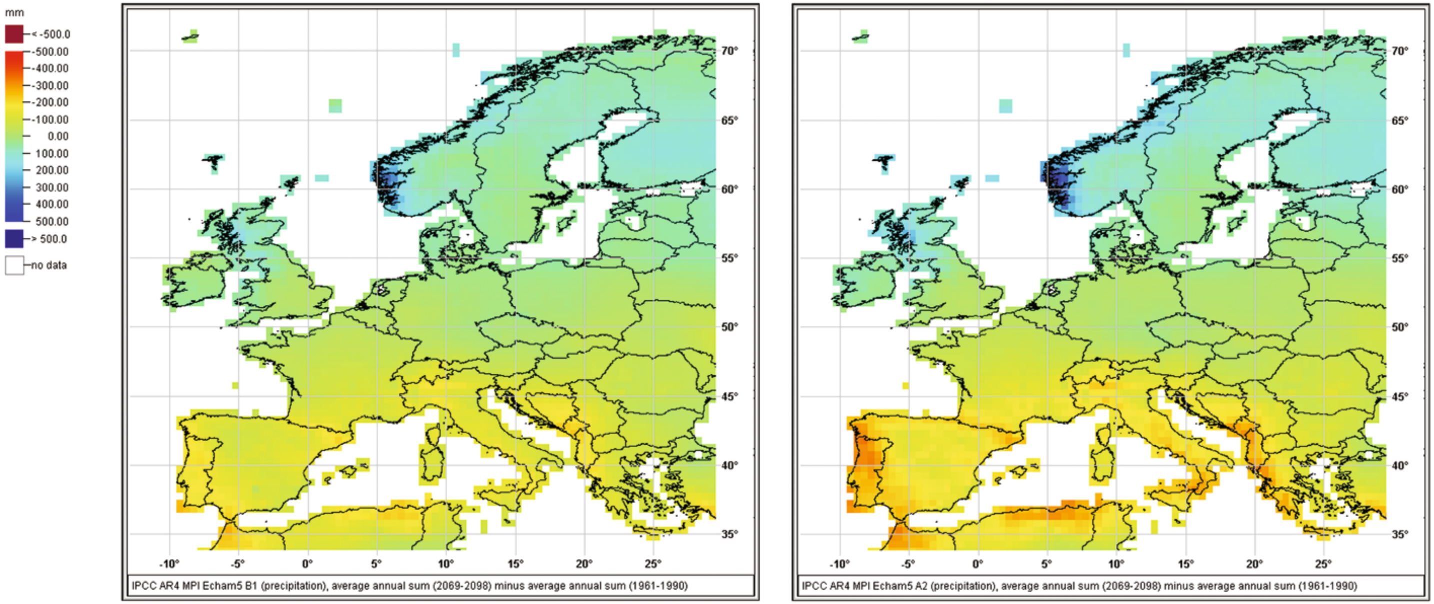


Fig. 5.6. Difference maps for the average annual sum of precipitation for the reference period 1961–1990 end of the 21st century (2069–2098) based on AR4 runs with the ECHAM5 model (Roeckner et al. 2003) (downscaled to $0.5° \times 0.5°$) for the B1 forcing (left) and A2 forcing (right)

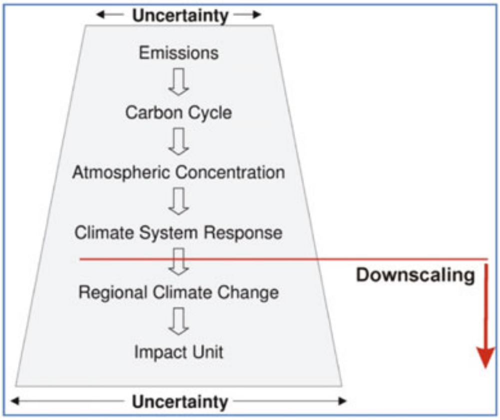


Fig. 5.7. Schematic representation of uncertainty propagation. Note that the largest uncertainty is located on the emissions side (forcing), since humanity itself decides on the future development. The total uncertainty (illustrated by the grey panel, not to scale) expands as individual uncertainties are combined (adapted from New and Hulme (2000))

Statistical downscaling is mostly based on empirical relationships between local-scale variables and their large-scale predictors. These relationships can be based on a range of mathematical functions and fitting routines (cf. Wilby et al., 2002, for an overview). Advantages of such methods are their computational efficiency, the possibility to apply them simply to several GCMs and the ease of use by communities behind the climate modelling community. Thus, this method is fast and easy. A significant disadvantage derives from the fact that most of the modelled relationships are assumed constant in the future, because here output is analysed and the influencing processes are regarded as black box. Further, not all feedback mechanisms may be integrated and there is a lack of systematic evaluation.

In Fig. 5.7, the raw GCM output is compared to the results of the two downscaling methods. It is shown that the general trend is not changing, even if we are focussing on regions. Nevertheless, the intensity of change may differ. For further details cf. Murphy (2000).

Models are only an approximation to reality. GCMs, in particular, are dealing with averages for the spatial resolution as well as with respect to time. Therefore climate change scenarios are not yet suitable to be used for prognoses of weather extremes.

Climate models can support decision-making, but they have uncertainties relating to the techniques used (statistical/dynamical). Further, a climate model ensemble opens only the space of possible developments, which in particular depend on political decisions which are taken now (e.g. the amount of current forcing, cf. above). Regarding how extremes are perceived by decision makers, the situation is even more complex. First, climate extremes are not weather extremes. Decision-makers are generally more interested in weather extremes. Second, extremes are also a matter of definition, since society partly decides what is an extreme event and what is not. Finally, quantitative estimates of changes of extremes depend on, to some extent, subjective assumptions because of lack of data or process knowledge. For example, it may be difficult to separate trends and natural variability when we analyse time series (Bunde et al., 2002; Kallache et al., 2005). Moreover, time series look into the past, and any kind of probabilistic extreme value assessment more or less assumes that the future behaves like the past. This assumptions is crucial when we discuss climate change. Nevertheless, several improvements of statistical methods are possible (cf. Kropp and Schellnhuber, 2011)

During the preparation of the IPCC reports 23 global circulation models were compared, i.e. they were run under similar starting and forcing conditions. Even though some progress has been made recently, it is difficult to quantitatively estimate the overall uncertainty, which increases in downscaling from the global to the local scale.

However, the overall message of climate modelling efforts is clear: temperature will increase, precipitation will show a tendency to more heavy rain (but parallel to changes in seasonality), etc. Since it is impossible to provide exact estimates for the future developments (limits of prediction), the only strategy is to develop a bunch of (policy) options allowing a "safe landing", or in other words an adaptation (sustainable mitigation). This is indeed a scientific challenge and needs some focus on regional impact studies (see Chapter 6).

The IPCC (2007a) has provided maps showing how large the coincidence of the model results regarding the mean warming and precipitation trends is. Further, spatially agreements are also supplied. The maps indicate areas of high coincidence and these areas are associated with qualitative probabilities. Nevertheless, there are areas where the agreement among models is low. This does not imply that these regions are at safe limits, i.e. in the sense that nothing will happen (Fig. 5.7). The differences between the model results only indicate that the direction of change is not clear yet; it might be positive or negative.

Given the described uncertainties, it is necessary to understand how a framework to tackle dynamical hazards must be designed in order to support decision makers. Here the Scenario project suggests a concept which is based on three dimensions:

- shared knowledge about impact and adaptation studies
- qualitative and quantitative risk assessments
- integration of multidimensional facets of the problems in order to make clear the natural and socioeconomic dimensions of the problem.

5.3.1 Climate Change-Related Hazards

Heatwaves

Increasing temperatures might be an important threat for the future. Nevertheless, extreme temperatures alone are only one side of the coin, since high temperatures are often associated with less precipitation. Normally the demand for water increases during episodes of hot weather. In the 21st century this will be an important problem, in particular for the Mediterranean regions. Competing interests, e.g. between farmers, power plant owners and water intensive tourism, may cause a reduced water supply in several southern European regions (e.g. Iberian peninsula, Balkan).

Our current knowledge regarding extreme weather and what could happen in the future is based on statistical examinations of empirical time series data and scenario runs obtained from climate models. There are a few regions and climate variables, however, where regional and global changes in weather and climate extremes have been reasonably well documented. Yan et al. (2002) found for several European and Chinese stations a decrease of cold extremes since the late 19th century and increasing warm extremes since 1961. A detailed analysis by Alexander et al. (2006) shows for over 70% of the land surface an increase in the annual occurrence of warm nights, implying a significant shift in daily minimum temperatures in the 20th century. The same trend holds for the daily maximum values, but with smaller magnitudes. Previous analyses indicate that this warming trend has been occurring since the early 1900s (Klein Tank et al., 2006). Eleven of the last twelve years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature (IPCC, 2007a). The 100-yr linear trend for the global mean (1906–2005) of 0.74°C is larger than the corresponding trend for 1901–2000 given in the third assessment report of 0.6°C (IPCC, 2001). The warming trend over the last 50 years (0.13°C per decade) is nearly twice as high as that for the last 100 years (IPCC, 2007a).

A good impression of the things to come are comparisons of empirical measures and model runs (e.g. Beniston, 2004; Rebetez et al., 2006). Here, for example, the summer of 2003 in Europe is a good indicator (cf. Fig. 5.8). It was the hottest summer in Europe since 1500 (Luterbacher et al., 2004). Beniston (2004) examined station measurements and results from local model runs (A2 forcing) and found that for, e.g. the city of Basle/Switzerland, the summer of 2003 was an event which may happen again in the period comprised between 2071 and 2099 every year. He further mentions an asymmetric shift for some regions (e.g. Western France), i.e. the average increase of daily maximum temperatures of approx. 5°C was associated by 6–8°C in the upper extremes. Situations regarded as extreme in 2003 (Rebetez et al., 2006, Fig. 5.9) might become the rule by 2050 and beyond. The fourth assessment report of the IPCC (2007a) makes clear what we can expect in the next century. For the next two decades a warming of about 0.2°C per decade is projected for a range of anthropogenic forcing (emission) scenarios.

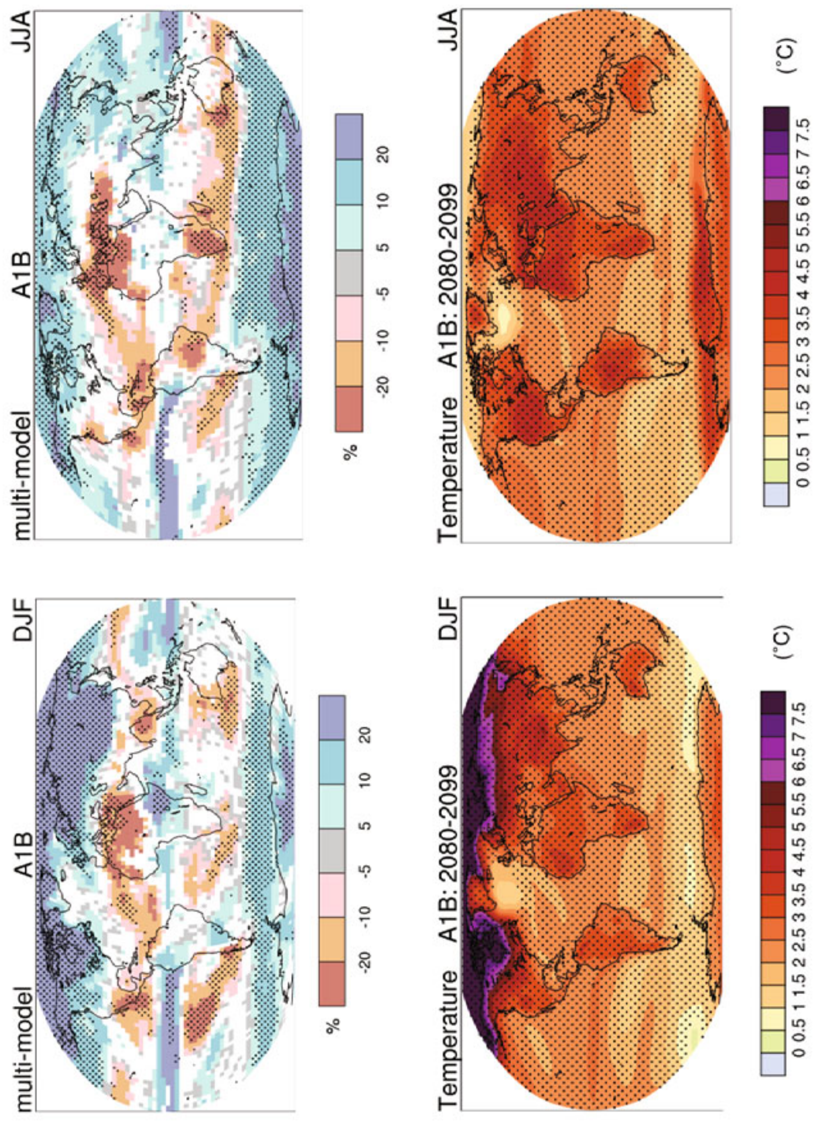


Fig. 5.8. Multi-model comparison for the A1B forcing scenario, which lies in between the B1 and A2 scenario (cf. above). Upper panel: Relative to 1980–1999 changes in precipitation (in percent) for the period 2090–2099. The values are multi-model averages for December to February (left) and June to August (right). White areas indicate where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. Lower panel: Multi-model mean changes in surface air temperature (°C) for the period 2080–2099 relative to 1980–1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation (IPCC, 2007a)

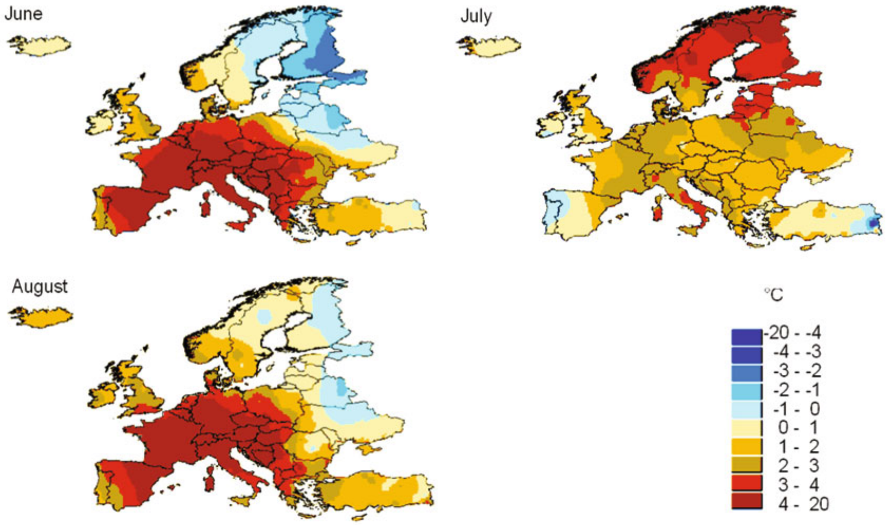


Fig. 5.9. Empirical monthly maximum air temperature anomalies (deviations from 1961–1990) over Europe during the summer 2003 (from Rebetez et al., 2006)

Even if concentrations of all GHGs and aerosols are kept constant at the year 2000 level, a further warming of about 0.1°C per decade is unavoidable. For the A2 storyline the likely range of temperature increase in the global mean temperature will be 2.0–5.4°C, but the regional differences may be even larger. As a likely example we have analysed the maximum and minimum temperatures (monthly means) for Europe at the beginning and the end of this century (Fig. 5.10).

Bättig et al. (2007) have tried to estimate the occurrence of additional extreme years at the end of the century, suggesting that for a 20-yr period up to 19 yrs will be characterised by extreme warm summers. Diffenbaugh et al. (2007) show that for the Mediterranean regions heatwaves in the future, in particular in larger cities, will approach uncomfortable living conditions. This will hold even if we are successful in reducing or stabilising greenhouse gas emissions.

Sea-level Rise

The question of how much sea level will rise during the next 100 years is broadly discussed in science and in the media. In particular for stakeholders this issue is important, as they have responsibility for safe environmental conditions for populations in coastal zones. It is estimated that approx. 200 million people live in coastal floodplains, and two million square kilometers of land and one trillion dollars worth of assets lie less than 1 m above current sea level. A detailed literature review showed that after publishing

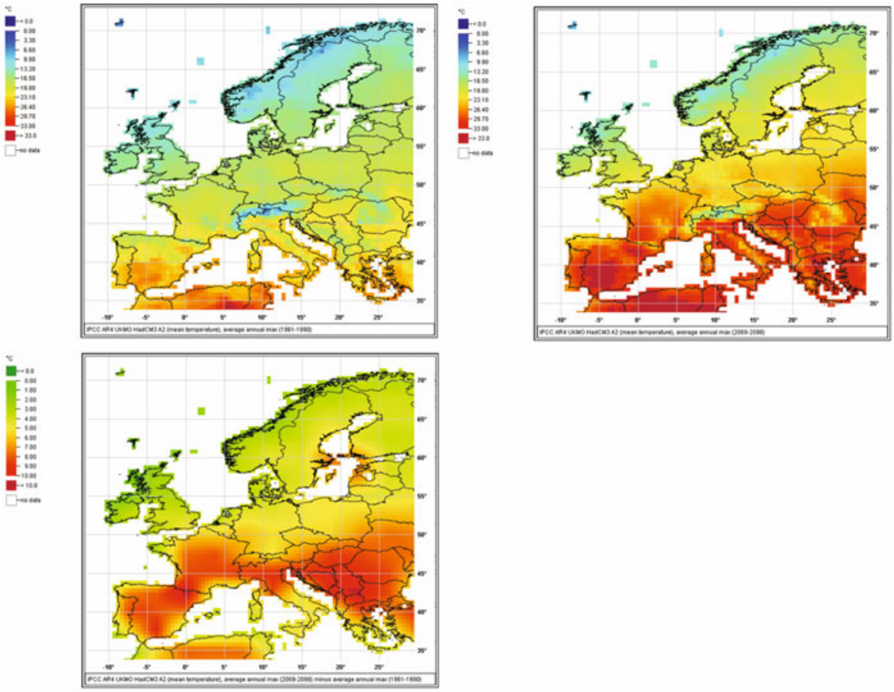


Fig. 5.10. Average annual maximum temperatures 1961–1990 (upper left), projected average annual maximum temperature 2069–2098 (upper right), and the difference map for both maps (AR4, HadCM3 model, A2 forcing, cf. Gordon et al., 2000)

of the recent IPCC (2007a) report, additional, newer information indicates that sea-level rise estimates could be too low. Rahmstorf (2007) estimated that sea-level rise could approach more than 1 m by 2100. In a new work, Vermeer and Rahmstorf (2009) presented a reasonable approximation of the future sea-level response to global warming. For a given emission scenario, sea level will rise approximately three times as much by 2100 as the projections (excluding rapid ice flow dynamics) of the IPCC (2007a) have suggested. Even for the lowest emission scenario (B1), sea-level rise is then likely to be 1 m; for the highest, it may even come closer to 2 m. However, due to gravitational effects, sea-level rise is not uniformly distributed. When discussing sea-level rise, two climate-related components have to be considered: first, the so-called eustatic sea-level rise, which considers the mass of water in the oceans, mainly driven by melting ice masses on land and surface run-off from land; second, the steric component, which considers the thermal expansion of water due to a warming stimulus. While the ocean is warming, its density and volume increase as the mass keeps constant. Due to the high heat capacity of surface waters, the propagation of a warming stimulus to deeper layers is delayed. This implies that one can try to estimate a sea-level response time following a shift in temperature, which amounts to 2900 yrs (Siddall et al. 2009). Hansen et al. (2007) estimated this response time to be 2500yrs using sea-level rise data of the recent Holocene (10 kyr1 kyr BP). Grinsted et al. (2009) stated that the response time which applies today, however, may be very different from that which governed sea level rise throughout most of the Holocene. They conclude that data obtained from sea-level rise during the last interglacial excludes response times of oceans longer than about 1500 years. In contrast, Grinsted et al. (2009) state that the consideration of paleo-temperature reconstructions by which present-day sea-level rise is dominated, a 200–300 year response time can be derived. However, despite the ongoing debate on the response time, SLR will be a problem for centuries and cannot be halted, in particular when a warming stimulus is introduced into the system. Figure 5.11 shows these general effects, since the long response time of the oceans on a warming impact has protected humankind from more drastic effects so far. Nevertheless, the German Advisory Council on Global Change to the Federal Government expects, due to recent alarming results, that sea level can rise by up to 25 m by 2300 (WBGU, 2006). On the mid-term timescale this might be threatening, since it is necessary to adapt to sea-level rise for areas of low-lying land with subsiding coasts (IPCC, 2007; Nicholls and Cavenaze 2010). Sea-level rise will cause at least a loss of 20% of coastal wetlands and (together with an increase in storminess) migration from coasts to inland areas. The IPCC (2007) estimates that coastal flooding related to increasing storminess and sea-level rise is likely to threaten up to 1.6 million additional people annually. This will affect coastline industries and infrastructure. McGranahan et al. (2007) estimate that already today approximately 634 million people worldwide live below a height of 10 m and further urbanization will also proceed in coastal areas. This underlines the importance of this future problem. The benefit of coastal adaptation versus non-adaptation is presented in the next chapter.

Salinisation and Climate Change

Many areas face increasing soil salinity as a major problem, in particular those already suffering from water scarcity. Increased salinity can have direct toxic effects on both plants and animals, reduce reproduction and growth rates, and limit the geographical range of species. In several areas of the world soil salinity has been considered as a major constraint to foodgrain production, for example. It is believed that the impact of climate change in combination with the effect of sea-level rise will cause a net increase in salinity in already affected soils in the coastal regions. Wetlands, as low areas in the landscape, are particularly vulnerable to increased salinity levels through the direct effects of high water tables due to sea-level rise. Another important threat is the salinization of freshwater sources, which is already today a problem in overexploited coastal aquifers. Future sea-level rise will increase the pressure on freshwater aquifers by inducing seawater intrusion (Priyantha

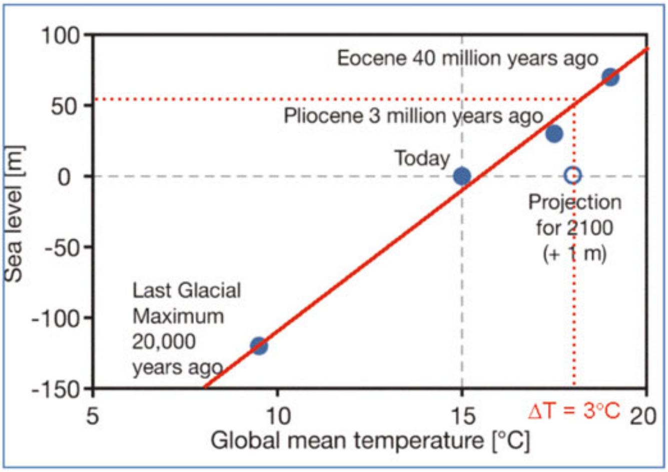


Fig. 5.11. This graph shows the potential impact of an increase of about 3°C of the global mean temperature by the end of this century, when assuming an equilibrium for the ocean-atmosphere system. In this case an increase of sea-level of approximately more than 50 m will be likely, which nevertheless is a process on very long timescales. For the end of the 21st century approximately 1m rise will be likely (modified from Archer (2006))

Ranjan et al., 2006a, 2006b). In several regions of the world parallel exploitation of these aquifers by humankind has already led to severe water scarcity. It is anticipated that this process will accelerate when sea level rises.

Potential Consequences for Ecosystems, Biodiversity and Human Health

In general climate change will have an impact on biodiversity, but it acts on longer timescales. An ecological disruption caused by climate change is slower than that currently caused by humankind, e.g. by habitat destruction and fragmentation or changes in land use (cf. Fig. 5.12). For 2050 and beyond climate change nevertheless can become the most important factor. Then the shift of climatic borders will be fundamental. It is estimated that each increase of 1°C will move ecological zones about 160 km. In case temperature increase reaches approximately 3–4°C by the end of the 21st century, a shift of climate zones of approx. 500 km may be likely. Some of these trends are well documented, e.g. for several terrestrial plants a shift of approximately 6 km per decade has been observed in the Northern Hemisphere (cf. Thuiller, 2007). Changed climate regimes also cause an upward shift of species that traditionally inhabit lower elevations. Plant diversity of some high-elevation peaks in Switzerland, for example, increased over the past 100 years, which indicates this effect (cf. Rebetez, 2006).

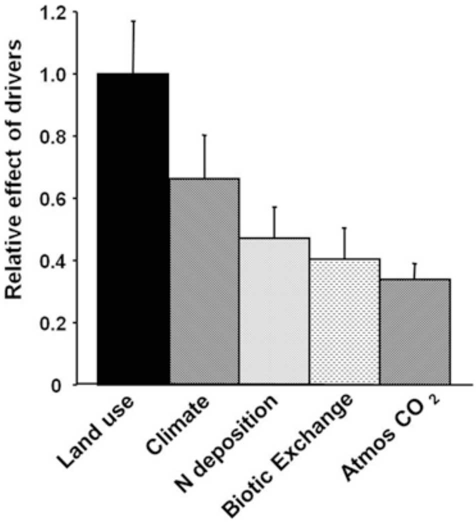


Fig. 5.12. The main drivers affecting biodiversity. This summary of the relative effects by the year 2100 is a composite derived from calculations carried out for 12 individual terrestrial and freshwater ecosystems by Sala et al. (2000)

In principle all ecosystems will be affected by climate change, but regionally the impact might be different. Not only are changes in biodiversity anticipated, but reduced soil moisture in dry seasons or an increase in fire risk and water scarcity due to extreme heat events. This will also have an impact on various agricultural sectors. Systematic analyses of the 2003 heatwave show that the vegetation growth across Europe was reduced during the dry and hot summer in an unprecedented way by about 30%. Further, it was found that ecosystems absorbed less carbon dioxide from the atmosphere or even released it (Ciais et al., 2005). The situation for forests was similar (e.g. Breda et al., 2006). Regarding crop yields, the impact of very high temperatures for a few days versus the above average summer temperatures is unclear. But it is well documented that extreme high – as well as extreme low – temperatures at key development stages inhibit crop growth. Furthermore, land-use change may cause a decrease of pollinators, on which 35% of t world crop production depends (cf. Klein et al., 2007). Nevertheless crop yield is projected to increase (1–3%) slightly for mid-latitudes (IPCC, 2007b). Livestock, such as pigs and poultry, are also severely impacted by heatwaves. Overall 20–30% of plant and animal species assessed so far are likely to be at increased risk of extinction if global average temperature rise exceeds 1.5–2.5°C (IPCC, 2007b). Several (agro)-ecosystems will have problems adapting to climate change.

Climate change is a significant and emerging threat to public health. In its fourth assessment report the Intergovernmental Panel on Climate Change highlighted a wide range of implications for human health. Climate variability and change may cause death and disease through natural disasters, such as heatwaves, floods and droughts. Moreover, many important diseases are highly sensitive to changing temperatures and precipitation. These include common vector-borne diseases[3] such as malaria and dengue; as well as other major killers such as malnutrition and diarrhoea. The spatial distribution of these threats is very different. Furthermore, in European countries the public health systems are often strong enough to cope with adverse climate effects on human health. Nevertheless, and although climate change is a long-term process, there is a lot of evidence that already now extreme weather events have caused human health impacts. For example, extreme high temperatures can directly cause the loss of life, as shown in 1995 in Chicago (700 heat-related deaths, cf. Klinenberg, 2002) or in 2003 in France (approx. 14,000 heat-related deaths). They cause deaths from heart disease and strokes, in particular among the elderly. People suffering from heart problems are especially vulnerable, because their cardiovascular system must work harder to keep the body cool during hot weather. Hot weather can cause also dehydration and heat exhaustion (Kovats and Jendritzky, 2006). Urban areas are especially risk-prone, since due to a lower evaporative cooling and increased heat storage average temperatures can be 5–11°C warmer than in surrounding rural areas (this effect is known as urban heat island, cf. e.g. Aniello et al., 1995). Hot temperatures increase air pollution, e.g. the concentration of ground-level ozone. While the ozone in the upper atmosphere blocks harmful UV radiation, the ozone in the lower atmosphere is a pollutant. Its concentration is related to fuel combustion which provides photochemical oxidants, increasing ground-level ozone concentration. Ozone damages the lung tissue and causes particular problems for people with, e.g. asthma. Global warming may also increase the risk of infectious diseases, since a northward spreading of so-called vector-borne diseases has already been observed. This holds for, amongst others, malaria and encephalitis. The impact of El Nino events on an increase of malaria cases in Southern America is well documented (Hasselmann, 2002). While this disease is mainly confined to the tropics, we have seen a clear northward shift during recent decades for encephalitis. This was mainly because the increase in temperature creates better conditions for tick-borne encephalitis (Materna et al., 2005). Extreme cold temperatures may also cause serious consequences. Similar to heatwaves, an increase of mortalities may be due to respiratory illness, age and social conditions (Ballester et al., 2003). Hypothermia, for example, as a result of inadequate dwellings or influenza epidemics related to inadequate public health systems may cause an additional death toll in cold episodes. Several authors report that winter mortality is higher than that induced by extreme hot weather (cf. Healy, 2003), but this may change in the future. To conclude, these risks are not inevitable consequences, since adaptation in

[3] A vector-borne disease is one in which the pathogenic microorganism is transmitted from an infected individual to another individual by an arthropod, such as ticks or mosquitoes.

Europe is possible. Heat-related deaths can be prevented, e.g. by guaranteeing that vulnerable people can stay in cooler environments, by wearing light and comfortable clothing and by keeping hydrated. The cold-related death toll can be decreased by improving social conditions. Many of the impacts of extremes in Europe on health could be avoided through the maintenance of strong public health. Others are difficult to control, like the earlier onset and extension of the season for allergenic pollen (Huynen and Menne, 2003).

5.3.2 Potential Influence of Cimate Change on Natural Hazards

Climate Change and Meteorological Hazards: Tornadoes and Effects on Global Lightning Activity

Observational evidence for changes in small-scale severe weather phenomena (such as hail and thunderstorms) is mostly local and too scattered to draw general conclusions up to now. The largest experience regarding the phenomena of tornadoes, their frequency and magnitude, and possible correlations between that and climate comes from North America. In many European countries, the number of tornado reports has increased considerably over the last decade (Snow, 2003), leading to a much higher estimate of tornado activity (Dotzek, 2003). It is likely that this increase in reports in Europe is at least dominated (if not solely caused) by enhanced detection and reporting efficiency (IPCC, 2007a). A future way to associate the occurrence of tornadoes to climate change may be to link severe thunderstorm occurrence to larger-scale environmental conditions in places where the observations of events are fairly good and then consider the changes in the distribution of those environments (Brooks et al., 2003; Bissolli et al., 2007). Nevertheless there are no clear indications regarding climate change and its effect on tornado activity yet.

The relationship between global warming and global lightning activity is complex. There is evidence that the variability of global lightning activity is closely related to surface temperatures, tropical deep convection, rainfall, upper tropospheric water vapour and other important parameters that also affect the global climate system (Rycroft et al., 2000; Williams, 2005). In particular the upper tropospheric water vapour shows a close correlation to global lightning activity (Price, 2000). Nevertheless, it is difficult to estimate this effect, since the two processes that mainly govern the water vapour content also have a direct effect on global lightning activity. First the water vapour content is controlled by the amplitude of future global warming in response to greenhouse forcing. Second continental deep convective storms transport large amounts of water vapour into the upper troposphere. These storms also produce the majority of our planet's lightning, which mainly occur over terrestrial land. A positive response of lightning activity on temperature increase is also mentioned by several authors. Reeve and Toumi (1999) for example use satellite lightning observations to show the agreement between globally observed lightning activity and global temperatures.

While the majority of lightning occurs in the tropics, there are some hints of increased activity also in Europe. Conedera et al. (2006) found that in hot and dry summers, such as the drought period in summer 2003, lightning fires became particularly frequent, with a significantly higher burned area and higher fighting costs in the southern Alpine regions. This is an important point that has to be taken into consideration in view of the postulated climate change toward an increase in severity and frequency of prolonged summer drought periods. It might also be a first indication that global warming influence could increase the risk of damage caused by lightning in Europe. For a review regarding climate change and lightning activity we refer to Williams (2005).

Floods

The most comprehensive available global study examined worldwide information on annual extreme daily flows from 195 rivers, principally in North America and Europe, and did not find any consistent trends, with the number of rivers showing statistically significant increases in annual extreme flows being approximately balanced by the number showing a decrease (Kundzewicz, 2004). However, in terms of the most extreme flows, when data were pooled across all the rivers surveyed in Europe, a rising trend was found in the decade of the maximum observed daily flow, with four times as many rivers showing the decade of highest flow in the 1990s than in the 1960s.

Especially flash and urban floods, triggered by local intense precipitation events, are likely to be more frequent throughout Europe (Christensen and Christensen, 2003; Kundzewicz et al., 2006). Flood hazard will also likely increase during wetter and warmer winters, with increasingly more frequent rain and less frequent snow (Palmer and Räisänen, 2002). Even in regions where mean river flows will significantly drop, such as in the Iberian Peninsula, the projected increase in precipitation intensity and variability may cause more floods. In snow-dominated regions, such as the Alps, the Carpathian Mountains and northern parts of Europe, spring snowmelt floods are projected to decrease due to a shorter snow season and less snow accumulation in warmer winters (Dankers and Feyen, 2007). A decrease in peak snowmelt floods is also projected in parts of the UK (Kay et al., 2006).

Landslides

Since heavy rainfall is among the most common triggering factors of landslides, climate change may affect future trends in this hydrogeological hazard as follows:

- Concentrated but intense rainfall together with soil erosion and degradation, consequent to an increase in temperatures and the aridity index may cause more frequent debris flows.

- Slow landslide phenomena are instead expected to decrease, due to the drop in overall precipitation able to recharge the water tables.
- Increase of slope instability (rock falls due to freeze thaw, debris flows and earthflows) due to progressive increase in temperature and the resulting reduction in the permafrost and the glacial areas.

Avalanches

In general, climate change will lead to a decreasing snow cover at low and medium altitudes and in addition it is anticipated that the snowline will rise by up to 100 m per decade. This will change only the height where the effects become obvious. Martin et al. (2001) therefore mention that the risk at the end of the winter season will decrease, in particular at low and medium altitudes. However, another important influence not to forget is the changes in the precipitation regime. Since the beginning of the 20th century, precipitation in the European Alps has been increasing, in particular in winter. Climate models reveal that this tendency will persist in the future. Further, variability of extreme snowfall changes is expected. Seasonal shifts (more precipitation in shorter time spans) and to some extent[4] also warmer conditions can result in more snowfall, in comparison to dry and cold weather. Therefore for lower altitudes a critical combination of higher temperatures, possibly wet conditions and therefore heavy snow can be expected. This could increase avalanche risk, in particular that for wet-snow avalanches (Martin et al., 2001), and may cause disasters like the collapse of a gym in Bad Reichenhall/Germany (15 deaths, more than 30 causalities) induced by heavy precipitation of wet-snow in 2006. Further temporary increases of temperature above the freezing point in high altitudes can prevent a sufficient combination of snow layers and may lead to avalanche disasters similar to the one in Galtür, Austria (31 victims, 18 causalities) in 1999.

Droughts

For the coming decades, higher temperatures, dryer summers, as well as more and longer dry spells, will very likely result in more frequent, severe and persistent droughts in large parts of Europe, especially in the south. River flow droughts are projected to increase in frequency and severity in southern and South-Eastern Europe, the UK, France, Benelux and in western parts of Germany (Lehner et al., 2006; Dankers and Feyen, 2007). In snow-dominated regions winter droughts are projected to be less severe because a lower fraction of precipitation will fall as snow in warmer winters. The projected decrease in summer precipitation, accompanied by rising temperatures,

[4] Due to the Clausius-Clapeyron law, warmer air can carry more water vapour than cold air, i.e. an increase of 1°C implies about 7% more water vapour in the atmosphere.

which enhances evaporative demand, will lead to more frequent and intense summer droughts in most parts of Europe (Douville et al., 2002; Dankers and Feyen, 2007). Important European waterways, such as the Rhine, are projected to suffer from a reduction of summer low flows of 5–12% by the 2050s, which will negatively affect river navigation and water supply (Middelkoop et al., 2001).

It is likely that due to both climate change and increasing water withdrawals more river basins will be affected by severe water stress, resulting in increased competition for available water resources. Regions most prone to an increase in drought risk are the Mediterranean and south-eastern parts of Europe, which already suffer most from water stress. Apart from the threat that drought poses to farmers, the water shortage combined with more frequent and intense heatwaves will likely cause notable reductions in summer tourism. Extra power demand for cooling, compounded by a reduction in hydro-production and problems with cooling water availability could cause disruption to energy supplies (Alcamo et al., 2003; Schröter et al., 2005).

Forest Fires

Fire risk depends on many factors of a different nature such as weather, vegetation (fuel load and condition), topography, forest management practices and socioeconomic context, to mention the main ones (Costa et al., 2011). Although most of the wildland fires in Europe are of anthropogenic nature, it is clear that weather conditions play a dominant role in affecting the changing fire risk over time. Most, if not all, of the extreme fire events that occurred during recent years were driven by extreme fire weather conditions. The European Forest Fire Information System (EFFIS), managed by JRC,[5] provides daily estimates of the meteorological component of fire risk (referred to as fire danger in the forest fire sciences), through the processing of weather forecast data and the production of fire danger maps based on the Fire Weather Index (FWI) (Van Wagner, 1987). FWI is based on air temperature, relative humidity, precipitation and wind speed of the current and past days and is made up of six components rating fuel moisture content and potential fire behaviour for a reference fuel type and in no slope conditions.

The first three codes account for the moisture content of different fuel layers with different drying rates and are called Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC) and Drought Code (DC). The last three codes are fire behaviour indices representing respectively the rate of spread (Initial Spread Index – ISI), the fuel weight consumed (Build Up Index – BUI) and the fire line intensity (FWI) as the energy output rate per unit length of the fire front. These indices, applied on a daily basis, can be summarised on

[5] Joint Research Centre of the European Comission in Ispra, Italy.

a seasonal basis to rate the overall fire potential of a given year (seasonal fire severity) or month (monthly severity rating) due to meteorological conditions.

Based on these assumptions, the JRC is currently analysing future projections of forest fire potential under climate change scenarios, processing daily estimates of FWI over EU and summarising corresponding seasonal and monthly severity ratings. Projections were derived for the SRES scenario A2, processing data from the PRUDENCE[6] data archive, namely the daily medium resolution data from the regional climate model HIRHAM for the time periods 1960–90 (control) and 2070–2100 (projections). Preliminary results confirm in Europe projections assessed for North America (Flannigan et al., 2005) with a significant increase of fire potential, enlargement of the fire-prone area and a lengthening of the fire season.

5.4 Scenarios of Change in Exposure and Vulnerability

When looking into futures related to societies and economies, trying to imagine how the built environment will look when changes in infrastructures and technologies will transform the way people communicate and move from one place to another is even more challenging than trying depict the effects of climate change on a variety of threats.

As mentioned above, the decision was made to adopt an "if–then" strategy, producing pictures of how changes in population, land use and critical infrastructure may shape future patterns of exposure and vulnerability. The SRES macro-scenarios or storylines developed by the IPCC were considered as a reference for this exercise, while data and projections were derived from the many studies available in European institutions and research centres, some of which developed in the previous projects.

5.4.1 Population Patterns

In 2003 natural population increase had fallen to just 0.04% per annum (EC, 2005b). The fertility rate represented a fall well below 2.1 children per woman, i.e. this is the threshold needed to replace the existing population, and in some states the fall was to below 1.5 children per woman.

Despite this post-baby-boom decline in natural replacement, trends in population growth in the EU over the next few decades are projected to result in a population *increase* of some 13 million i.e. from 456.8 million in 2004 to 470.1 million by 2025. After this period, however, the Union's population is projected to fall, reaching 449.8 million by 2050 (Eurostat, 2005). Over the whole projection period the population in the EU25 could decrease by

[6] Prudence project: Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects.

1.5%. This would be experienced as an increase of 0.4% in the EU15, with the population in the ten Member States who joined in 2004 declining by 11.7%.

It must be remembered that while projections on the birth rate are considered fairly reliable, those related to migration patterns are much less so, because of the many social and political variables that enter into the estimate and that may be dramatically changed by both internal and global factors, which are hard to forecast today.

As for the population, what clearly will make the difference are qualitative aspects, like age classes, cultural composition and degree of wealth/disadvantage.

Macro-scenarios generally agree regarding the fact that Europe, in line with what is going to happen worldwide, is likely to host a much more aged population. The effect of these trends on the percentage of the population considered to be economically active (i.e. those between 16 and 64) would be that of a decrease from 67.2% to 56.7% by 2050; i.e. a projected Europe-wide fall in the productive labour force of 48 to 52 million inhabitants (EC, 2006b; Eurostat, 2005). This is considered a challenge in terms of its effect on the population support ratio (i.e. the number of people aged 65 years and above relative to those aged from 15 to 64). Under the Eurostat projections countries such as Spain and Italy may have total populations comprised of only 52.9% and 53.5% economically active individuals by 2050, whilst in Luxembourg and Malta these percentages could be relatively higher at 61.3% and 60.8% respectively. Such changes could mean that in the EU the support ratio of economically active to dependent population would, for at least a few decades, fall from 4:1 to 2:1 (EC, 2006b).

A more aged population represents a challenge for risk mitigation in some respects. In social vulnerability assessment it is taken for granted that people aged more than 65 are likely to represent a further burder in emergencies, because of reduced mobility capacity, and additional difficulties in living in precarious conditions that may be associated to evacuation and temporary shelters. This has actually proved to be true in a number of disasters. It was documented in the aftermath of the Kobe earthquake, but also in the more recent l'Aquila earthquake. Furthermore, aged persons are more likely to suffer some kind of disease and therefore be in need of continuous care, which may be difficult to deliver, at least in the initial aftermath period. The burden on the aged population may also be more pronounced in the longer term, during recovery and reconstruction, because they are less likely to accept relocation and abandon their houses and community environments.

Nevertheless, Handmer (2003) suggests that some caution is needed when trying to generalise these statements.

> "Some indicators of vulnerability may be based on stereotypes with little research support, whereby particular groups of people are assumed to have little resilience or coping capacity within the ambit of public policy. Elderly people are frequently seen as a vulnerable group, but during the recent Victorian gas crisis, it appears that they generally coped better than younger

people; Melbourne's large population of women from the Horn of Africa was thought to be a special needs group, but officials now report that as a group they appear to be particularly adaptable and resilient. The policy context is important, for example young children may be very vulnerable, but are generally very well supported in Australian communities".

As suggested by Buckle (2000), it would make more sense to explore in detail why some elderly or some poor, in specific contexts, are more fragile in the face of natural extremes. The same can be said regarding the diversity of cultural groups within European countries.

Changes in population may result also due to migration. Increased immigration is more likely to occur either as a consequence of increased mobility (A1) or, more likely, increasing gaps between rich and poor countries (A2). During the years between 1960 and 2005 the population of the EU25 rose from 376 million to 460 million. This increase is characterised by three distinct periods of change. During the 1960s the growth rate was steady at around 3 million per year, during the 1970s and 1980s this trend declined slightly and then in the 1990s another increasing trend in population numbers occurred. This last increase, which has endured into the new century, is of a different nature to that experienced in the post-war "baby-boom" period. This rising trend, which began in the 1990s, has been attributed to increases in the level of net migration (Fig. 5.13).

Immigration is seen as being an important factor in maintaining national growth targets. Through both the targeting of technically qualified workers and the use of unskilled labour from outside the Union, states will be able to continue to feed their "need" to recruit workers to fill both high- and low-tech labour vacancies. In fact, migration is seen as a way in which states might attempt to counterbalance the gradual post-baby-boom decline in the size of their indigenous workforces. The International Organisation for Migration, however, expresses a concern that even this influx of labour will not offset the "greying" of the continent's population (IOM, 2005), while it entails also the potential for conflict due to social, cultural and political factors.
Predominantly, significant growth in migration has occurred in Germany, France, the UK and Italy, now comprising 57% of the EU25 population; whilst the 10 states that joined in 2004 comprise only 16%. Although this population expansion through net migration is dependent on an influx of migrants from outside the Union, the South-E astern European issue is highlighted by the increase in intra-union migration and emigration to other nations such as the USA, the projections for which indicate a reduction in the population of countries such as the Baltic States and Poland by as much as 10% by 2050 (EC, 2006).

The significance of migration in terms of exposure and vulnerability to hazards does not just relate to the total number of people in Europe that could potentially be affected in different places. Migration also provides an increasing cultural and ethnic mix to the population, with potentially different norms

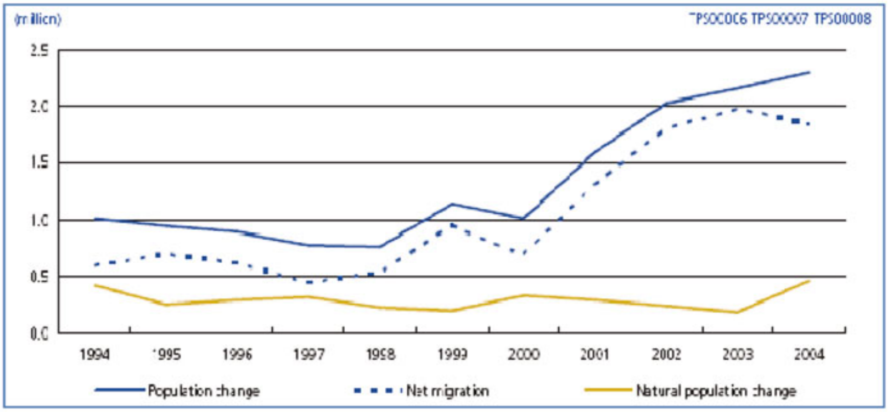


Fig. 5.13. Population change in the EU25 states 1994–2004. Note the prevalence of migration (dotted line) as the driving force behind the increasing trend (solid blue line) (source: Eurostat (2006, p. 53))

of ways of living, modes and languages of communication, degrees of social capital and patterns of social exclusion. These considerations can make particular migrant populations potentially more vulnerable during hazard events both intrinsically and/or as a consequence of management measures that are insensitive to cultural, ethnic and language differences (see Box 5.1).

Box 5.1
Warning and Informing Minority Groups

In their study of a number of populations affected by the severe flooding across the UK in 2000, Thrush et al. (2005, p. 10) identified examples of the challenges to communication faced by agencies charged with providing hazard warnings for racially and ethnically mixed populations.

"Disseminating warnings amongst minority ethnic groups is not necessarily a simple matter. Although the Environment Agency produces flood warning literature in several languages, including those spoken in the Stockbridge area, literacy levels in its Asian community were reportedly low, especially amongst older people. A local Environment Agency officer added that foreign language information was distributed only on request; non-English speakers may either be ignorant of its existence or be uncertain how to access it. Similarly, radio and television broadcasts were said to be unlikely to reach all sections of the community. There was only one Asian radio station in the catchment area; it was said by one informant to have been unwilling to broadcast the flood warning. Radio listening was apparently not part of the daily life of Asian women."

There are also ways in which issues of migration and ageing might be expected to interact in creating particular vulnerabilities. The literature suggests that the increase in "snow-bird" migration – the migration of older people from the north of Europe to the generally more clement south – being witnessed in the Union can have positive impacts on local economies through the injection of extra capital and the creation of leisure- and health-related jobs which this process encourages (King et al., 1998). However, in some circumstances, the increasing vulnerability of those who move abroad and who suffer unpredicted health or financial problems, whilst not fully engaged with the host country's social care system, can be significant (e.g. because of language or social-network barriers or due to their lack of sufficient contribution to relevant care schemes) (Hardill et al., 2005).

If in the future the incidence of flooding, flash flooding, wildfires in rural areas and heatwaves increases in intensity and frequency throughout the Mediterranean region, as suggested by the IPCC (Alcamo et al., 2007), then the risk to such population groups will increase significantly; as will the onus on the regional and local health and emergency planning authorities in such areas to plan for the contingencies of these events for such vulnerable populations (Salagnac, 2007; EC, 2007d). Box 5.2 provides another example of how population redistribution and ageing may interact.

Box 5.2
Internal Migration, Ageing and Healthcare in England

The issue of international migration is not the only one highlighting potential problems for healthcare and emergency planning services. Intrastate migration can also present challenges. In the UK the number of retired people in coastal resort towns has been identified as an issue requiring recognition. For example, in Blackpool, the seaside resort in North-west England, the migration issue is double sided. Whilst it is anticipated that by 2020 the percentage of the town's population that is of retirement age will rise from 16% to 21%, this rise is predicted to result more from the tendency of the young people to move away to find work and to seek affordable housing elsewhere than it is for the elderly to migrate in (ODPM, 2006). This is not a problem *per se*, due to the fact that in the UK the retired population is considered to control 80% of the population's wealth and 40% of its spending power (ABI, 2006). However, the increasing nature of the coastal flood hazard, which is projected under all climate change scenarios (OST, 2004), and the insurance industry's increasing reticence to supply policy cover for flood risk in such an apparently non-stationary climate could "result in future uninsurable losses being most concentrated within these retired population groups who would be left with little opportunity to re-build their wealth" (ABI, 2006, p. 19).

The European Commission is increasingly accepting the mainstream, scientific understanding of the projected environmental and societal impacts of Europe's changing climate (Alcamo et al., 2007). For example, the Green Paper on Adapting to Climate Change (COM (2007) 354 final) is explicit in its call for a unified approach to developing policies and plans to deal, multilaterally (with Member States and neighbouring states), with "cross-border issues such as regional seas, river basin management, ecosystem functioning, research, biodiversity and nature, disaster management, human health, economic transition, trade and energy supplies" (EC, 2007e, p23). Within this there is an acknowledgement that climate-forced migration is a possibility, but the management of such population movement is envisaged to be dealt with through the EU Common Foreign and Security Policy (CFSP). It should be pointed out here, however, that the instruments that currently relate to crisis management under the CSFP (EC, 2003a) are explicit in stating that, in relation to "displaced" people, "rehabilitation and reconstruction" are principle policy aims; one needs to ask whether such aims will always be adequate or feasible given the extreme nature of some of the projected environmental impacts climate change could have on certain, already vulnerable, countries and regions of Europe and the globe (Schubert et al., 2007). The term "environmental refugee" is gaining traction with respect to population movements from areas suffering various forms of environmental degradation (Myers, 2002), as it more adequately implies the greater connotations of the need to accommodate permanent rather than remediable displacement. However, there is still largely an absence of policy within multinational organisations in relation to this issue; something which is ascribed to the complexity of apportioning responsibility for the local or regional environmental degradation that drives the phenomena (McNamara, 2007). Whilst, as yet, no numbers are being spoken of, there is increasing discussion about the implications if large movements of people are experienced due to a changing climate, and specifically in the case of rising sea levels, movement of those populations who currently inhabit low-elevation coastal zones (Reuveny, 2007; Nordas and Gleditsch, 2007; Raleigh and Urdal, 2007; McGranahan et al., 2007).

Finally some observations should be made regarding the potential future situation in terms of social and economic disadvantage of some groups in Europe. Inter-regional disparities, including an East–West divide, exist but there are also issues in relation to intraregional and intranational disparities (Heidenreich, 2003).

Being at risk of poverty is a relative concept: it refers to the capacity of the individual to fully participate in the society in which she or he lives. In 2004 the percentage of the population of the EU25 "at risk of poverty" was 16% of the total. Across Member States, however, noticeable national and regional variability is found. National rates ranged between 9% in Sweden and the Czech Republic, to 21% in Lithuania and Poland.

Such poverty rates are not constant across age groups. At-risk-of-poverty rates for children and young people were 19% overall for children under 17, but again there is strong variation; in Poland the risk of poverty for children is as high as 29%. For those aged over 65 years, the highest risk of poverty is suffered in Ireland (33% at risk) and Cyprus (51% at risk), with older women suffering disproportionately. In the new Member States the elderly were well protected from poverty before accession, but child poverty was particularly high (Matkovic et al., 2007).

Whilst poverty has been experienced in both urban and rural areas across Europe, in the "transition economies" and in some Eastern and South-Eastern European countries rural poverty is a particularly serious problem despite the implementation of EU-encouraged poverty reduction strategies (Spoor, 2003). It is suggested that such intranational income and development inequality is due to the particular economic growth model that forms the basis of many poverty reduction policies. In effect, it is argued that whilst the GDP of states has grown *per se*, this growth has not been broad-based or inclusive of sectors where the poor are located and, therefore, the growth (wealth) is not trickling down. In other words, free-market-driven technological advances have unquestionably assisted growth in the skilled labour sector of Member States. Concurrently, however, employment opportunities for unskilled labour have declined and there has been a failure to provide the training resources needed to upskill this group into the knowledge-based economy (EC, 2007b). Unfortunately, these policy limitations are impacting rural poverty, particularly in the poor countries of South-Eastern Europe, which have substantial or even majority rural populations and where strategies for educational and continuing vocational training are rare (EC, 2007b; Spoor, 2003).

In terms of identifying trends of change over time, between 2000 and 2005 Member States experienced a small increase in relative poverty, and a somewhat more marked rise of inequality, which was particularly significant in Portugal, Poland, Latvia and Lithuania (Matkovic et al., 2007). Success in reducing poverty has been recorded in those states with the most equal income distributions, such as the Nordic countries: Sweden appears to be reducing poverty faster than any other state. Conversely, in countries such as the UK, Ireland and some South European countries, poverty reduction rates have been relatively low (Matkovic et al., 2007). In the new Member States, recent changes in social structure have resulted in an increase in poverty driven by the collapse of communist systems of social security and the rapid introduction of market-based inequalities mentioned above (*ibid*).

Such changes in patterns of income inequality are reflected in indicators that compare the income of the poorest and the most wealthy social groups. These indicators show that since 1995 the income distribution in the EU15 was at its highest in that year before declining to a low in 2000 and then resurging through to 2005. In the EU25 as a whole only a gradual increase in inequality has been monitored as it shadowed and then in 2005 slightly exceeded that in the EU15 (Table 5.1).

Datasets such as these are acknowledged, however, to have difficulty in identifying the existence of a European "underclass" (Russell and Whelan,

Table 5.1. Income inequality in the EU (source: EuroFound, 2007)

Countries	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
EU-15	5.1	4.8	4.7	4.5	4.5	4.3	4.4		4.6	4.8	4.8
EU-25					4.5		4.4		4.6	4.8	4.9

The ratio of total income received by the 20% of the population with the highest income (top quintile) to that received by the 20% of the population with the lowest income (lowest quintile)

2004). This is because of the nature of the employed household-survey methods. That an "underclass" might exist is, though, problematic because it would inevitably contain those who suffer most from a persistent cycle of multiple deprivation and economic marginality. Describing the results of her work in six EU and CIS countries, Domanski (2002) produces evidence that such an underclass does exist (as indicated by attributes of material deprivation and placement outside the labour market) and that in some countries, most notably Poland, this underclass is feminised; i.e. women apparently suffer more than men from severe differential discriminations which act to perpetuate this deprivation. Whilst such a bias did not exist in Bulgaria or Slovakia, the finding is of particular importance in relation to risk mitigation in those countries where it does exist, because women have been identified as being significantly more vulnerable to hazards than men (Fiordham and Ketteridge, 1995; Morrow, 1999; Wisner et al., 2004) and deprivation inevitably acts to compound such vulnerability. The implication of this is that although the European Commission has been relatively proactive in legislating for gender equality (e.g. through its ratification of 12 gender/employment specific Directives between 1975 and 2004 (EMCC, 2004)), in some Member States more needs to be done to curtail this particular inequality.

In terms of how problems of poverty and inequality are likely to change in the future, this is particularly hard to forecast. Key factors include the experience of economic growth across Europe, political change and the success of policies intended to address income inequalities and reduce poverty, where and when these are in place. As already described, recent experience indicates that poverty is persistent and deeply entrenched and that if anything it is worsening rather than improving across many parts of Europe. However, it should not be automatically assumed that consistent deprivation (in the sense of describing those who endure low income and lifestyle deprivation) is concentrated in specific areas. In fact, the relationship between consistent deprivation and living in areas of high vandalism and neighbourhood crime is very weak. This indicates that deprivation amelioration requires a more encompassing approach than merely focusing policies toward improving disadvantaged neighbourhoods (Russell and Whelan, 2004).

The implications of these patterns on trends of exposure and vulnerability are multidimensional. First, there is some evidence that poor people disproportionately reside in areas at risk of hazards, even within the core Member States. Box 5.3 describes the results of an analysis of the relationship between deprivation and flood hazard data in the United Kingdom showing that for coastal flooding there is a strong bias towards more deprived people living at risk in exposed areas. Similar geographical patterns may or may not exist for other forms of hazard and it is unknown whether trends of change are pushing poorer people disproportionately towards risky areas of land over time. One

Box 5.3
Deprivation and Flooding in England

Walker et al. (2006) describe the findings of research carried out to evaluate the relationship between flood risk and multiple deprivation in England and Wales. Data: Aggregated Indices of Multiple Deprivation (IMD) (a multi-domain dataset of mostly census-derived deprivation indicators); postcode address points; boundary data for census Super Output Areas (SOA); the Environment Agency Flood Map (a GIS map layer which indicates the calculated extent of flood zone 3 (1:100, high probability) and flood zone 2 (1:1000, low probability/extreme) flooding events which may emanate from the major rivers within England and Wales or inland from the sea).

Analysis: Within a GIS environment, Walker et al. (2006) applied the mean IMD score to each SOA in England and Wales at a postcode address-point resolution (i.e. every residential building within each SOA in each country was attributed with the mean IMD score for the SOA in which it was situated). They then applied the flood map layer to this data and calculated the deprivation characteristics of all those postcode address points which fell within the respective flood outlines.

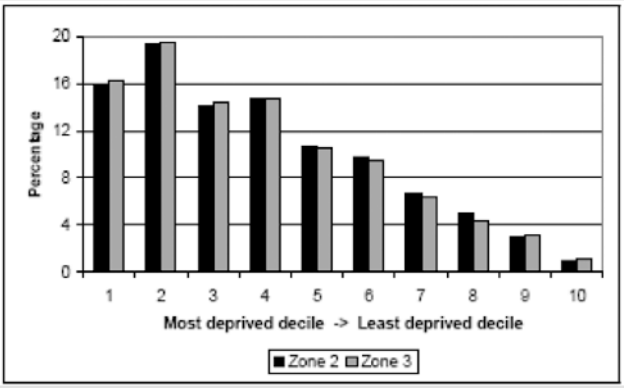


Fig. 5.14. Percentage of total population within zones 2 and 3 for sea flooding by deprivation decile (Walker et al., 2006, p. 59)

Results: Two interesting patterns were revealed by the analyses:

1) For river flooding, all regions have populations at risk but there are concentrations of the most deprived at-risk populations in some regions (North-East, North-West, East of England and South-West) and concentrations of the least deprived in others (South-East, Yorkshire and Humberside), reflecting to some degree the underlying highly uneven geography of deprivation. The proportional patterns within each region are also highly variable; in some regions, the most deprived are disproportionately found within flood-risk zones while in others it is the least deprived.

2) For sea flooding, the population at risk is dominated by two regions, which also contain, in absolute and relative terms, a disproportionate number of deprived people at risk. In fact, the national picture of a disproportionate concentration of deprived populations in flood-risk zones is maintained fairly consistently across the regions. In every region, the lowest proportion of people at risk is found in the two least deprived deciles (figure below).

Conclusion: There is evidence of a disproportionate exposure of deprived people in England and Wales to sea flooding, however this apparent inequality disappears when analysis shifts to river flooding exposure. In both categories of flood exposure there are particular aspects of regional and local differentiation (e.g. development legacy) which would make a broadly focused risk mitigation strategy or policy intervention problematic.

side effect of policies that are set to increase the availability of hazard and risk maps to the public and private sectors (e.g. through the Floods Directive or the INSPIRE Directive) could be that house buyers and house builders become more sensitive to risk in assessing land and property values. If this activity were to result in a localised premium being created in the pricing of those developments situated in safer areas, then the ability of the deprived to relocate themselves away from the more risky areas would be further reduced. As an aside, the availability of hazard zoning information can also have subtle effects on social resilience. Crozier et al. (2006) suggest that people are more inclined toward preparedness and adaptive activity in areas indicated as being low-hazard zones, whereas in high-hazard zones perceptions of fatalism or resignation are more dominant and the likelihood of preparedness is reduced.

Second, for persistently poorer communities, social protection measures such as pension provision and access to heathcare will be fundamental in providing the social safety nets that they need (EC, 2007f). However, effective non-structural measures such as local healthcare provision and insurance, which can build resilience into communities and households, are still either only sporadically available in some areas or for some social groups (Sethi et al., 2007; Priest et al., 2005). They are also subject to increasing questions over whose responsibility it is to provide them for the vulnerable sections of society, who may also be disproportionately hazard exposed (Box 5.3) (Schwarze and Wagner, 2004).

As far as self-protection measures are concerned, insurance against natural hazards has been defined as an important one, at least in some European countries, and sometimes proposed as one to be potentially extended to the entire Union (see Chapter 4).

The availability of insurance cover can be particularly problematic for poorer people and communities. Insurance is regarded as an important tool for sharing losses from natural hazards (Crichton, 2005; Pelling, 2003; Smith, 2001) and it is also increasingly recognised as an important climate change adaptation measure by the insurance industry itself (CEA, 2008; Munich Re Foundation, 2006).

If climate-related hazards do become more severe and less predictable, this is likely to make insurance cover more expensive and less affordable for those who are in poverty and at the bottom end of income distributions. This issue highlights the importance of institutionalised safety nets (such as in the Netherlands) which, if applied effectively, can compensate the most vulnerable members of society for losses they experience and assist in their recovery. The extent to which all Member States across Europe will be prepared to move in this direction over future decades is unclear, although there are few indications at present and introducing state schemes can be problematic. Where such systems do exist alongside private insurance, feelings of inequity have resulted; as those who have bought insurance may consider that those who did not as receiving "undeserved" and sometimes, ironically, more effective assistance in case of disaster (Thieken et al., 2006; Fiordham and Ketteridge, 1995).

5.5 Potential Trends and Changes in Land Uses in Europe

There is a double difficulty in producing scenarios of land uses in Europe, due to the complex interaction between land use changes and the more comprehensive trends of macro-scenarios on the one hand and the need to downscale the consequences of specific policies and pressures at the regional level, as required to be able to produce a meaningful picture for the European Union.

As far as the IPCC storylines are concerned, only in the B2 urban sprawl is it explicitly expected to be controlled, while it is likely to significantly increase under A1. Market-oriented policies (A1 and A2) are less concerned with imposing limitations on the construction industry, an important pillar of economic development. Planning policies have weak effective powers to impose the most convenient use of land, including avoiding development in the most hazardous areas, while free market processes have proved to provide

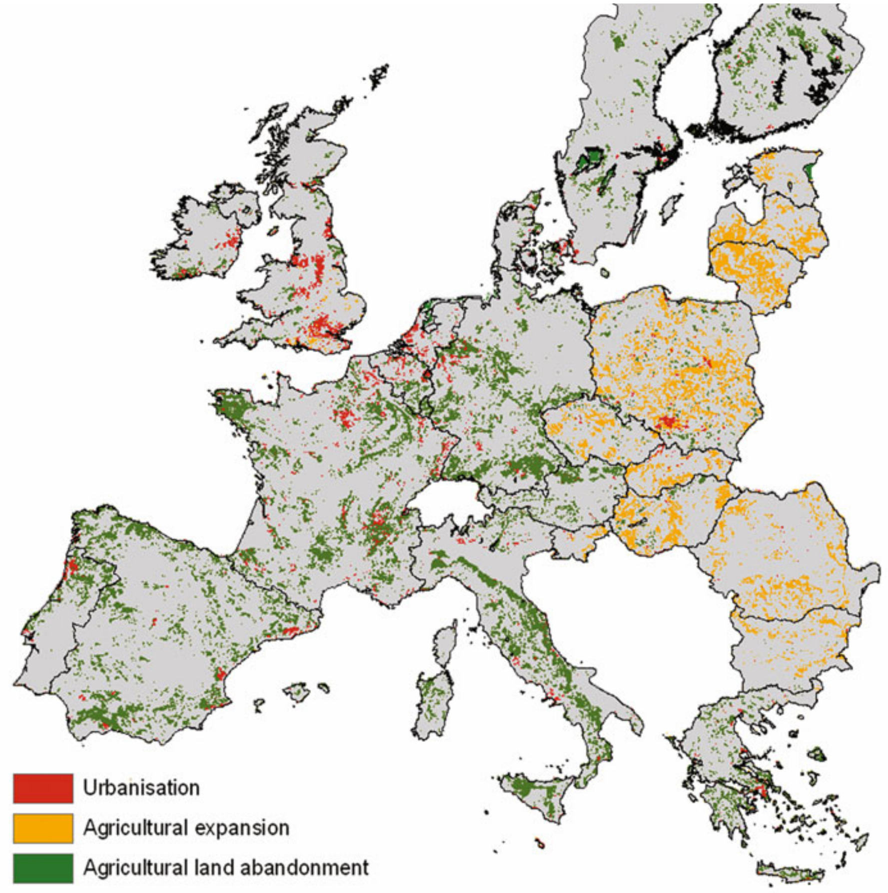


Fig. 5.15. Example of scenario map produced by Eururalis version 2.0 (courtesy of Prof. Peter Verburg, University of Amsterdam)

poor mechanisms in regulating public goods (Stiglitz, 2009), including land and safety, if the latter has to be considered as a public good (Reddy, 2000).

Some projects have attempted to develop scenarios of land use changes in Europe looking ahead to the year 2030 and to the year 2050. As a reference, two projects have been considered: the Prelude project developed by the European Environmental Agency (EEA, 2007), and the Eururalis project, commissioned in 2003 by the Netherlands government when the country took the Presidency of the EU (in the second half of 2004).

While the first is aimed at analysing and making projections on land use changes, to support environmental analysis, the latter was specifically designed to develop scenarios relevant for the agricultural sector.
The two databases used by the projects are Corine (Coordination of Information on the Environment) land use cover and Pelcom (Pan European Land

Cover Monitoring). The first is more accurate, as it adopts a 100-m grid and conveys information regarding 44 categories and compounds information from Landsta/SPOT satellite data and aerial photographs, while Pelcom uses only satellite data (NOAAA-AUHRR) with a 1-km grid. The scenario approach works addressing land use changes in every cell according to what is most likely in given conditions under given pressures, driven by market forces, by the capacity of governments to manage and control regulations addressing a variety of environmental goals, which include control of urban growth, protection of natural resources, safeguarding biodiversity, etc.

According to the different macro-scenarios, oriented towards free market mechanisms rather than towards the primacy of environmental policies and social processes heading towards solidarity rather than conflicts, a variety of conditions are considered, in which control, free market mechanisms may compete for getting the maximum benefits (intended in rather divergent ways) of every parcel of land. The two projects agree in some respect, even though differences exist particularly in downscaling the results of the different projections at the regional and subregional level. There is a significant interplay between natural and agricultural land and within the latter category among different types and intensity of use. In particular, market-oriented changes would likely lead to more profitable cultivations, extended over wide areas, with a loss of variety and biodiversity. Apart from ecological concerns that may be raised, changes in agricultural methods of cropping, intensive soil use have dramatically increased erosion, particularly in some Northern European countries, with the consequence of much more frequent and severe floods also in areas where they have not been reported in the past (Boardman et al., 1994). While it is usually taken for granted that urbanisation contributes to worsening hydrogeological risks, the big flood in the USA in 1993, the Piemonte flood in Italy 1994 and several events reported in Boardman et al. (1994) suggest that agricultural practices may also worsen the same natural phenomena.

Future research oriented towards producing sectoral scenarios of risks could consider how changes between natural and different types of agricultural uses may impact on a variety of hazards, from hydrogeological ones to forest fire. Examples in the case of landslide, particularly mudflows, are available, consequent to changes in land uses and even in the kind of trees that are planted to guarantee a more profitable production from woods.

As for urbanisation patterns, the situation seems more complex as far as projections are concerned. The two projects agree that large urbanisation trends are not expected; this is consistent also with demographic projections made by the UNCHS report 2001 for urban population in Europe. The latter estimates that by the year 2030 82% of the total European population will live in urban areas, while in the year 2000 it constituted 75%. Countries like Poland, Ireland and Portugal are expected to contribute most to this further increase.

According to the Eururalis project (Verburg et al. 2006; see Fig. 5.15), there are some hotspots of urban and metropolitan areas which are more likely to increase: Paris, the Rurhgebiet and Southern Poland in all identified macro-scenarios; Randstadt, Lyon, Brussels Atenorp and Budapest for three of the selected macro-scenarios. It may be relevant to estimate the potential impact of such increasing urbanisations in areas already exposed to floods and other hazards, as was attempted by Barredo et al. (2005b) using the Moland (Monitoring Land Cover / Use Dynamics) database produced within a project run by the Joint Research Centre of the EU Commission in Ispra.

However, what makes the most relevant difference between one scenario and another is the mode of urban growth, when it is expected, and urban change. In fact, even in the absence of large new development, the actual trend that may be labelled as “rurbanisation” is likely to continue, particularly under the most permissive scenarios, where little if any control is exercised by public authorities. The Prelude project speaks, for example, of fragmentation of landscapes, which may be particularly dangerous for urban areas, creating the conditions for large conurbation where very little space is left for natural areas; on the other hand urban sprawl is considered to be driven by commercial and industrial districts as well as by infrastructures. The latter consume 100% more soil than residential areas. It has been calculated that “in the last 50 years the amount of space consumed per person has almost doubled. Even with a very little increase of urban areas per year, the overall extent of urban “landscapes” may be doubled in a century from now”. Urban sprawl is a particularly worrying phenomenon as it generates development which is “partly, scattered, and strung out, with a tendency for discontinuity” (see EEA, 2006).

It may be worth hinting at what those changes may mean in terms of natural hazards. As mentioned also for agricultural changes, both hazards and vulnerabilities may be affected. In fact, scattered urban areas imply an over-extension of paved areas, reducing runoff surface for rivers, but it may also imply the over-development of roads and transport systems to reach every new single location, with drawbacks both for emissions levels and on hydrogeological conditions. In terms of vulnerability, the management of large, unplanned or poorly planned areas, creates problems of access to resources in case of need, huge traffic congestion at normal times and certainly during emergencies, and difficulties in assisting the most remote components of the population. Furthermore, poorly planned neighbourhoods may imply the vicinity of functions that are not compatible with each other, like industrial zones, sometimes hosting hazardous plants, and residential blocks. Clearly, in case of natural hazards, such compounds constitute favourable locations for triggering na-techs.

Box 5.4
Future for Istanbul Metropolitan Area

Natural disasters are the results of accumulated mistakes made before the event, but at the same time can open a window of opportunity window. The Kocaeli earthquake, which occurred in 1999 in Turkey, is such an event that created a breaking point and opened a window of opportunity in Turkey. It affected the entire country profoundly and altered the ways in which Turkish government, scientists, citizens and all the NGOs look at the existing risk in the city. The changed legal system and the projects authorised by the governments and municipalities indicate this altering perspective and strategies.

Firstly, the focus of the Turkish legal system has changed from post-disaster activities to pre-disaster activities by issuing the 8th National Development Plan and Compulsory Earthquake Insurance (decree no 587). While the existing 1982 constitution and 7269 disaster law stress emergency activites for the post-disaster period by paying attention to the emergency activities and the responsibilities of the emergency aid organisations, in the contrast the 8th national development law and compulsory earthquake insurance focus on pre-disaster activities by using risk mitigation and preparedness tools. The settings and objectives of 8th National Development Law clearly state the importance of pre-disaster activities and Compulsory Earthquake Insurance stresses the importance of accumulating money in an insurance pool before the occurrence of a disaster.

Secondly, the aftermath of the 1999 Kocaeli earthquake increased the perception of disaster risk, leading to the formation of new projects which determine the quantitative and qualitative value of related risk in a concrete situation. Research on hazard assessment started with the preparation of the bathymetry map of the Marmara Sea, focusing on the segments of North Anatolian Fault with national and international academics. This research was handled by different universities and research institutes and realised between 2000 and 2002. In August 2000 AKOM (Coordination Center for Disasters) was established under the Istanbul Greater Municipality. In September 2000, TCIP (Insurance against Natural Hazards) was founded. In 2002, two comprehensive studies were released: one was by Istanbul Greater Municipality and Japan International Cooperation Agency, and the other one by Bogazici University. Both studies include earthquake scenarios, vulnerability level of Istanbul and risky areas. IGM and JICA worked on neighbourhood scale and Bogazici University on 500×500 m geo-cells. The results of both studies were similar and they indicated similar areas as high-risk zones. In 2003, the Istanbul Greater Municipality, with contributions from the academic staff of four pioneering universities of Turkey (Istanbul Technical University, Bogazici University, Middle East Technical University and Yildiz Technical University), developed the “Earthquake Master Plan” for Istanbul. In 2002, the Metropolitan Municipality of Istanbul signed a memorandum of agreement with the Bogazici, Istanbul Technical, Middle East Technical and Yildiz Technical Universities to develop a comprehensive earthquake risk mitigation master plan. The Earthquake Master Plan for Istanbul was established to make an overall assessment of the current situation; undertake a seismic assessment and rehabilitation of existing buildings; address urban planning, and legal and financial issues; and to deal with social and educational issues, and risk and disaster management issues (IEMP, 2003). Following negotiations between the Earthquakes and Megacities Initiative and Istanbul Metropolitan Municipality in 2004, the Municipality decided to have the Earthquake Master Plan for Istanbul (IEMP) evaluated by an International Team of Experts. The experts emphasised the importance of the IEMP for the reduction of risk in Istanbul and considered the Zeytinburnu Pilot Project as the laboratory of this plan. The Zeytinburnu Pilot Project Framework is in response to the IMM and JICA report and the IEMP. The project is the first phase of the implementation of the IEMP. In 2005, the agreement of the ISMEP Project was signed between the Republic of Turkey and International Bank of Construction and Development. The Istanbul Project Coordination Unit (IPCU) has been established within Istanbul Governorship, Special Provincial Administration to implement the Project, which is planned to be completed by 31 March 2010. The activities of the ISMEP Project are being implemented under the three components: (1) enhancing emergency preparedness capacity; (2) seismic risk mitigation for critical public buildings; and (3) building code enforcement. The recent accomplishments of the ISMEP Project can be cited as reinforcement of more than 200 schools, 7 health centres and paigns and training activities for decision makers, technical staff and community representatives.

In 2005, the Istanbul Metropolitan Planning and Design Office was established to prepare a comprehensive development plan for Istanbul targeting the year 2023. The Master Plan of Istanbul was first released in 2006, however due to appeals, critics and comments by several NGOs (mostly professional chambers) and institutions at different levels, the plan had to 3 dormitories; establishment of a Disaster Management Center under the coordination of the Istanbul Governorship; and disaster awareness cam be revised. Finally, the Master Plan of Istanbul was approved pn 15 June 2009. The main objectives of the plan are to achieve sustainable development while upholding ecological values, historical heritage and economic diverisy, and improving the quality of life in the entire city. Within the objectives, the Master Plan of Istanbul aims to improve the city with an economic structure based on science and technology, to increase touristic activities in both historical and environmental values and to make Istanbul a competitive world city. Regarding the natural threats that Istanbul faces, the main notices are on enforcement of building codes and microzonation plans which will be basic input on smaller scaled plans. Hazardous industrial facilities, on the other hand, are planned to be decentralised from the inner city. However, in the plan there is no definite instruction on how to rehabilitate low-quality building stock and decayed areas, which are very vulnerable against any kind of hazards. Furthermore, retrofitting and reconstruction processes/

methods for industrial, large commercial and touristic facilities are not mentioned in the plan either. Nevertheless, urban regeneration projects which are being developed parallel to the Master Plan are very important tools to mitigate urban risks in unplanned areas of the city.

For the last 10 years, since the 1999 earthquakes, local and central governments have accomplished much research and several projects to find a way to decrease the vulnerability of the city. But the fact is that Istanbul has gained its current structure mostly in the last 60 years. Vulnerabilities at every level have come about due to several instant solutions and decisions. A comprehensive regeneration project for Istanbul requires both financial power and a large labour force. Therefore before facing a severe earthquake Istanbul is likely to fix some of its deficits but obviously not all. In this case, decision makers of the city and the community should be in cooperation and collaboration with a participatory planning process, providing inhabitants with knowledge on how to decrease their vulnerability in their living environment.

5.6 Potential Changes and Trends in Transportation and Critical Infrastructures

> "*The every day life of modern citizens has become dependent on the function of a wide range of infrastructures and services provided by and through them. Most citizens take for granted that water will come from the tap, the light will go on when one turns the switch and that there will be a signal when one picks up the phone. The criticality of these infrastructures is not obvious to citizens until a disruption occurs*" (Fritzon and Ljungkvist, 2006, p. 23).

Both everyday life in Europe and continued economic growth have in recent years become increasingly reliant on various forms of network and hub infrastructure; everything from roads and fuel pipelines to high-speed broadband connections are becoming more interconnected. Such interconnectedness has allowed for unprecedented economic growth in the Member States but it has also created new forms of vulnerability. Increasingly, responsibility for the maintenance of these systems' critical infrastructure (CI) is cross-cutting between institutions, across regional and national borders, and between public and private sector interests. As a result of this the potential for a minor event at a single weak point in a network to trigger disproportionate physical, social and financial effects across a large geographical area is growing (Egan, 2007).

There are many different forms of critical infrastructure. The European Commission Green Paper "A European Policy on Critical Infrastructure Protection (EPCIP)" (EC, 2005c) identified the following CI sectors:

- Energy
- Nuclear and chemical industries
- Information and communication technologies (ICT)
- Water
- Food
- Health
- Finance
- Transport
- Space and research

Trends and evolving patterns for three of these sectors (energy, transport and ICT) are highlighted below to illustrate the scale and implications of greater networking, interconnection and dependency. Critical infrastructures are likely to grow in consistency and importance in the A1 storylines; following the B1 and B2, more environmentally friendly solutions are expected to be sought, while in the A1 and B1 mobility and ICT will get the larger boost.

For *energy*, a resource and commodity that is ever more essential to economic and social security, there has been an increased lengthening and internationalisation of European energy networks. For example, new gas pipelines have been established along a series of axes, including from Algeria to northern continental Europe and from Russia to the UK. Electricity "rings" have also already been connected which supply, amongst others, Greece and the Balkan countries, and planning is underway for two more priority projects which will connect, respectively, the Mediterranean Member States and Germany with Slovakia and other new Member States (EC, 2004).

Box 5.5
Case Study: Thames Gateway Development

The Thames Gateway is identified as a national priority area for regeneration and growth and, in the Sustainable Communities plan, as one of the four growth areas for new housing in the South East of England. Thirteen out of the fourteen proposed development zones in the Thames Gateway lie within the Thames tidal floodplain on which 120,000 new homes are planned to be built. These zones will largely be on land behind a high standard of existing flood defence (with an annual probability of 0.1%, i.e. a 1 in 1000 chance of occurring in any one year) which includes allowance for future sea-level rise until 2030. However, this area is still potentially vulnerable to a large-scale storm surge event. River flood defences upstream of the Barrier are in need of improvement and many tributary river flood defences are in poor condition. Additionally, according to the London Assembly London Under Threat? report (2005), the current drainage system will not be able to cope with the anticipated increase in pluvial flooding from intense storm events which will result from climate change.

Institutional Mitigation Responses:
Various mitigation measures are being planned to protect the new development against flood impact and to reduce vulnerability. These include the use of Sustainable Urban Drainage Systems as well as flood-resistant building design. The use of occasional flood storage adjacent to rivers is also being advocated. Development can be planned to incorporate riverside parkland, open spaces, walkways or wildlife habitats that can act as flood storage as well as add benefit to the environment and local community (Fay, 2006). A recent strategic flood risk assessment (SFRA) concluded that a significant number of proposed development sites fall within the higher risk areas and suggested that even after the costing and identification of flood-risk mitigation careful consideration should be given as to whether to proceed with development on certain higher-risk sites (ENTEC, 2005).

Whilst vulnerability may be reduced, exposure will still be significantly increased as a result of the strategic development plan. If land use planning policies had been more strictly applied and development priorities directed elsewhere, this increased exposure could have been avoided. Concerns have been expressed throughout the planning process by the UK Environment Agency (EA) – in its role as statutory consultee under Planning Policy Statement 25 (PPS25) – but as no major plans have gone ahead against their advice they have stated that they consider the economic and social regeneration benefits of the Thames Gateway programme to outweigh the risk of developing in the flood plain (NAO, 2007).

The Agency do though, suggest that £4 billion will need to be budgeted for expenditure on increasing the flood defences for the tidal River Thames and Central London in order to mitigate the effects of climate change on flood risk until 2100 (ibid). The Association of British Insurers, however, point out their fear that unless substantial year-on-year increases are made in the allocation of total funds to the EA flood defence budget, the need for such a significant proportion of what is available to be set aside for just the protection of London and its environs could have knock-on effects for other flood defence infrastructure projects and maintenance and could, therefore, increase flood risk in other regions of the country (ABI, 2006).

This trend reflects the fact that use of reciprocal energy trade arrangements can provide important buffers to both assist states at times of peak demand and to provide them with a mechanism for reducing their base-load generation costs (i.e. where energy is bought from a neighbouring state because they can produce it more cheaply than can be achieved domestically).

Overland connections are not the only means of international energy exchange either. Natural gas is being delivered across significant distances under the seas (e.g. the 235km "Interconnector" between Belgium and the UK) and the transport of Liquid Natural Gas (LNG) is being streamlined between newly constructed port facilities along the "motorways of the sea": shipping routes (EC, 2007c). From the perspective of renewable energy there is speculation about long-distance electricity connections bringing electricity from solar generators in North Africa (GAC, 2005) and also from a "Supergrid" of offshore wind turbines arrayed around the European coastline (Airtricity, 2006).

Such interconnection does not, however, come without its challenges and the fragility of international supply networks has already been illustrated on a number of occasions. For example, two power blackouts in Italy in 2003 (see Box 2.3) highlighted the importance of maintaining uninterrupted energy supplies between Member States (EC, 2003b, Turmes, 2003). Also, in November 2006 a network overload caused a huge power blackout across Western Europe during the first cold snap of winter. This event, which disrupted the electricity supply to millions of homes and businesses, may have been triggered in Germany by a routine operation involving the closing of a high-voltage line over a river to let a boat pass beneath (Strauss, 2006).

Arguably, shifts towards more distributed, local-scale generation of energy may improve local resilience in the event of a failure in the greater network (Li, 2005). An example of this would be roof-mounted solar panels that would continue to provide electricity or hot water to the building on which they were sited, regardless of a greater power outage. However, indications of a continuance of the current concentration on centralised energy supply, through the building of next-generation large-scale nuclear power stations (for example in the UK), raise, amongst other significant concerns, worries about such facilities' lifetime vulnerability to climate change-enhanced hazards; even though such policy is seen as being part of a broader strategy to reduce greenhouse gas emissions. Such worries include, in the UK, the risk of future sea-level rise affecting the facilities' coastal sites through flooding (Walker, 2008) and, in France, the effect on the facilities' capability to supply energy at their design capacity, given the environmental constraints on how river water is processed through the plants' cooling systems (Gentleman, 2003; Wenisch and Meissner, 2007).

For *transport networks*, trends show ever more movement of people and goods around Europe and ever more dependence on transport infrastructure. Passenger transport activity within the EU25 for instance, is projected to rise from the 170 Gpkm[7] recorded in 1990 to 923 Gpkm in 2030 (EC, 2003c). Low-fare operators have now produced demand for and expectations of low-cost travel, and through this established dependencies between people's home countries and distant destinations where they have a second home, holiday flat or family members living abroad. Although rising costs of fuel and climate change concerns may put a brake on low-cost flying, current projections are for the air transport sector to experience the highest growth rates, up to 2030, of between 4.2% and 3.8% (reducing) annually (ibid); therefore, without reformatory regulation, there will be a need for increasing airport capacity well into the foreseeable future.

[7] Gpkm: Gigapassenger-kilometres or 10^9 passenger-kilometres

Box 5.6
The Modernisation of the Swedish Railway Connecting Goteborg to Malmo

The well documented history of the modernisation of Swedish railways in the segment connecting Goteborg to Malmo clearly emphasises the need to pay much more attention to natural and potential na-techs, particularly as large-scale projects, facilitated through substantial contributions of Community funds, are underway across the European Union (see Boholm and Lofstedt, 1999; Lofstedt and Boholm, 1999).

According to numerous authors, it is possible to talk about a long-lasting failure in planning to include critical geological and geomorphological conditions within the project's preliminary environmental assessment. The new path of the railways had to pass through a horst (an up-faulted geological unit of rock) in the Southern region of Hallndsas. This is a vital agricultural area, which produces fruit and vegetables early in the year, particularly by Northern European standards. Right at the beginning of excavation works, the water table was lowered, putting stress on the agriculture in the area. Then, signs of water infiltration into the tunnel under construction became obvious and required a rapid intervention to isolate the excavation from further water ingress. Unfortunately, the grouting material chosen contained large quantities of the chemical compound acrylamide, which infiltrated into the rock and contaminated the water table. The area was declared chemically contaminated in 1997 and it became impossible for agricultural producers to sell their goods at market.

The whole incident lasted for more than 10 years, with substantial economic and environmental losses suffered. The case highlights the vulnerability of the current design process in relation to transport infrastructure. Something which is not only part of the more comprehensive land use and spatial planning system but which can also be affected by unsustainable time schedules that impede appropriate geological and geomorphological surveys, as well as risk analyses in areas where complex features may be found.

Road and rail travel have also shown increasing trends of mobility and movement of people and goods. In the case of rail the planning and building of high-speed international networks has become an important European-scale initiative and the further extension of this network is planned to include 20,000 km of track, suitable for speeds of up to 200 km/h, by 2020 (EC, 2005d). Road construction too is undergoing a substantial increase in investment across the Member States, with plans for 4800 km of new road as well as the upgrading of a further 3500 kms. These increases are being justified by the projections for gradually increasing passenger kilometres travelled (Table 5.2). The increasing use of "just in time" and intelligent supply logistics has been part of these trends and made the availability and smooth operation of transport networks all the more important, with disruption causing major problems for retail and

Table 5.2. Projected increases in passenger kilometers travelled by road, rail and air 2000–2030 (source: EC (2003c, p. 120))

Year	**2000**		**2020**		**2030**	
	Gpkm	*Annual growth %*	*Gpkm*	*Annual growth %*	*Gpkm*	*Annual growth %*
Road transport	4785	1.5	6321	1.3	7031	1.1
Rail transport	402	0.3	479	1.5	538	1.2
Air transport	298	4.2	664	4.0	923	3.3

production units dependent on receiving materials and products to a tight schedule. Similarly for people commuting longer distances to work transport disruption can have significant impacts on availability and productivity at work. In the future rising fuel prices may slow down the growth of movement around Europe, but in general policies are seeking shifts between modes (e.g. away from cars and flights to rail) rather than a restriction of mobility demand.

In addition across Europe importance is being put on reducing network bottlenecks (at a range of scales from national borders to urban boundaries), in order to increase the ease of inter- and intra-regional trade. Due to their cost, inter-regional transportation links will have a tendency to concentrate on the connection of specific nodes within and between Member States, i.e. links between members' primary urban centres. Big projects which fit this model have been designated as the "30 priority axes" under the Trans-European Network Transport (TEN-T) initiative (EC, 2005d: map of axes on page 12 of the referenced document).

On the other hand, it is hard to estimate how the transportation network will actually develop in Europe, as several economical, social and political drivers have to be considered. Again, their development, according to a baseline scenario or to significant transformations, may have substantial effects on the accomplishment of the predefined projects.

Interestingly enough, though, the scenario approach followed for climate change forecasts or for land use changes has not been taken also for transportation networks. According to the Petersen et al. (2009) report, a rather simplified approach was adopted, confronting a baseline scenario with a more sustainable one. The first prolongs present conditions with minor changes, while the second forecasts larger economic and demographic growth, leading to increasing transport demand.

Differences between the two scenarios that may have an impact on risks and on coping capacities would derive from the level of integration achieved between countries as far as networks are concerned. The latter is minor in the baseline scenario, while major corridors designed in the current projects are expected to be completed under the sustainable scenario. The two configurations (more or less connection among countries) delineate different imaginable outcomes regarding hazards and vulnerabilities. While interactions with hazardous areas can be envisaged in both configurations, as shown by the case of the Swedish railway modernisation project described in Box 5.6, as for systemic vulnerabilities, related to interdependencies, the second scenario is clearly more challenging.

Hazards that have impacts on key nodes can therefore be particularly disruptive, although an overall increase in connectivity may make the adjustment to "unusual network" conditions more flexible. However, there would be a need to address such risk factors both in the detailed design of networks and in the forecast of their operational stage. Both aspects seem, at least in the accessed documents, poorly considered.

Furthermore, interconnections between different types of infrastructures should be considered, for example between energy supply and transport. Interdependencies between the two are essential to prepare both for occasional contingencies and to guarantee long-term measures are taken to prevent extreme events from disrupting critical nodes or affecting the entire network in multiple locations at the same time.

Information and communication technologies provide a third form of critical infrastructure that European societies have become increasingly reliant upon. Information and data have become an increasingly valuable resource, around which economic activities and patterns of retail and commercial activity have been reformed. For some time aspirations of growth in the "knowledge economy", as outlined in the Lisbon strategy, have been seen as dependent on the significant growth of the ICT sector. ICT have increasingly been seen as drivers of innovation, as tools for transforming government and business models, and as instruments for improving our quality of life. There has been a rapid increase in the availability and use of ICT. In broadband take-up, the emergence of new services and access to *e*Government, the leading EU countries are world leaders (EC, 2007a). For example, in 2007 the EU drew parallel with Japan and the USA in respect to its broadband market penetration, exhibiting a growth rate of 16% mostly fed by competition through "loop unbundling", where companies compete to rent the "last mile" of loop from the national incumbent (ECTA, 2007).

With this increasing connectivity there has been a concurrent growth in *e*commerce, with growth rates of 50% per year being experienced (although starting from a very low base of 2% of market share) (Regan, 2002). All trends in the future point towards a greater use of ICT and greater penetration into many areas of society. These patterns have not, however, been evenly distributed across the Member States and European regions.

Figure 5.16 shows the range of broadband penetration across the EU (in 2006), from Denmark's highest level of 29.3% to the Greece's lowest of only 2%. This inequality of service provision, and the implications it holds in relation to equitable development across the Member States, has been recognised by the European Commission explicitly in its invitation to all governments

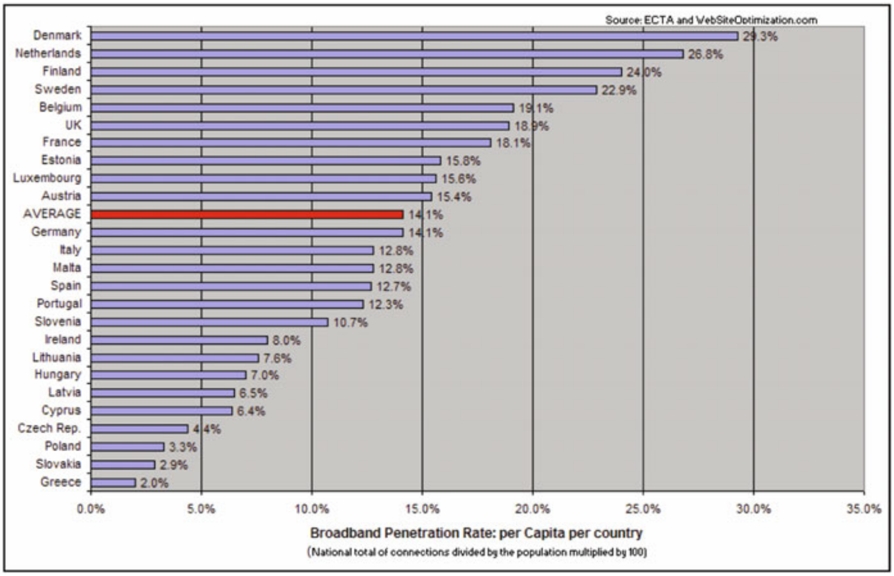


Fig. 5.16. Broadband penetration in European Member States (reported in the first quarter of 2006) (source: ECTA (2006))

to be more proactive in stimulating their national ICT sectors' growth (EC, 2006a).

From some perspectives the increased use of ICT is clearly beneficial for the collection and flow of information about risks and hazards and for the development of risk management tools. For example the EU are supporting concerted efforts to increase public access to hazard and risk information through the use of ICT, with the express intention of increasing the role of inclusive governance in risk management at all scales (Fabbri and Weets, 2005). Projects concentrating on improving the availability, interoperability and harmonisation-across-borders of ICT systems (e.g. the INSPIRE, ORCHESTRA and GMES initiatives) are also having measurable effects in influencing the risk management of trans-boundary hazards.

However, on the other hand, the increasing reliance and dependence on ICT across many areas of economic activity and everyday life means that disruptions can be particularly problematic and damaging. Hazard events may create disruption to ICT through the knock-on impacts of damage to electricity supply networks (see above), but also through direct impacts on information networks, key communication technology nodes, data stores and on end-user equipment.

Following the attacks on 9/11 and in Madrid and London, terrorism is viewed as the primary threat to critical infrastructure. However, experiences across Europe show that natural hazards and meteorological effects also

Box 5.7
Critical Infrastructure: The Mythe Water Pumping Station, Tewkesbury, UK.

In July 2007, during the series of extreme summer floods that affected broad swathes of the UK, a large section of the County of Gloucestershire was left without a mains water supply for up to a fortnight. This disruption occurred because during the event the Mythe water pumping station near the town of Tewkesbury was overwhelmed by flood water. Even though the station's close proximity to the main River Severn was obviously vital, due to the fact that it was built in order to extract water from it, there was still a great deal of shock and surprise expressed by the public, the water operator and the Environment Agency when the building was inundated (Henry and Smit, 2007).

The Mythe pumping station (circled) lies almost completely within the UK Environment Agency low probability (0.1%) flood outline and surrounded by the high probability (1%) flood outline (EA, 2005). Despite this the plant had insufficient structural flood defence and wassimply overwhelmed by the flood event whose return was subsequently calculated as being 1:150 years (EA, 2008). Due to the duration of the station's inundation, the need to pump-dry and service submerged equipment and a lack of pumping system redundancy, at the peak of the relief operation bottled or bowered potable water had to be provided for in the region of 350,000 of the water company's customers (Henry and Smit, 2007).

increase the risk of disruptions in a variety of ways. In accordance with this, an "all hazards approach with a terrorism priority" has been adopted into the concept of EPCIP (EC, 2006c). In some circumstances these disruption-causing effects might be reasonably foreseeable (see Box 5.7), in which case it might be possible for contingency measures to be put in place. Such contingency plans are regarded as anticipatory measures and as a means by which the robustness of a system can be increased. However, the increasing complexity of critical infrastructure systems makes the identification of their potential weaknesses, the hazards which might affect them and the full consequences of system failure harder to quantify. It is increasingly recognised that building system and societal resilience in face of failure may significantly counterbalance vulnerabilities and risks (Boin and McConnell, 2007).

5.7 Limits of Scenarios

While acknowledging the relevant role of scenarios to look into the future so as to be able to make sound decisions, in designing risk mitigation strategies, one must be also aware of their inherent limits.

The first, more obvious, is that scenarios cannot be verified in any scientific sense. They do not constitute theories but only assumptions about the future. Furthermore, they are often drawn with the precise intention to avoid the outcome described as possible. Therefore the success of scnarios cannot be judged upon its occurrence at the expected time. A successful outcome would rather be the non-occurrence of the feared scenario.

Another important limit derives from the lack of instruments to assess correct versus erroneous scenarios; partially this depends on the impossibility to validate or verify in any sense the scenario itself, but also from the variety of methods existing to derive scenarios. Those methods are partly qualitative and partly quantitative, and integration between the two is not easy. Because there are models about the future in specific fields, they share with models the more general fallacies that have been widely indicated for them, ranging from errors due to the quality and quantity of data available to run the model, to epistemic uncertainties.

The question of "how to judge scenarios" can be answered only in very relative terms. We can often tell when a scenario is clearly completely wrong and what elements make it rather unlikely; we may judge its usefulness in guiding actions and decisions towards better ends and positive outcomes (Rotmans et al., 2000; EEA, 2001). In light of these considerations the reader should take the scenarios that have been presented as coarse representations of basic drivers that may significantly influence the sectoral scenarios and their direct and indirect effects on hazards and vulnerabilities.

Images that have been proposed are not only affected by high levels of uncertainty, but are also grounded on a weak capacity to project even the "simplest" baseline scenario. The latter, in fact, rests on a less than optimal representation of current risks faced by Europe, as discussed in Chapter 2.

Scenarios have to be taken as input for highlighting systemic connections that have been little addressed in the past by both research and mitigation strategies and that deserve to be analysed in those aspects that seem more strategic (like critical infrastructures) or where our knowledge is clearly missing.

Among the many trajectories that could be taken in future projects, a couple will be briefly mentioned here. The first refers to the selection and identification of the most meaningful scenarios as far as their direct or indirect consequences for risks are concerned. As shown in Section 5.2., a rather large variety of scenarios, storylines, have been developed, most of which have a strong policy-oriented goal. Difficulties that can be encountered then in extracting projections from storytellings may depend on the characterisation of the latter rather than on how they may influence the consequent links in the chain.

The second path for future studies is related to what has been just mentioned, that is working on the connections between one set of storytellings and the derived sectoral or thematic scenarios and further on looking at the consequent images of hazards and vulnerabilities. Perhaps the "if ...

then" approach that has been attempted in previous sections could be further explored to identify the critical outputs and features that each chain of connections between large trends and high-level policies may have, downscaling to sectors and individual regions.

Clearly, the gaps here are very large; the following chapter is therefore an attempt to look more closely to multiscalar links, considering the interconnections between large-scale phenomena and local impacts, as well as local phenomena with potential regional, national and even global effects. Those connections are often non-linear, implying ripple and amplification effects through systems, and emerging in the interfaces between societies and territories, infrastructures and a variety of stakeholders as well as in the modes of use of land, buildings and parts of cities.

6

From Global to Local and from Local to Global: Examples of Event Scenarios in Europe

A. Galderisi, J.P. Kropp, A. Ceudech, M. Kallache

This chapter logically follows the previous one. After having sketched some visions of future potential hazards and vulnerability patterns for Europe, here more specific event scenarios are developed. An attempt to combine hazards, exposure and vulnerabilities to obtain damage estimates is thought to be possible only with respect to individual threats, or to individual events, whose impacts can be evaluated across sectors of economy and society. According to the Scenario project this can be considered an important advancement in research with respect to what has been made up to now: current available risk assessments, indeed, generally consist of hazard assessments, with scarce or no consideration of vulnerability of exposed systems. Coherently with what has been stated in Chapter 3, not only direct physical losses have to be accounted for, but also indirect and secondary damages due to systemic links among elements or sectors, as well as the effects on physical assets of otherwise intangible organisational, social and institutional factors.

The type of scenarios that will be sketched in the following paragraphs responds to the features characterizing climate change storylines and industrial risk analysis as described in the previous chapter.

Codes developed within the IPCC have been implemented to estimate the consequences of sea level rise for different European national economies, with or without adaptation.

On the other hand, the concept of chain of losses and failures, that is clearly embedded in the Vesuvius scenario, derives from the concepts used in failure tree analysis as well as in other techniques of similar kind.

Both types of scenarios are oriented to support decision-making: in the first case a cost benefit analysis of mitigation measures is carried out; in the second the many consequences at different geographical scales, mainly on the Naples and Campania regional economy, of a Vesuvius volcanic crisis are appraised.

On purpose the two scenarios start from the opposite scales: the first explores the local differences of a global hazard whilst the second addresses the potential regional, national and European impacts of a local disaster.

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

The reason for this choice is not haphazard: it is meant to make the reader reflect on scale issues, on the importance of being able to evaluate aspects that have been sometimes dismissed as non relevant by scientists and economists with respect to disasters and their consequences.

With respect to the first scenario, sea level change is a considerable point of interest due to its potential impact on human populations living in the coastal regions and on islands. McGranahan et al. (2007) estimated that 10% of the world's and 13% of urban population worldwide settle in regions below an elevation of 10 m. Almost two-thirds of urban settlements with populations greater than 5 million fall, at least partly, in the zone. The high concentration of valuable natural and socio-economic assets in the coastal zone makes of sea level rise a significant concern (Watson et al. 2001). Although the response time of the oceans on a warming stimulus is much longer than that of the atmosphere, sea level rise must become an issue of long term planning. In particular due to the circumstance that infrastructures and other assets in coastal regions cannot be easily removed. Coastal zones are a major focus of human habitation and economic activity.

Nowadays, the costal systems are already negatively affected by a number of factors such as over-urbanization and high population increase rates. This enhances the socio-economic vulnerability and could constrain the adaptation capacity of coastal systems to sea level changes.

Scientists' capacity to forecast is limited by uncertainties, despite of the significant evidences that even worse situations occurred in history compared to those expected for the next 100yrs (cf. next section). Nevertheless current observed processes, e.g. the increase of sea surface temperature, the melting of Arctic sea and of Greenland's ice shield are alarming. The aim of the scenario is therefore to enlighten what are the conditions for EU countries to be able to put in place and benefit from adaptation measures.

The Vesuvius' scenario provides a qualitative description of a potential volcanic event which might occur in the Campania Region, Southern Italy, and of its main consequences. The scenario is mainly addressed at highlighting how, during an eruption, different volcanic phenomena characterized by different lengths and affecting heterogeneous territorial targets, may induce numerous types of damages, failures and troubles at different geographical scales, from the local one, whose extension largely depends on the hazard scale, up to a European or even a global scale, as recently demonstrated by the eruptions of the Eyjafjallajökull volcano in the South of Iceland.

The over national relevance of some local disasters has already been recognised by the European Union. In the last few years, indeed, two main steps towards European cooperation to face these kinds of events, have been undertaken. The first one was the establishment of the Community Mechanism for Civil Protection (Council Decision, 23rd October 2001) aimed at facilitating the co-operation in civil protection assistance interventions in case of major emergencies occurring inside or outside the European Union. To this aim, even a financial instrument was established (Council Decision, 5th March

2007) "under which financial assistance may be given, both as a contribution to improving the effectiveness of response to major emergencies, (...) and to enhancing preventive and preparedness measures for all kinds of emergencies". The second step was the establishment, in 2002, of the European Union Solidarity Fund, which has been activated in several cases of "major natural disasters", such as the 2002 floods in Central Europe (Germany, Austria, Czech Republic) which caused direct damages total to 14.3 billion Euros, the Molise earthquake in 2003 (1.6 billion Euros), the forest fires which occurred Portugal in the summer 2003 (1.3 billion Euros). As mentioned above, the EUSF supports actions in case of "major natural disaster"; more specifically, according to the present rules, it is activated when the estimated cost of the direct damage is over 3 billion Euros (2002 prices) or over the 0.6% of the gross domestic product of the hit State. Moreover, the Fund can be activated in case of an extraordinary regional disaster that affects the majority of the population of a region and has serious and lasting effects on its economic stability and living conditions. Proposals for a modification of the EUSF Regulation are still under discussion. The new EUSF would cover major crisis situations resulting from natural disasters as well as industrial/technological disasters, public health threats and acts of terrorism. Furthermore, the new Regulation proposes to lower the threshold for defining a "major" disaster (from 3 to 1 billion Euros) and new criteria, besides the quantitative ones, for mobilising the Fund.

The above mentioned modifications underline how difficult is to establish precise quantitative thresholds for defining a local disaster as a "major" one, requiring funds and means by the European Union. Besides, it has to be noticed that current thresholds are defined taking into account only the cost of direct damages, while indirect or secondary damages are neglected. Unfortunately, these damages are harder to quantify than physical ones and go generally "unreported" in case of event. Indirect damages generally result as a consequence of physical damage due to a hazardous event (e.g. losses in functioning of relevant activities or temporary unemployment due to physical damages to industries) and generally occur in the immediate aftermath of a hazardous event but also over a long period of time after the event itself, affecting areas wider than the one directly hit by the hazard. Permanent or temporary losses in relevant economic activities at local scale can also reverberate on macroeconomic variables, both at national and global scale.

In case of volcanic eruptions, systemic damages, not differently from the physical ones, may also occur in the immediate aftermath of the hazardous phenomena and although they are difficult to quantify in terms of economic losses, they largely contribute to multiply the negative effects of the hazardous event, affecting also remote areas, very far from the hazard source and the areas directly hit. The scale of the potential consequences of a local event largely depends, according to Chester et al. (2001), on "the strategic position of the threatened city within the economy of a country and/or region" or, as the Icelandic eruption occurred in April 2010 has shown, by the strategic role of the affected elements and systems.

Therefore, although in relation to the potential systemic damages due to a Vesuvius eruption, according to the role of the affected region in the national and European economic contexts, it might be easily suggested that substitution mechanisms could quickly take over the economic drawbacks due to the lack of export from the Campania region, other aspects should be considered as well.

First, the tsunami event in 2004 has shown how large the psychological and social impact of an event can be when European tourists are caught in the middle of a larger calamity, as it occurred in South-Eastern Asia. The challenge to deal with multilingual groups, stricken, shocked and in search of protection has to be faced not only by national authorities of the country where the disaster occurs, but also by diplomatic bodies located in the affected area. Among other concerns, the Communication from the Commission on Reinforcing the Union's Disasters Response Capacity adopted in 2008 addresses the question of how aid to European citizens must be provided by consulates and similar agencies regardless of their specific nationality.

Moreover, the complex chain of failures, troubles and damages, which has followed the recent eruption of the Eyjafjallajökull volcano in southern Iceland (April 2010), has largely demonstrated that also an event occurring in places which do not hold a relevant or strategic position within a wider economic context (as the South of Iceland), may induce damages in areas very far from the hazard source. In this case, indeed, the propagation of the volcanic ashes over a large area, from Europe to North America, due to the features of the ashes themselves and to meteorological conditions, has induced relevant consequences both at European and global scale.

Another aspect that should not be dismissed too easily concerns the potentially dramatic local economic consequences. The latter, although local, with little or no permanent influence at a larger scale in the global economy, could be still considered of European relevance, at least because of the solidarity principle at the basis of several tools and instruments in the field of protection from natural and technological hazards as mentioned above.

6.1 From Global to Local: Cost and Benefits of Adaptation to Sea Level Rise in Europe

A close link between sea level and temperature can be observed during the climate history (cf. Archer, 2006) (Fig. 6.1). Figure 6.1 implies that it holds only for an equilibrium climate a situation not given for today. During the Eocene (approx. 35 Mio yrs ago) earth did not had any polar ice caps and the sea level was 70 m higher than today (Barrett, 2003). 20.000 years ago during the last glacial maximum, the sea level was more than 100m lower than today and the climate up to 7°C colder. Assuming a very likely increase of global mean temperature of 3°C by 2100 currently a sea level rise of approximately 1 m is projected. If this projection is interpolated for an equilibrium climate,

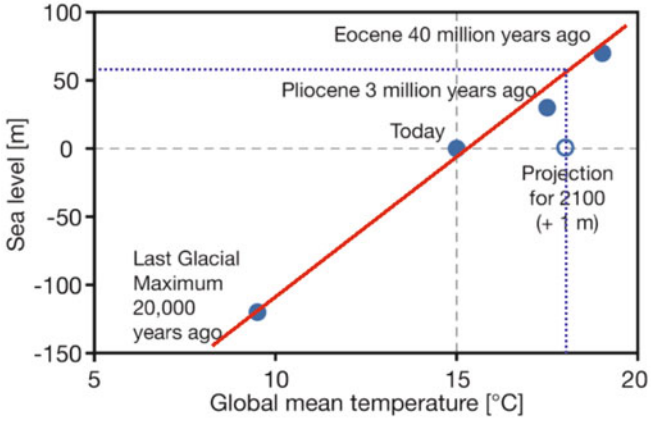


Fig. 6.1. Mean global temperature and sea level rise (relative to today's) at different times in Earth's history with the temperature projection for the year 2100 (from Archer, 2006)

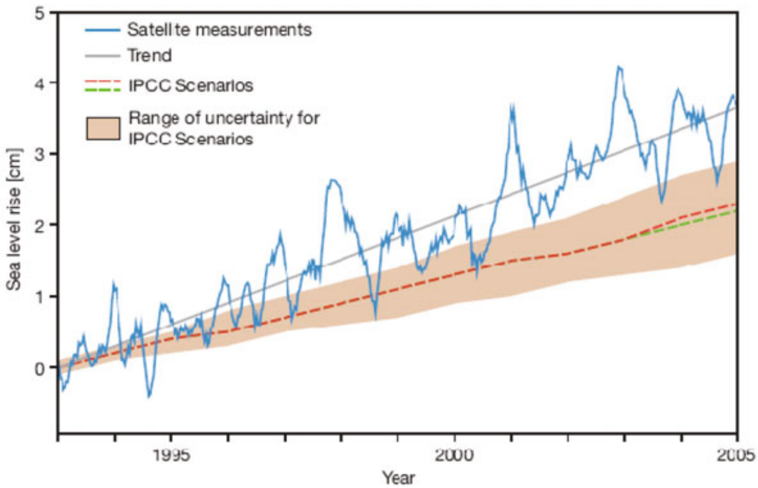


Fig. 6.2. Global sea-level rise recorded by satellite measurements with the projections of the IPCC (2001a) and it's range of uncertainty. Obviously the satellite measurements ly already above the estimates of the IPCC (2001a) and this situation could remain if considering results from more recent satellite measurements (e.g. Chen et al. 2006)

sea-level will rise more than 50 m. The WBGU (2006) estimates that already by 2300 sea-level could be 2.5–5 m higher than today.

The problem for the next 100 yrs is that there are large uncertainties how fast ocean and glaciers will respond to global warming. Recent results indicate that sea-level rise – which is an unavoidable consequence of global warm-

Table 6.1. IPCC (IPCC, 2007) estimates a sea-level rise between approx. 20 and 60 cm by 2100. Recent results imply that these estimates might be too low

Emissions	Forcing Scenario	Temperature change (K)		Sea-level rise (m)
		best estimate	variance	
low	B1	1.8	1.1 – 2.9	0.18 – 0.38
	A1T	2.4	1.4 – 3.8	0.20 – 0.45
	B2	2.4	1.4 – 3.8	0.20 – 0.43
	A1B	2.8	1.7 – 4.4	0.21 – 0.48
	A2	3.4	2.0 – 5.4	0.23 – 0.51
high	A1FI	4.0	2.4 – 6.4	0.26 – 0.59

ing directly correlated with hot temperatures (thermal expansion, melting of glaciers) – is accelerating and possibly underestimated. Rahmstorf (2007) estimated that sea-level rise could approach more than a meter by 2100. At least the uncertainty interval for sea-level rise estimates may be 50% too low (in the AR4 these recent results have not been included as they were published after the editorial deadline of the report, cf. Table 6.1). Further Greenland is losing ice at an ever-increasing rate, according to data from the GRACE gravity-measuring satellite (Chen et al. 2006).

The magnitude of the impacts of a sea-level increase on the costal zones will largely depend on local site characteristics (like population density or infrastructures). Due to the gradual and slow change on sea-level (derived from the long response time the ocean); perception of the risk by the population and decision makers may be difficult.

So far the above mentioned assessments focused mainly on the global scale, though scientists recognize that local situations may differ quite significantly from one place to another.

Local changes in sea level at any coastal location depend on the sum of global, regional and local factors and is termed relative sea-level change (Nicholls, 2002a). Over the main time scale of human concerns, relative sea level is the sum of three components: global-mean sea-level rise (cf. above), regional meteo-oceanographic factors and vertical land movement (Church et al. 2001). The latter is most important for the coast of Belgium, Netherlands, and Germany (land downlift, e.g. for Germany approx. 25cm per 100 yrs) and for the northern parts of Sweden, Finland and Norway (land uplift). The reason for this land movement is due the retreat of the approximately 3 km thick ice sheet covered large parts of Scandinavia during the last glacial maximum. The heavy load of ice depressed Scandinavian earth crust at least 600m below its present position (Tikkanen and Oksanen, 2002). As the ice started to decrease the crust began to rebound to the normal level. Parallel we had a wave effect. While the Scandianvian land mass depressed the North sea coast moved up. These processes are now on the other way round and still ongoing. During the 21st century, vertical land movement is expected to be less than the rise resulting from oceanographic changes at most locations (Nicholls and Lowe, 2004).

Regional meteo-oceanographic factors refer primary to regional differences on the thermal expansion effects and changes in the ocean currents (cf. Leverman et al. 2005). As long as the global sea-level trend is small, the regional processes can prevail and significantly influence the relative sea level rise, although, a more pronounced global sea level rise will eventually overcome the local effects.

Although a global mean sea-level rise will very likely have a negative impact on low lying coastal areas, the most destructive effects to the coastal zones may be provoked by storm surges.

Nowadays coastal zones are facing the prospect of changing storm statistic also as a consequence of climate change (Storch, 2006). Modifications of storms regime may lead to more frequent and higher intensity events implying larger risk of damages on these areas. Some regional studies were already conducted in order to evaluate the future behaviour of the occurrence of storm surges. For example, Storch (2006) predicts that under future climatic conditions, storm surges extremes may increase along the North Sea coast towards the end of this century and that mean sea-level rise essentially adds to the storm surge heights.

If the frequency of extreme storm surges events becomes shorter several socio-economic issues arise. The continued repair of damaged human infrastructures will start to become economically unsustainable, evacuating persons during storm surges events may also become more frequent an increased land lost will threaten the already stressed ecological ecosystems. All these impacts are plausible and are likely to lead to an increase economic loss over time for some coastal regions.

6.1.1 Assumptions for the Analysis

A local reassessment of sea-level rise for Europe's coastal countries has been performed in the context of the Scenario project. The *Dynamical Interactive Vulnerability Assessment* (DIVA) tool allows to calculate sea-level rise for specific regional coastline segments which enables local stakeholders to discuss adaptation under a regional perspective (DINAS COAST, 2004). The calculation is based on simulation runs provided by (i) the CLIMBER model (cf. Ganopolski et al. 2001) and (ii) by economic cost calculations based on the Tol (1995) and Yohe and Tol (2002). Regarding the costs of dike construction we refer to Hoozemans et al. (1993). Due to the above discussion we assume a regional sea-level-rise scenario (forced by A2) up to 1 m by 2100 (cf. Fig. 6.3). For two normative policy decisions we calculate the total damage and adaptation costs: (i) a business as usual scenario indicating that existing coastal protection buildings will be only maintained, and (ii) a protection against a

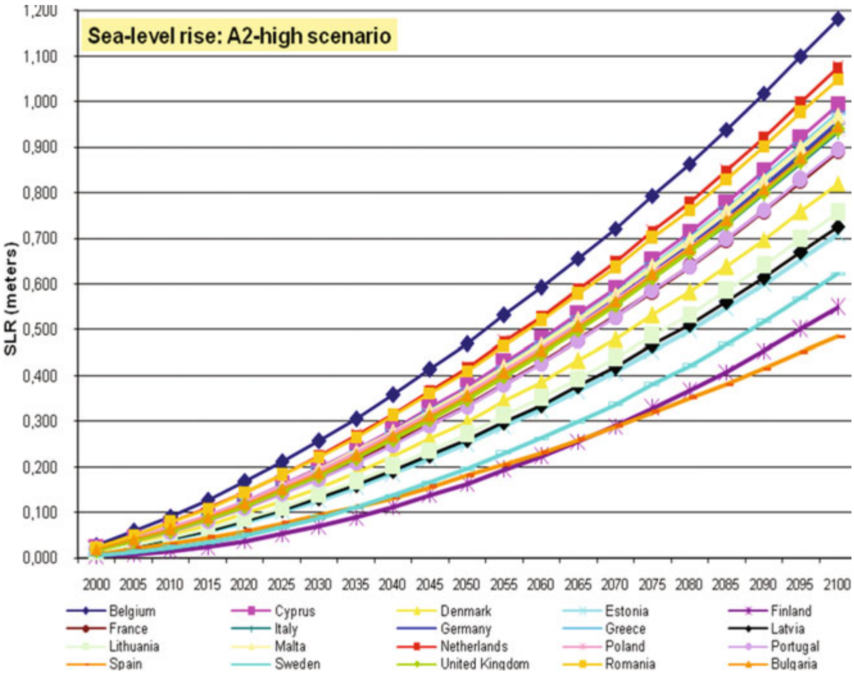


Fig. 6.3. Relative SLR projections for the European coastal countries under the A2 SLR scenario

sea flood with a return period of 100 yrs (common for example in Germany for the state of Schleswig Holstein, Table 6.2).

In general valuing the costs of climate change is a critical issue, as it is to produce any estimate of future costs. The standard procedure is discounting costs for the future in order to include inflation; economic growth is appraised projecting into the future the average growth of the last a hundred years.

Table 6.2. Total area to be protected in Schleswig-Holstein: approx. 3,700 km^2 (24% of total) with 350,000 inhabitants: North-Sea coast: +5m asl, Baltic coast +3m asl

Input measure	*Characteristics*
Level estimate for a 100 yr flood	Statistical measure
Safety surplus (0.5m)	"Rule of thumb" related to estimate's uncertainty and potential climate change
Wave ramp level	Local feature, normally less data
Wind pressure and main direction	Local feature, normally less data
Result: design flood value (DFV) for sea-dikes; Evaluation of DFV any 10–15 yrs.	

Therefore, economic calculations are based on more or less vague assumptions. But there exists an agreement that climate change adaptation/mitigation will cost only 10–20% (global GDP estimate) of that amount which will necessary in the case of non-adaptation (WBGU, 2004; Stern, 2006). But focussing in regions this picture might differ fundamentally, since the environmental settings of regions can be quite different. This also partly expressed in the analysis presented here. The analysis combines benefits of coastal protection buildings and a chosen protection level. For instance, if the protection level is zero then also the benefit is zero. If the protection level increases also the benefit may increase. To estimate this, income levels, design flood values for the dikes (is a normative measure and can be, therefore, defined in the simulation tool) and return periods of flood events (statistical calculation) are necessary. The total adaptation costs are defined as: $TAC = rdc + sdc + bnc + wnc$, where *rdc* are the river dike, *sdc* the sea dike, *bnc* the beach nourishment, and *wnc* the wetland nourishment costs. The total damage costs are a sum of $TDC = sfc + rfc + llc + mc + sic$ where *sfc* are sea flood costs, *rfc* the river flood cost, *llc* land loss costs, *mc* the migration costs (due to land loss) and *sic* the cost associated to salinity intrusion. The scenarios for the income development are based on the IMAGE model (IMAGE Team, 2002). The climate impact considered in the DIVA assessment model is only the sea level rise. This implies that storm tracks, frequency and intensity of storms are constant during the next 100 yrs (this is an important simplification, cf. comments above cf. also Leckebusch and Ulbrich, 2004).

The estimated costs consider the coastal elevation profile of a region, the income density in this region, the actually flooded area and a maximum flood height. The result depends on the events being considered, as e.g. a 10, 100 or 1,000 yrs event. To compute the costs related to migration, the land permanently flooded and the population density in the area of concern have been considered. The economic value e.g. of houses, is 3 times the per capita income per resident.

In order to estimate the costs adequately we compare both policy scenarios for each European coastal country, e.g. by summing up the costs for the whole 21st century. Therefore $TAC_{cum} = TAC_{BAU} - TAC_{100yr}$ and $TDC_{cum} = TDC_{BAU} - TDC_{100yr}$. Further we normalise the two cost categories to the 2006 country GDP in order to obtain a relative measure. For a few countries Fig. 6.4 shows that under the assumed forcing scenario in case of the business-as-usual scenario the protection level falls below the normative 100yr goal at different points in time. Besides the impact of sea-level rise this has also to do e.g. with specific orographic features and/or influences of the land up-/downlift for the different European countries. But another point becomes important here when calculating the adaptation costs. Obviously countries like Estonia and Poland should benefit most from investments in coastal protection. But cost assessments show differences which are not easy to explain (Fig. 6.5).

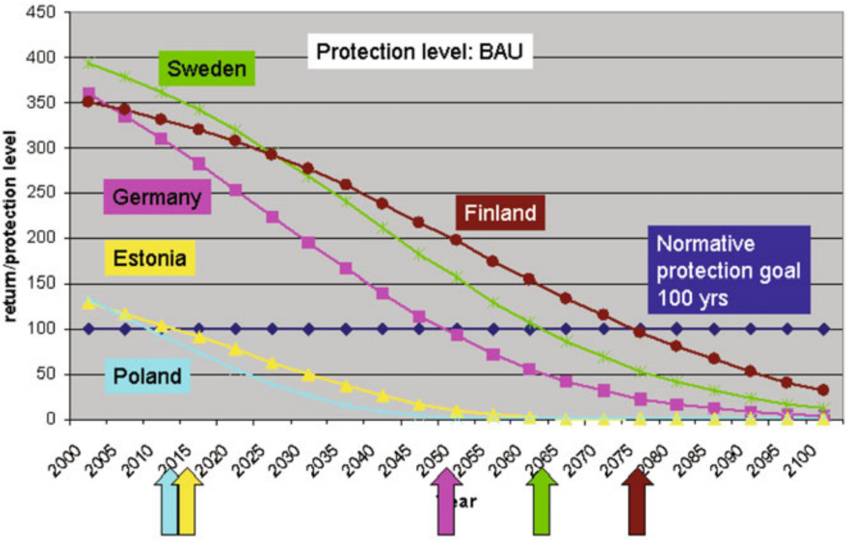


Fig. 6.4. Average protection level under the A2 SLR scenario (2000–2100): Here it seems that Estonia and Poland would have the largest benefit when they invest in coastal adaptation, because their coastal protection falls already below the 100 yr level by 2015. But also well protected countries like Germany has to readjust their coastal protection strategies beyond 2050. BAU stands for "business-as usual"

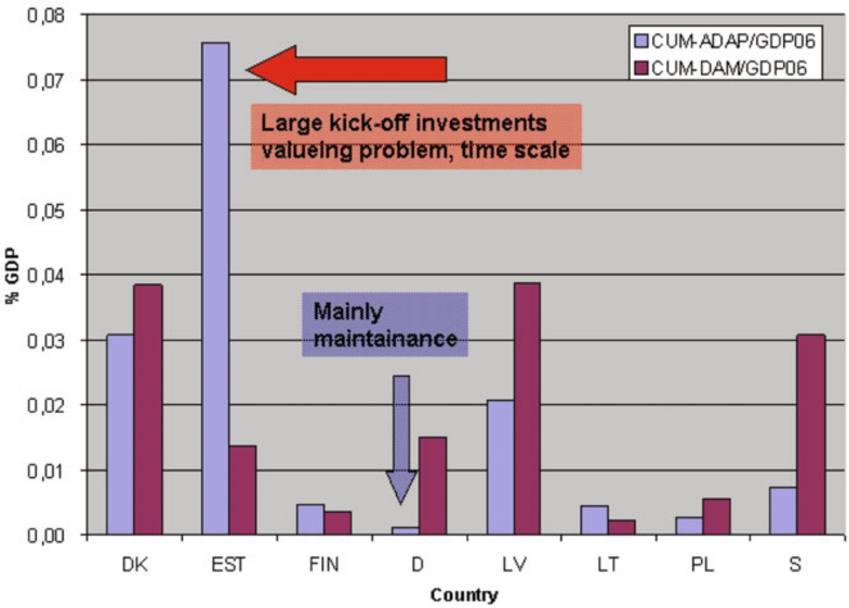


Fig. 6.5. Normalised cumulative damage and adaptation costs for different European countries

Eye-catching is that although Estonia's protection level is already rather low the investments in coastal protection is rather high in comparison to avoided damages.

The overall balance becomes negative. This result can be explained as follows: because Estonia currently does not have sufficient coastal protection, large kick-off investments are necessary to guarantee the normative goal of 100yrs. Furthermore, Estonia's coastlines are mainly rural areas and it might be that it makes no sense to protect agricultural land and forests by large dikes. On the other hand these are natural assets for Estonia, rather important as tourists attraction. Whether Estonia decides to protect their coast is again a normative decision. The assessments presented here could only provide an idea of how political decisions come into effect. Furthermore the results depend also on the time frame. In particular, I might be that the investments amortise beyond 2100. However, the example shows that each economic analysis has limits, deriving from additional assumptions which must be clearly communicated. But the results are also consistent, since for the example of Germany (Fig. 6.5) the low investment costs can be explained by the situation that Germany has already large dikes. These must only maintained and increased, kick-off investments are not necessary. A more refined comparison was performed, showing lands below 1 m height divided between rural and urban uses (Fig. 6.6). It permits to understand the apparent contradiction mentioned above, regarding the return of investment of adaptive policies in different countries (particularly the case of Estonia).

Figure 6.7 in general show the European wide synthesis of this study. Almost all coastal countries will benefit from coastal adaptation, in particular in the second half of the 21st century. The highest cumulative benefits are gained by the Netherlands, Belgium, France, UK, Malta and Sweden (2–6% GDP). For Estonia, Romania, Spain, Finland, Cyprus, and Lithuania the

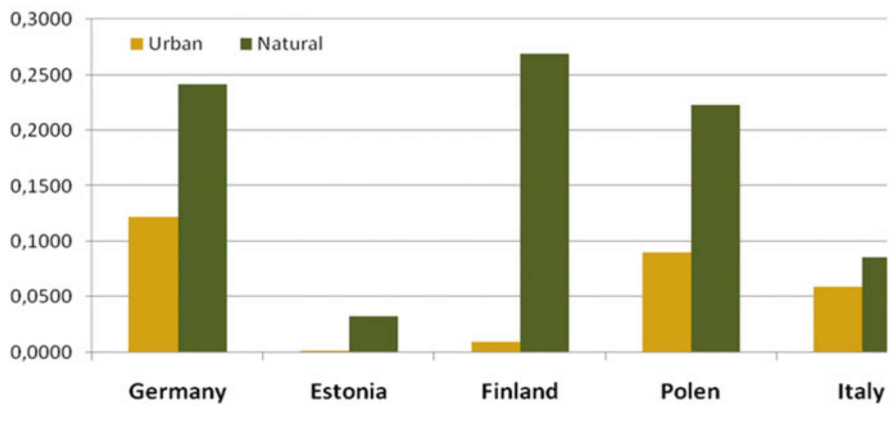


Fig. 6.6. Km^2 of urban/agricultural land below 1 meter elevation per km of coastline for different European countries

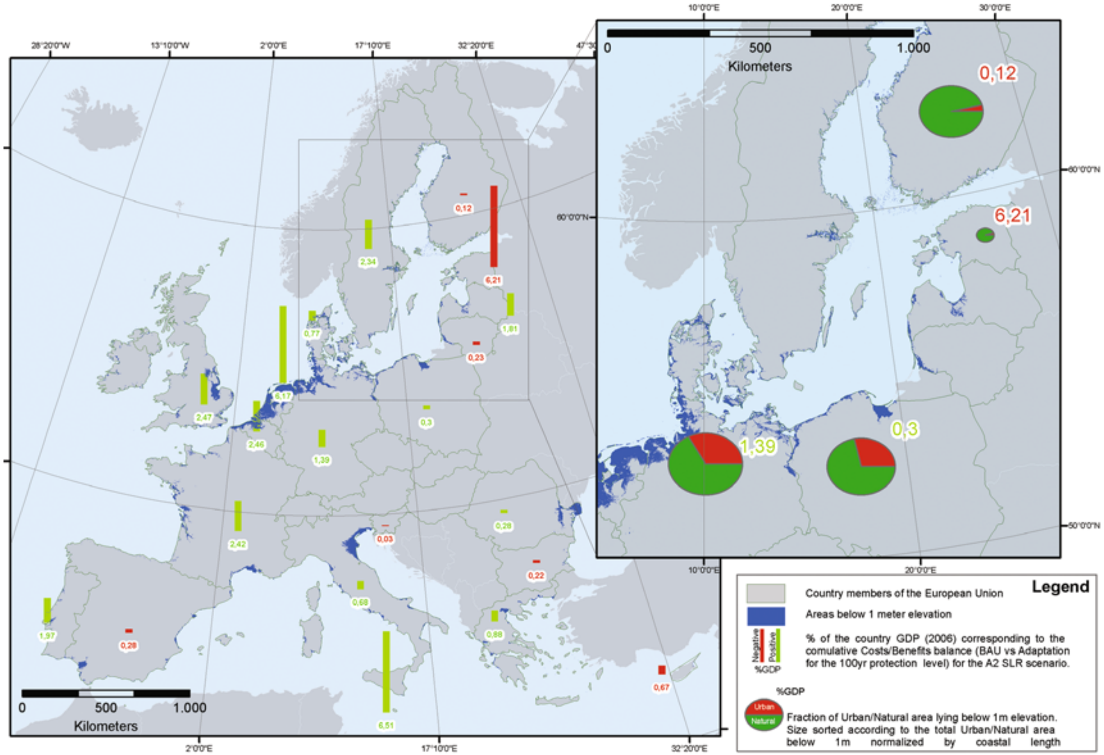


Fig. 6.7. Cumulative Cost/Benefit (BAU vs. 100 yr average protection level, A2forced SLR scenario (2000–2100) normalized to Country GDP (2006). The map shows also where are the most risk prone areas are located (blue below 1 m) independent from the question whether coastal protection buildings exist or not

cumulative balance will be negative (−0.3 bis −6% GDP). But once again, each protection target is normative and depends on the nation's willingness to pay. But the values allow also another interpretation: the higher the negative values the more vulnerable the countries could be in economic terms. Since it might be that a country GDP is too weak in economic terms in order to make to achieve the benefits of coastal protection. The lower the value the easier it is to achieve the benefits (under the assumption that the economic situation in the country remain similar in the future).

6.2 From Local to Global: The Vesuvius Risk Scenario to Explore Physical and Systemic Impacts

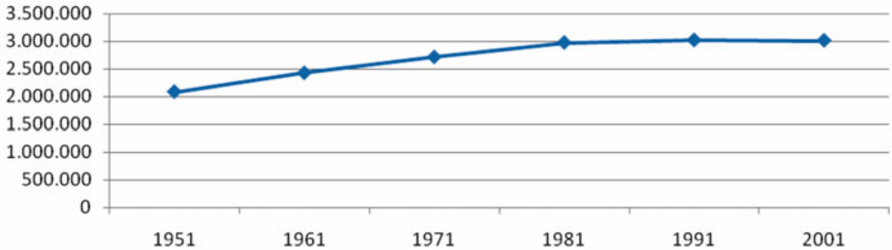
6.2.1 The Vesuvian Area

The hazardous features of the Province of Naples, combined with the current development trends in this area, highlight a very alarming situation: more than 3 millions of inhabitants, about the 53% of the population of the Campania Region, are tightened between the two volcanic areas of the Vesuvius and the "Campi Flegrei".
Namely, Vesuvius volcano is very well known all around the world as a high risky volcanic complex, because of its eruptive type, which is predominantly explosive and, even more, because of its proximity to densely populated urban area of Naples.

It is worth noting that the last eruption of the Mount Vesuvius occurred in 1944. Starting from the Fifties and up to now, the Province of Naples has been characterized by phenomena of intensive urbanization, increase of population and relevant growth of illegal buildings so that currently this area is one of the widest and most densely populated volcanic region in Europe.

The demographic trend of the population in the Province of Naples (Table 6.3) shows a relevant increase in the last decades: from two million people in 1951 to more than three million in 1991. Nevertheless, the rates of growth are very different: over the time span 1951–1961, the population growth was really significant, with a rate of 16,4% in ten years. During the

Table 6.3. The demographic trend of the population in the Province of Naples



following two decades (1961–1971; 1971–1981), the rate was respectively equal to 11,9% and 9,6%. Over the 1981–1991 decade, the population had a light increase with a low growth rate (1,5%); finally, in the last decade (1991–2001), a light decrease has been registered (−0,2%), highlighting a tendency toward the stabilization of the demographic trend.

The Vesuvian area is a relevant part of the Province of Naples and the Vesuvius is one of the most studied volcano around the world. Based on the eruptive history of the volcano, the in-depth analysis of the volcanic hazard allowed scientists to define the maximum expected hazardous event and, according to this, to identify, three zones characterised by different phenomena:

- *the red zone*: an area of 240 km^2 potentially affected by pyroclastic flows, lahars and tephra falls, which includes 18 Municipalities belonging to the Province of Naples (about 552.000 inhabitants, according to the ISTAT data 2001)
- *the yellow zone*: an area of 1.100 km^2 potentially affected by ash falls, including 96 Municipalities (1.075.070 inhabitants, according to the ISTAT data 2001), of which 34 comprised in the Province of Naples
- *the blue zone,* which is the part of the wider yellow one, mostly affected by hydro-geological phenomena (floods, mudflows, etc.), including 14 Municipalities, all of them comprised in the Province of Naples.

Table 6.4. Population of the municipalities of the Vesuvius' red zone 1991–2009 (source: Istat data)

Municipalities	*1991*	*2001*	*2002*	*2003*	*2004*	*2005*	*2009 (01–01)*	*2005–2009 (%)*	*2001–2005 (%)*	*1991–2005 (%)*
Boscoreale	27,310	27,618	27,663	27,715	27,616	27,326	26,996	−1.21	−1.0	0.06
Boscotrecase	11,295	10,638	10,642	10,781	10,817	10,875	10,595	−2.57	2.23	−3.7
Cercola	16,901	18,876	18,901	19,127	19,277	19,165	19,161	−0.02	1.53	13.4
Ercolano	61,233	56,728	56,728	56,549	56,174	55,261	55,118	−0.26	−2.6	−9.7
Massa di Somma	5,490	5,900	5,920	5,930	5,930	5,920	5,805	−1.96	0.22	7.81
Ottaviano	21,973	22,670	22,685	22,648	23,284	23,519	23,733	0.91	3.75	7.04
Pollena Trocchia	12,216	13,326	13,359	13,498	13,535	13,756	13,719	−0.27	3.23	12.6
Pompei	25,177	25,751	25,678	25,702	25,820	25,728	25,768	0.16	−0.0	2.19
Portici	68,980	60,218	60,068	59,156	58,494	57,059	54,743	−4.06	−5.2	−17.28
S. Giorgio a Cremano	62,258	50,763	50,585	50,332	50,222	48,777	47,031	−3.58	−3.9	−21.65
S. Giuseppe Vesuviano	26,336	24,531	24,689	24,825	25,272	27,871	28,120	0.89	13.6	5.83
S. Sebastiano al Vesuvio	9,480	9,840	9,840	9,920	9,890	9,800	9,571	−2.34	−0.5	3.31
Sant'Anastasia	27,300	28,023	28,047	28,086	28,367	28,040	28,871	2.96	0.06	2.71
Somma Ves.	29,079	33,261	33,259	33,374	33,671	34,196	34,754	1.63	2.81	17.6
Terzigno	13,653	15,870	15,923	16,310	16,806	16,985	17,565	3.41	7.03	24.4
Torre Annunziata	52,875	48,011	48,008	47,666	47,780	47,959	44,386	−7.45	−0.1	−9.3
Torre del Greco	101,36	90,607	90,465	89,661	89,198	88,372	87,735	−0.72	−2.4	−12.81
Trecase	9,590	9,170	9,140	9,120	9,100	9,150	9,300	1.59	−0.2	−4.6
Total	582,52	551,83	551,64	550,41	551,26	549,76	542,971	−1,21	−0.3	−5.6

As for the Municipalities around the Vesuvius' crater, the population included in the red-zone has decreased over the period 1991–2009 (Table 6.4). The total population amounted to 582.520 in 1991; 549.764 in 2005 and 542.971 people in 2009, with a decrease of 32.756 inhabitants from 1991 to 2005 (−5,62%) and a further, lighter decrease in the last years equal to −1,21%.

The Vesuvian area can be considered ad "a good example of how risk can increase dramatically in a short time because value and vulnerability increase much faster than hazard. In 1944 about 300,000 people were living on its slopes. That population has more than doubled while schools and hospitals have been built on the volcano's slopes where in recent centuries eruptive vents opened" (Marzocchi et al. 2004).

6.2.2 A Brief Vesuvius' Eruptive History

The evolution of the Somma-Vesuvius and its eruptive history has been in depth analysed by volcanologists (Cioni et al. 1999; Orsi, 2001; Cioni et al. 2003) and it is very well synthesized on the website of the "Osservatorio Vesuviano" (http://www.ov.ingv.it/ vesuvio.html).

It is worth just reminding here that "the Somma-Vesuvius volcanic complex consists of an older volcano dissected by a summit caldera, Monte Somma, and a recent cone, the Vesuvius, which grew within the caldera after the AD 79 Pompeii eruption" (Cioni et al. 1999). The eruptive history of the volcanic complex is sketched in Fig. 6.8.

"During its eruptive history Vesuvius often experienced long periods of quiescence that lasted, in some cases, centuries or tens of centuries, with an *awakening* more and more violent the longer the repose-time preceding the eruption was" (Cioni et al. 2003). The first and largest Plinian event (Pomici di Base eruption) occurred about 18.300 years BP. Other Plinian eruptions occurred about 8000 years BP (Pomici di Mercato), 3800 years BP (Pomici di Avellino), and on AD 79 ("Pompeii" eruption). The two most recent events occurred in AD 472 and AD 1631 (Fig. 6.9). "Alternating with these major eruptions, several smaller explosive eruptions occurred" (Cioni et al. 2003).

Between 1631 and 1944 the volcano had his last phase of activity (with open conduit), characterized by quiescent eruptive cycles. The 1944 eruption started the new phase of activity (with obstructed conduit) which currently characterizes the volcano (Fig. 6.8).

6.2.3 Prevention and Mitigation Practices

Dealing with the volcanic hazard, prevention and mitigation measures addressed both to act on the hazard source and to reduce the other risk factors, namely exposure and vulnerability, as well as actions aimed at improving the emergency response of the hit communities, are required.

As regards the first group of measures, even though the hazardous event cannot be avoided, an effective monitoring network, providing constantly

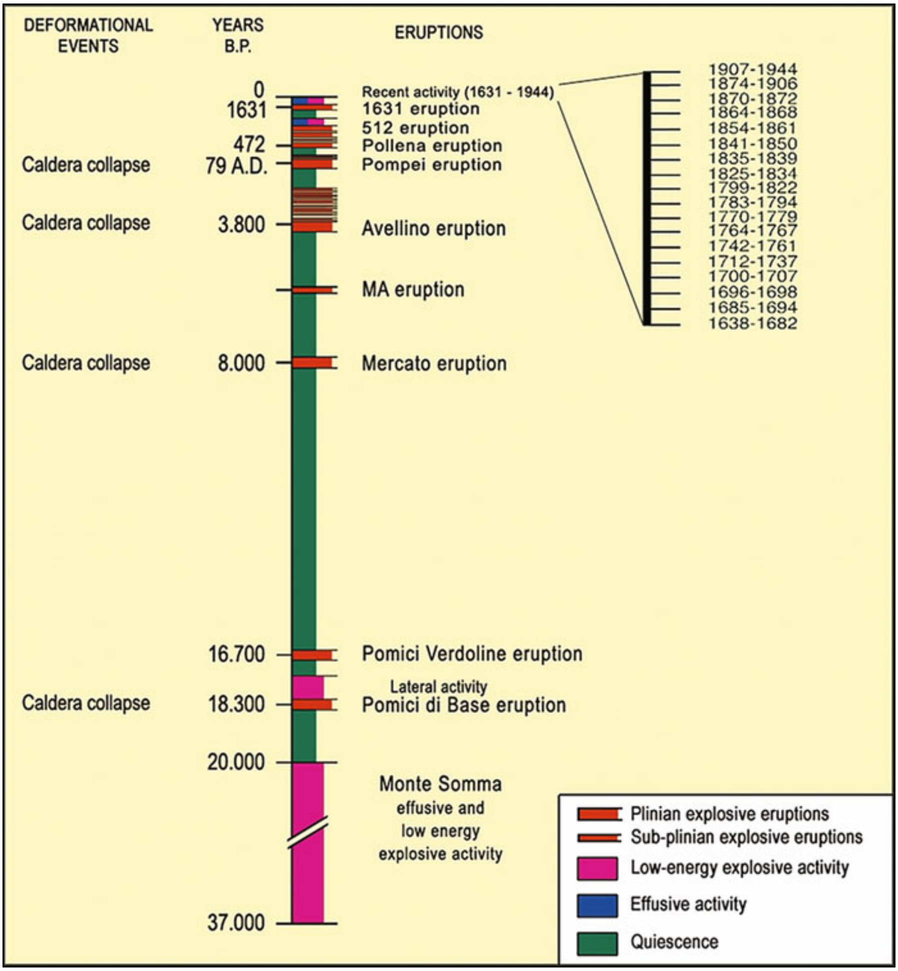


Fig. 6.8. The eruptive history of the Somma-Vesuvio (source: Osservatorio Vesuviano, 2004)

updated information on the state of the volcano, may support a comprehensive warning system. Volcanic crisis are indeed generally preceded by different precursory phenomena.

Currently, the Vesuvius monitoring network takes into account seismic activity, ground deformation and gas emissions. Data, recorded by the monitoring network, are analyzed through automatic procedures and managed by the Italian National Institute of Geophysics and Volcanology (INGV) through its Vesuvius Observatory. The surveillance system is linked to the Civil Protection Department, although an automatic system for sending warning messages is available only internally, while the communication with Civil Protection are in charge to monitoring operators, whose task is to validate and re-elaborate inputs provided by the automatic systems.

As specified in the Civil Protection Emergency Plan for the Vesuvius Civil Protection, together with other Organizations involved in the emergency management and grounding on monitoring data provided by the Vesuvius Observatory, defines the level of alert (attention, pre-alarm, alarm) and activates the planned procedures in the case of emergency.

The first release of the National Emergency Plan was developed in 1995 and updated in 2001. It was developed taking as a reference a sub-Plinian eruption like the one occurred in 1631, identified by scientists as the maximum likely event to be expected (Dipartimento della Protezione Civile 2005). Based on such a scenario, the Vesuvian area has been divided, as mentioned above, into three different zones (red, yellow and blue) according to the different volcanic phenomena each zone is exposed to. For people living in the red zone (about 550.000 inhabitants), the Plan provides rules and actions for evacuation. In detail, each Italian Region has been coupled with a municipality of the red zone. This coordination allows a better logistic and administrative management of the crisis. If necessary, people to be evacuated from the yellow and blue zone will be allocated in safe areas of the Campania Region itself.

As far as measures aimed at reducing exposure and vulnerability of elements at risk are concerned, it has to be highlighted that in the last few years numerous structural and regulatory measures have been developed.

First of all, it is worth mentioning that the area is interested by many Plans, all of them referred to a wide scale, such as the Regional Plan, the Provincial Coordination Plan, the Plan for the Vesuvius National Park, the Landscape Plan, the Hydro-geological Priority Plans of the North West and Sarno Basin Authorities. All of them are mainly addressed to safeguard natural resources and to reduce the overall risk in this area.

Moreover, based on the consciousness that the effectiveness of the National Emergency Plan would be higher if specific actions aimed at reducing the residential density, modifying urban shape and implementing suitable exodus ways were carried out, Campania Regional Authority issued some acts and implemented several initiatives addressed to pursue these aims.

The “Vesuvia” project (Vesuvius Risk Mitigation Program) started in 2003 has involved different administrative levels in an integrated land use management of the red zone, aimed at achieving different goals. The most relevant is to lower residential density, relocating those who have not been living there for long. To achieve this goal, a voluntary movement of the population has been encouraged through economic incentives for buying houses out from the red zone. Another goal is to stop building new dwellings and to guarantee infrastructures to permit dislocated people to commute to the red zone for work. These actions are described in the Campania Region Act n° 21 issued in 2003, “Town-planning rules for municipalities of the Vesuvian area prone to volcanic risk”. Moreover, a massive repression program against illegal buildings has been undertaken and the conversion of existing residential buildings into industrial, tourist, tertiary facilities and public interest facilities is favoured through economic incentives.

Furthermore, the Regional Law n.21/2003 introduced the Operative Strategic Plan (OSP) for the Vesuvian area, characterized by both binding and strategic contents. There are "no models available for this plan" (Sepe, 2007) and it has required innovative solutions for its elaboration and for its integration into the complex system of planning rules at different levels affecting the area. The OSP is not only a program of demographic lightening, but it is based on a wider strategy, addressed to the requalification and the development of the Vesuvian area. The OSP, according to the most critical features of the area, includes two types of strategies aimed at reducing risk conditions: widespread safeguard actions, aimed at reducing population and improving infrastructure networks in hazardous areas; targeted regenerative actions in strategic areas (Fiore et al. 2007). Besides, the OSP has introduced land use mechanisms providing awards, such as the possibility to increase the not-residential surfaces, for projects which favour the achievement of the Plan's objectives. Public interventions and land use planning awards are covered not only by means of structural EU funds (2007–2013), national and regional funds, but also through local private funds (Cinque and Mazzella, 2007).

6.3 The Vesuvius' Scenario

6.3.1 Aims, Features and Structure of the Scenario

The Vesuvius' scenario has been addressed, as mentioned above, to show the relevance at different geographical scale (regional, European, global), of a local event in terms both of people, network infrastructures, economic activities potentially involved (physical impacts) and in terms of "systemic" impacts, which are generally due to the interdependencies among elements or systems located in the affected area and elements or systems located in the surrounding ones or even in areas far from the affected one but functionally or economically linked to it.

The basic idea which has driven the setting up of the Vesuvius' scenario is that an event like a Vesuvius' eruption, which may be classified as a local one, may potentially induce not only physical damages affecting the areas surrounding the volcano, but also systemic, functional, and economic ones, at wider geographical scales. A volcanic event occurring today in proximity to a large urban area "would be devastating for the city in question, could cause disruption to the economy of an important economic region, and have effects throughout the world, including significant global climatic changes" (Chester et al. 2001). Moreover, as clearly highlighted by the recent volcanic eruption in Iceland, although it occurs far from large cities, it may threaten relevant strategic systems, in that case airlines, causing relevant economic damages to different sectors and at different scales.

Hence, the Vesuvius' scenario has been addressed to highlight what could happen in case of a disruptive volcanic event occurring today or in a short time span in the Vesuvian area and, according to the dynamic features of the hazardous event, to provide quantitative data related to people and buildings potentially involved and a description of the main systemic damages. Thus, the proposed scenario refers to a potential volcanic event and to its consequences both in the immediate aftermath of the event and in a medium-long time period.

The potential volcanic event or, better, the reference event has been defined, according to the main available results currently achieved by volcanologists, as the maximum expected one in case of unrest of the Vesuvius in a time period of 10 years.

The Vesuvius' scenario presented here has been conceived as descriptive, to provide a qualitative description of the temporal and spatial evolution of the volcanic phenomena which characterize the reference event, of their potential physical and systemic impacts were the current exposure and vulnerability left as they currently are. Such a choice is due to several considerations: first of all, the demographic trend seems to be quite stable over the last decades; moreover, according to the current land use planning, no further increase of the building stock in the Vesuvian area is allowed; finally, the measures aimed at reducing the exposed population have not been taken into account since, as mentioned above, they have been approved quite recently and they have not proved to be as effective as initially thought yet.

Some problems have arisen in the development of such a complete event scenario, that must be accounted for before presenting the results.

First of all, as far as the event is concerned, it has to be considered that volcanic events are characterized by different phenomena, temporally and spatially articulated.

Thus, a crucial point for the development of the scenario has been, apart from the choice of a given reference event, the definition both of the main phenomena associated to the selected event and of their temporal and spatial distribution.

The second key point has been related to the definition of the potential involved targets (elements or systems): in case of volcanic events, indeed, the potential targets will change over time and across space as a consequence not only of the intrinsic dynamism of volcanic events over time (each volcanic phenomenon occurring in each phase of the eruption and affecting different areas may involve different targets) but also of the mitigation actions which can be activated before and during the event. In detail, due to possibility to foreseen a volcanic eruption several days before the event and to the temporal length of volcanic eruptions, spatial changes of exposed elements may occur as a consequence of emergency procedures activated before or during the eruption and of people behaviours in face of the event itself.

Another crucial point can be referred to the identification of the numerous and heterogeneous damages or failures which may occur, in each phase of the eruption, in different areas.

To better understand temporal and spatial distribution of damages, first of all, physical and systemic damages have to be firstly distinguished.

Both of them change over time and across space; spatial distribution of physical damages largely depend on the spatial variability of the volcanic phenomena themselves which, over time affect different areas and targets, let different physical vulnerabilities arising within the same area or in different areas. Systemic damages may occur as a consequence of some volcanic phenomena or of some physical damages and can be relevant at different scales (local, regional, national, European, etc.).

The relevance and the potential large scale spread of systemic damages in case of volcanic events have been also clearly highlighted by the eruption of the Eyjafjallajökull volcano in southern Iceland occurred on the 14th of April 2010. In past Vesuvius eruptions, it is worth mentioning the fact that during the Second World War, in 1944, the Vesuvius eruption provoked serious damages to the military airport built up in Terzigno, destroying some equipments of the American forces and causing the stop of the military actions in the area.

The main steps followed for developing the Vesuvius scenario are synthesized in Fig. 6.9. It is worth noting that, although the scenario is mainly addressed to show the complex chains of damages and failures which may be activated by a given eruption rather than to provide predictions about future eruptions, the scenario structure has been articulated in three main blocks: the first one refers to the selection and the characterization of the reference event as the size of the expected event is relevant to the definition of its consequences; the second one is addressed to define the potential targets of each volcanic phenomenon; the third one is focused on the definition of potential impacts and damages.

6.3.2 The Reference Volcanic Event and its Main Targets

The first step for the scenario development is related, as sketched in Fig. 6.9, to the selection of the reference event.

As suggested by Marzocchi et al. (2004), "eruptive mechanism have so much intrinsic aleatory uncertainty and our knowledge is too rudimentary to make precise and unequivocal prediction of the magnitude of the next event" (Marzocchi et al. 2004) Two reference events were selected for the scenario development: the most likely and the maximum expected in case of unrest in the next 10 years. Those events were chosen following available results achieved by volcanologists.

Scientific literature drove us to exclude events characterised by a VEI (Volcanic Explosivity Index) minor than 2 and to focus on events characterised by

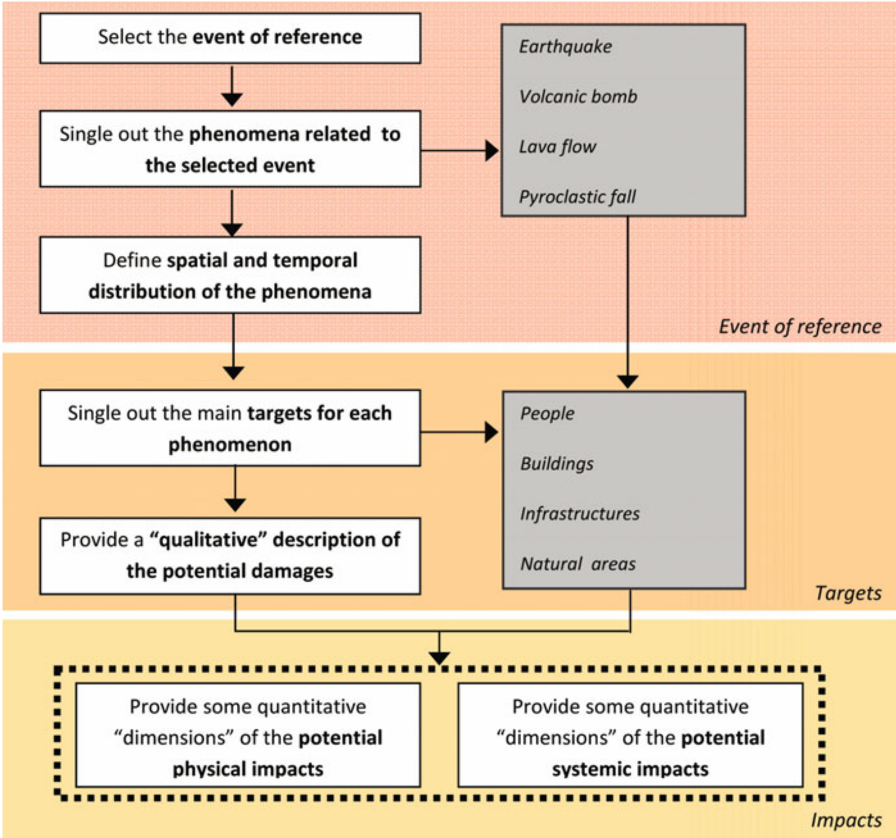


Fig. 6.9. The Vesuvius' scenario structure

VEI values included between 3 and 5 in the considered time frame (Marzocchi et al. 2004; Gasparini, 2007).

Subplinian (VEI 3 and 4) and Plinian (VEI 5) eruptions are characterized by a similar sequence of phenomena, although with different intensities and, consequently, different temporal evolution and spatial distribution.

Among them, according to the Emergency National Plan of the Vesuvius, a VEI 4 event (comparable to the 1631 Vesuvius eruption) has been selected as the reference event for developing the comprehensive scenario or, better, for defining the complex chain of volcanic phenomena, impacts and damages. The 1631 eruption was the most severe one in recent times, which caused more than 4.000 victims and lasted only 48 hours (see Box 6.1).

An eruption can be generally considered as a group of well-defined eruptive phases (for instance, phreatic, plinian, phreatic-magmatic phases, as in the Vesuvius 79 AD eruption).

Box 6.1
The 1631 Vesuvius' Eruption

The eruption occurred on 16 December 1631 can be subdivided into four main phases:

1. Development of the plininan column (sustained column full of ashes, lapilli and pumices) (from 7 a.m. to 6 p.m.)
2. Development of violent intermittent explosions (from 6 p.m. of 16/12 to 10 a.m. of 17/12)
3. Emission of pyroclastic flows (from 10 to 11 a.m. of 17/12)
4. Emission of phreatic-magmatic ashes (starting from the 17/12 afternoon).

The plininan phase was characterized by a pine-like eruptive column whose maximum height reached 13 km between h. 7 a.m. and 3 p.m. (first 8 hours) and 19 km between h. 3 p.m. and 6 p.m. (8–12 hours). The solid material carried by the column fell down to the east of the volcano, producing a deposit of lapilli and ashes in a narrow and lengthened area because of a very strong wind (about 100 km/h). The layer of lapilli shows 50 cm of maximum thickness in the plain to the east of the volcano (the area San Giuseppe Vesuviano). Several reports corroborate the thesis that a big thickness of produced material mainly piled up along a narrow segment to the east, at great distance from the Vesuvius too. Heaps of material big enough to cause the collapse of roofs are indeed testified as far as the village of Forino (400 houses were damaged) placed at 30 km from the volcano.

The second eruptive phase, occurred during the night between 16 December and 17 December, was characterized by several moderate explosions that mainly produced a great panic among people. Those explosions were capable of throwing blocks in a range of 2–3 km from the crater, producing only a weak fall of ashes and sable in the plain to the east of the Vesuvius. The amount of material produced in this phase was modest and the effects on built up areas were marginal. The pyroclastic flows occurred on 17 December morning flooded along the Vesuvius sides, destroying several villages at the foot of the volcano (Bosco, Torre Annunziata, Torre del Greco, Granatello and Cercola, not damaged by the lapilli fall during the pliniian phase, were razed by pyroclastic flows in 2 hours). Some considerable branches of the pyroclastic flows reached the sea creating 3 peninsulas near Torre Annunziata, Torre del Greco and Granatello. The pyroclastic flows occurred in the same time as the collapse of the volcanic cone and the depression of the top (caldera) with a diameter of 1,5 km. The pyroclastic flows were conditioned by the morphology: the wall of Monte Somma represented a strong defence for the towns of Ottaviano, Somma Vesuviana and Sant'Anastasia. Contextually to the pyroclastic flows, the sea level subsided by some meters in almost all the gulf of Naples for some minutes, which generated a tsunami 2–5 meters high. The eruption of the phreatic-magmatic ashes took place on 17 afternoon and with a decreasing intensity also in the following days. The last phase was characterized by mudflows and floods (starting from the 17 December afternoon) produced by strong rains. Some authors (Rolandi et al. 1993) suppose that on 17 December there were also some lava flows toward the sea, whose existence is very controversial (Rosi et al. 1993). In a vast area around the volcano, many houses had their roofs collapsed because of the humid ashes heap. Considerable mudflows were fostered by the almost overall waterproof of the high ground substratum hit by the ashes fall, which stopped the regular absorption of rainwater. The surface water surplus produced vast floods in the Campania plain between Acerra, Nola and Cicciano.

Based on the available descriptions, the reference event has been articulated in 5 temporal phases, each of them characterized by different phenomena, such as *earthquakes, pyroclastic falls,* including ashes, pumices, lapilli, etc., *pyroclastic flows,* which generally cause the total devastation of the hit area and *lahars*. In relation to the latter, it has to be noticed that the threat from rainfall-induced lahars may last for years after the end of an eruption.

The reference event for the Vesuvius is defined as a sub-plinian event[1]. Such an eruption is characterized by a big initial explosion, producing an eruptive column of gas and solid particles (pumices, ashes and lithic fragments). The explosiveness of the eruption is caused by the magma fragmentation, due to the magma gases decompression or to the instantaneous vaporization of water when in contact with magma.

Based both on the plinian eruption of 79 AD and on the 1631 eruption, the likely temporal development of a subplinian eruption for the Vesuvius has been outlined:

0 Precursors of the event.
1 Phreatic-magmatic vent of the conduit, opening of the obstructed conduit by the explosion, rising of the eruptive column, ballistic projectiles and debris of the explosion as far as 2–3 km from the eruptive vent, initial fall of ashes as far as 10 km from the volcano vent, moderate to strong earthquakes; the phase lasts from one to several hours; the overall affected area is about 10 km^2.
2 Sustained eruptive column reaching the altitude of 20 km, start of pyroclastic fragments, ballistic projectiles as far as 3–5 km from the crater, continuous very intense earthquakes; phase length about 5 hours; the overall affected area is about 150–200 km^2.
3 Sustained eruptive column in altitude, beginning of ashes dispersal produced by prevailing winds, deposit of pyroclastic debris on the ground

[1] The subplinian eruption is characterized by an energy minor than the plinian one with a consequent reduced areal distribution of ejected outcome, but similar phenomenology.

producing roofs collapse as far as 10–30 km from the crater, possible partial collapses of the column with lateral pyroclastic flows; the phase lasts about 12 hours; the overall affected area is about 200 km^2.

4 Collapse of the eruptive column with pyroclastic flows, ashes dispersal goes on, strong but isolated earthquakes, possible collapse of the cone top, tsunami; phase length 4 hours, the overall affected area is about 120 km^2 (*peak phase*).

5 Rains and last ashes deposits, explosion of the conduit produced by water-magma interaction, trigger of lahars, or flow of ashes and pyroclastic deposits triggered by volcanic rains; this phase lasts few days, the overall affected area is about 150 km^2.

6 End of the eruption.

The described temporal sequence points out the dynamic features of the volcanic event; during each phase, different areas are affected by different phenomena and/or with different intensity and, over time, different areas may be involved or different phenomena may overlap on the same area. Obviously, during the eruption, the widest areas affected by each phenomenon can change according to the intensity of the phenomenon. Hence, according to the worst phenomenon in each temporal phase, the widest affected area has been singled out (Fig. 6.10).

Then, on the basis of the achievements of a previous FPVI project, Armonia, the main targets for the different volcanic phenomena have been identified. Along the different phases of the event, the targets will also change over time.

As mentioned above, during a subplinian eruption, the volcanic phenomena are very heterogeneous and hit different territorial targets. While pumices and ashes, indeed, can cause the collapse of roofs and the loss of crops and breedings, but may not be necessarily fatal for people who may be able to escape, being far from the volcano, pyroclastic flows instead are likely to destroy anything along their path, as a consequence of their high temperatures and fast spreading. People being not directly hit by the flows can either be severely injured or even die from burns or suffocation.

6.3.3 Physical and Systemic Damages

Descriptions of past unrest episodes of the Vesuvius and of recent volcanic eruptions worldwide provided the necessary information to depict the different eruption phases and to identify the main potential targets for each phenomenon in the reference scenarios (Fig. 6.11).

Physical damages to population and buildings have been distinguished from systemic, related to functional disruptions of services and economic sectors due to the interconnection and interdependency of systems. Systemic damage have been considered at two scales: local and global. Generally, most of physical losses occur at the impact, while systemic damages are the indirect consequence of physical losses and failures. In the case of volcanic event,

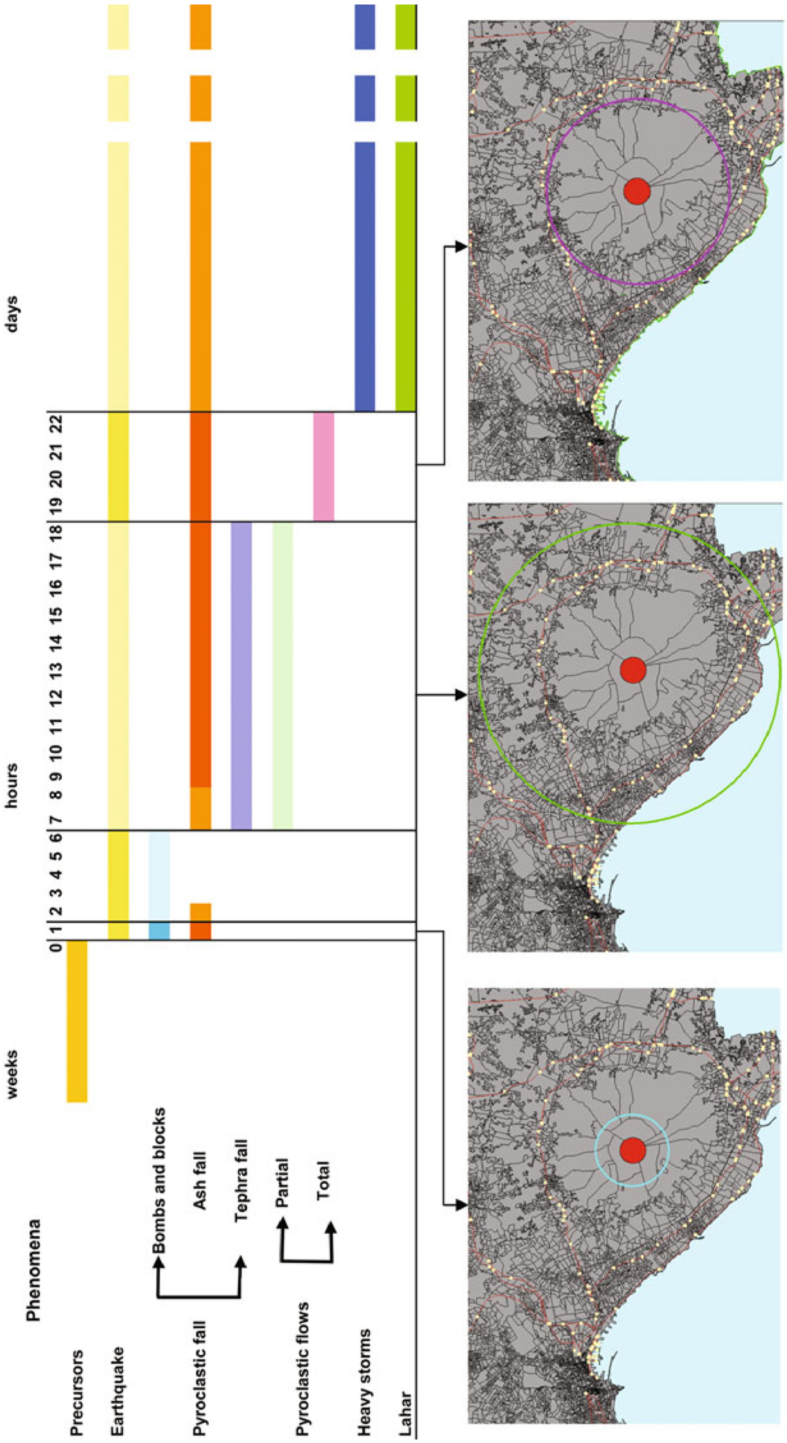


Fig. 6.10. The Vesuvius' scenario: phenomena in the temporal phases

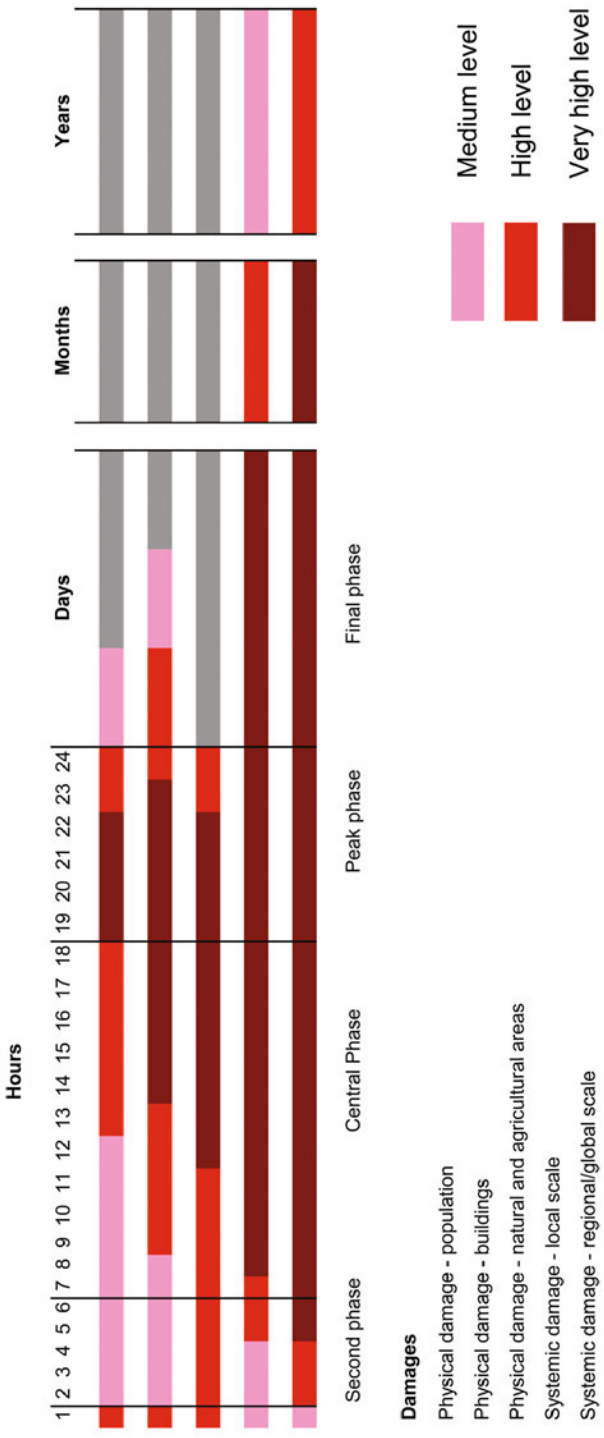


Fig. 6.11. Qualitative intensity level of damages during the eruption phases

Table 6.5. Targets, volcanic phenomena and qualitative level of impacts

Phenomena / Targets	Pyroclastic fall		Pyroclastic flow		Earthquake		Lahar	
Population			●	●	◖		●	
Buildings	●	●	●	●	◖	○	●	
Arable/het. areas	●	●	●	●				◖
Permanent crops	●	●	●	●				◖
Forest	●	●	●	●				
Road/rail netw.		●	●	●				●
Other net. infras.			●		○			
Emerg. equipm.	●	●	●	●	◖	○	●	●
Infrastructures	●	●	●	●	○		●	●
Monuments	●	●	●	●	◖		●	
Commercial areas	●	●	●	●	○		●	◖
Industrial areas	●	●	●	●	○		●	◖
Hazard.install.	●	●	●	●	○		●	◖

Physical damages: ● = high ◖ = medium ○ = low; Systemic dam.: ● = high ◖ = medium ○ = low

instead, systemic damages may be induced as a direct consequence of hazardous phenomena at a very early stage and may increase during the time. Physical damage may increase from the initial occurrence to become severe in the peak phase, characterised by pyroclastic flows and ashes falls. For example, people are more likely to be injured or killed during the peak rather than in the initial phase, by both pyroclastic flows and ash deposits.

Based on the selected phenomena and related targets, a qualitative description in terms of type and intensity of the main damages due to each phenomenon with respect to each target has been provided (Table 6.5).

Physical Damages

Even though a quantitative estimation of physical and systemic damages is beyond the scope of this work, exposed targets have been estimated on the basis of the forecast of areas affected by different phenomena during the eruption phases.

In detail, the number of exposed targets (see Table 6.6) has been first calculated in relation to the maximum areas affected by the different phenomena at the initial and peak phases. These areas have been drawn as circles whose radius is the maximum distance at which impacts of each phenomenon were registered in past eruptions, without taking into account the potential location of future eruptive vents (Marzocchi et al. 2007).

Then, exposed targets have been evaluated with respect to the areas affected by the eruption occurred in 1631. These areas have been identified and mapped according to the reconstruction of the 1631 event carried out by the Vesuvian Observatory analyzing deposits of pyroclastic flows and ashes.

Table 6.6. Exposed targets and parameters for measuring exposure (source: Armonia Project, 2006)

Spatial element	*Targets*	*Exposure*
Areas	Population	Population density (number of residents/surface of the area in hectares)
	Buildings	Number of buildings
	Arable land and heterogeneous areas	Surface of arable land and heterogeneous areas (ha)
	Permanent crops	Surface of permanent crops (ha)
	Forest	Surface of forest (ha)
Lines	Road networks	Length and hierarchical level of the network
	Rail networks	Length and hierarchical level of the network
Points	Monuments	Number of archaeological sites
	Hazardous installations	Number of hazardous installations
	Infrastructures (Airports, Railway stations, etc.)	Number of infrastructures
	Emergency equipments (Hospitals, Fire brigades, etc.)	Number of emergency equipments

In both scenarios, corresponding the most likely and the maximum event expected in case of unrest in the next 10 years, exposure has been evaluated according to the parameters set up within the Armonia project and measured referring to census units. The assessment of exposed elements may look more reliable in the second scenario, which refers to an event similar to the one which occurred in 1631. Nevertheless it has to be pointed out that even in case a comparable eruption occurred today, it would affect differently the surrounding areas, because of changes in the volcano morphology.

Thus, the first group of maps (Fig. 6.12) specifically refers to the first phase of the eruption (1 h) – mainly characterized by ash falls and volcanic bombs affecting a circular area with radius of 3 km – and to the peak phase, which may last about 4 hours. This phase, affecting circular area with radius of 7 km, is characterised by the collapse of the eruptive column and, consequently, by the pyroclastic flows.

The main exposed elements in the first phase (affecting the area represented by the smallest circle), are shown in the Table 6.7. It is worth noting that, even though the exposed population amount to 400 people and only isolated buildings can be affected, more than 1.000 hectares of cultivated areas and 3.000 hectares of forests can be involved, with significant consequences

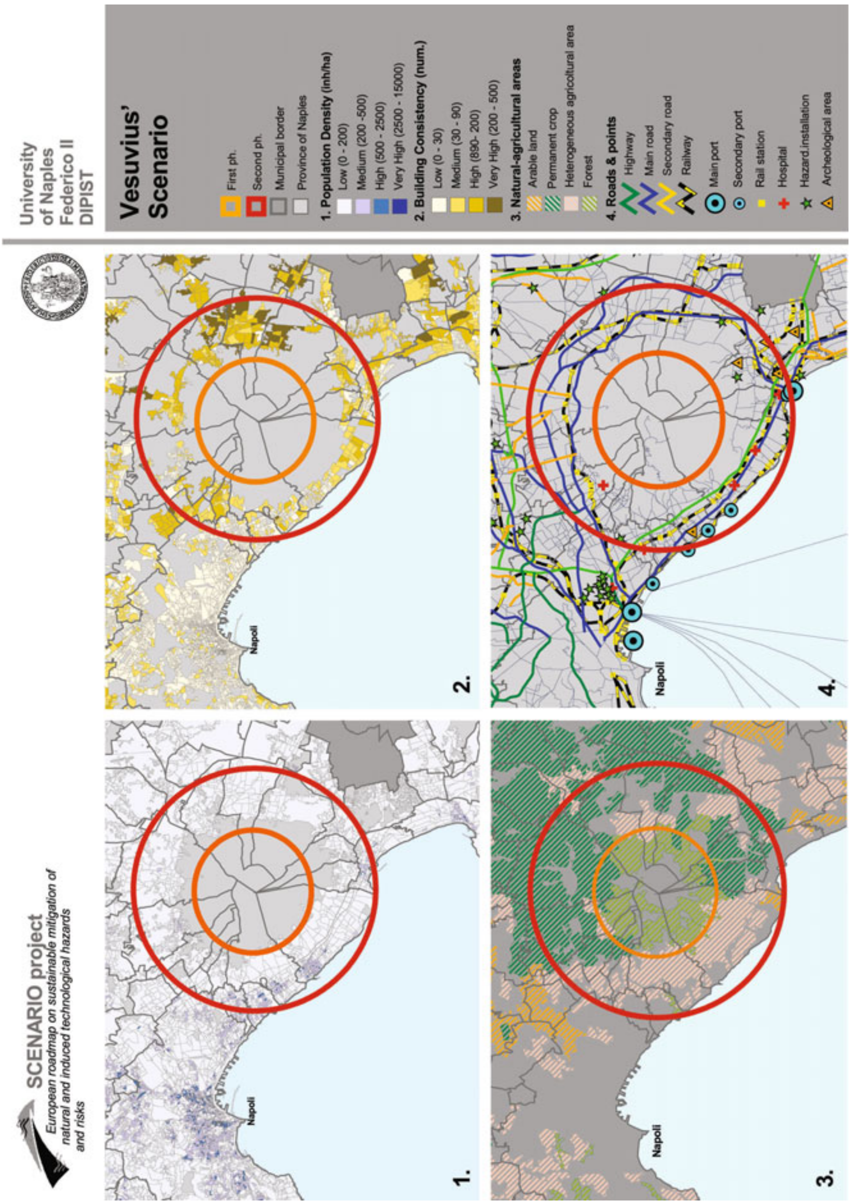


Fig. 6.12. Exposure in the first and peak eruptive phase

Table 6.7. Exposed elements in the first and peak phase

	3 km	*7 km*
Population	400 people	516,979 people
Urban areas	None	41,097 buildings
Forest	2,800 ha	3,000 ha
Arable & heterogeneous areas	300 ha	4,200 ha
Permanent crops	1,000 ha	5,700 ha
Networks	None	540 km
Emergency facilities	1 close to the involved area	5 hospitals
Monuments	None	4 archaeological areas
Infrastructures	None	5 harbours + 67 stations
Hazardous installations	1 close to the involved area	4

for natural environment and agriculture, which is still a relevant sector for the local economy. In the peak phase, more than 500.000 people and 40.000 buildings may be involved. Both population and building density are rather high along the coast line and near the metropolitan area of Naples. A relevant number of emergency facilities and monuments are located in the potential affected area. Moreover, 4 archaeological sites might be included: among them Pompei, one of the most attractive tourist site in Italy. Being Pompeii, Herculaneum and Oplonti (Torre Annunziata) included in an UNESCO site, the loss of such an heritage go significantly beyond the local boundaries, representing a significant damage at global scale too.

Finally, four hazardous installations, mainly GPL plants, are located in the affected area: each of them might be, in turn, a secondary hazard source, with relevant impacts at a local scale.

Road and railway networks passing through the potential affected area have been also taken into account. In detail, the road network has been classified according to the hierarchical role of each element: highways (A); national roads (SS), provincial roads (SP). Moreover, it has to be highlighted that the main roads linking the Tyrrhenian southern regions to the North of Italy (the Highway A3 and the national road SS18), the regional railway line "Circumvesuviana" and part of the railway linking Naples to Reggio Calabria are included in the affected area. Thus, the volcanic event may induce relevant problems to the transportation system in the South and between the South and the North of Italy, causing the interruption of people's and freights' flows. As a consequence of the tsunami which is expected as a secondary consequence of such an eruption, the maritime traffic too is likely to be severely affected. In particular the harbour in Torre Annunziata, which is the third in Campania for freight flows, and 4 secondary harbours, may be blocked.

A potential loss of functioning (even though temporary) occurring in some of the elements of the transportation network may significantly reduce also the coping capacity of the area during the emergency phase.

Table 6.8. Elements exposed to pyroclastic flows

Population	444,704 people
Urban areas	32,204 buildings
Forest	2,900 ha
Arable & heterogeneous areas	5,500 ha
Permanent crops	2,700 ha
Networks	450 km (road and rail)
Emergency facilities	5 (hospitals)
Monuments	5 (archaeological areas)
Infrastructures	5 harbours; 51 railway stations
Hazardous installations	7

Table 6.9. Elements exposed to ash fall

Population	76,302 people
Urban areas	16,393 buildings
Forest	1,726 ha
Arable & heterogeneous areas	4,100 ha
Permanent crops	25,000 ha
Networks	180 km (road &rail)
Emergency facilities	1 (hospitals)
Monuments	None
Infrastructures	18 (stations)
Hazardous installations	2

The second group of maps shows the areas involved in the 1631 event. In detail, the red polygon (Fig. 6.13) shows the distribution of pyroclastic flow deposits related to the 1631 Plinian eruption (OV-INGV Napoli). The amount of potential targets is shown in Table 6.8: according to the current situation, about 450.000 people and more than 30.000 buildings may be involved.

In detail, the first map (Fig. 6.13) shows the exposure of population calculated through the *population density.* The census units with very high (450–1850 inh./ha) and high (250–450 inh./ha) levels of population density belong to the Municipalities of San Giorgio a Cremano, Napoli, Portici, Ercolano, Torre del Greco and Torre Annunziata.

The second map refers to the built stock, showing the highest density in the North-Eastern part of the area, mainly in Ottaviano, San Giuseppe Vesuviano and Terzigno Municipalities. In the North-Western part, the highest density is concentrated in the Municipalities of Pollena Trocchia, Cercola, San Sebastiano al Vesuvio. Along the coast the Torre del Greco has the most dense built stock.

The third map shows other potential targets belonging to the natural and agricultural environment and highlights their spatial distribution. Specifically, forests are located all around the Vesuvius' Cone; heterogeneous and perma-

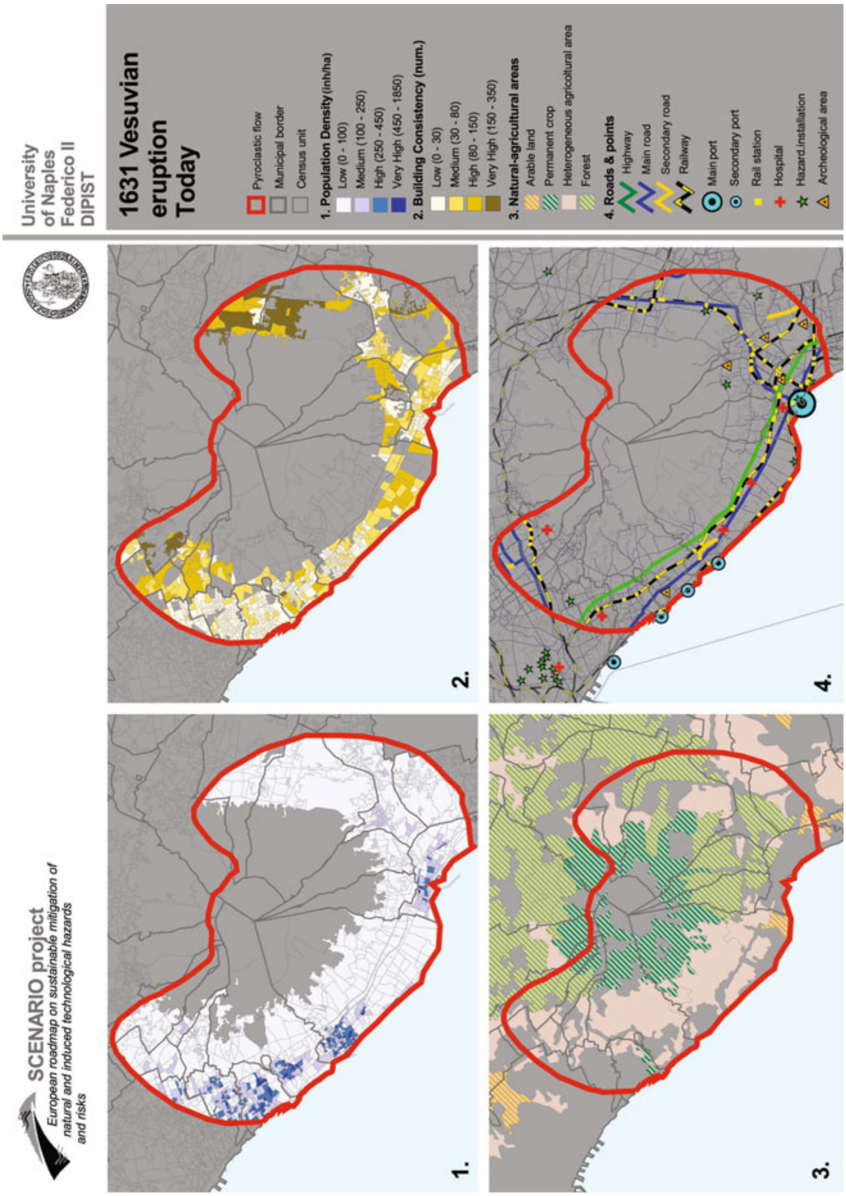


Fig. 6.13. Exposure to pyroclastic flows (1631 eruption)

nent crops form a second belt around the Cone; arable land are concentrated in two small polygons in the south-eastern part of the hazardous area.

Finally, in the fourth map linear (road and rail network) and point-shaped (emergency facilities, infrastructures, monuments, hazardous installations) exposed elements are represented. Also in this case, the main roads and railways linking the Southern-Tyrrhenian area and the North of Italy pass through the hazardous area.

Moreover, 5 harbours – including the Torre Annunziata Port which is the third in Campania for freight flows, after Naples and Salerno – 61 railway stations, 5 hospitals (Pollena Trocchia, San Giorgio, Torre del Greco and Torre Annunziata), 5 archaeological areas (Ercolano, Pompei, Torre Annunziata, Boscotrecase, Boscoreale) and 7 hazardous plants are located in the potentially affected area. One of the hazardous installations, a GPL plant in Boscotrecase, is just 5 km far from the crater of the volcano.

Also the spatial distribution of potential physical damages due to ash falls has been considered (Fig. 6.14). The extension of the affected area has been determined according to the one of the hit area during the 1631 event.

This area largely overcomes the boundaries of the Province of Naples. Nevertheless, considering the only Province of Naples, 6 Municipalities, more than 75.000 people and 15.000 buildings would be affected (Table 6.9).

In the first map population density has been represented. The census units which present very high (70–140 inh/ha) and high population density (40–70 inh/ha) levels belong to the Municipalities of San Giorgio a Cremano, Terzigno, Ottaviano and Striano.

The second map shows the building consistency. The census units with the highest levels belong to above mentioned Municipalities, including the one of Poggiomarino too.

In the third map, the targets belonging to the natural environment are represented. They are distributed into three different bands: forests, all around the cone, heterogeneous and agricultural areas and, finally, permanent crops and arable lands.

In the fourth map, the distribution of linear and point-shaped targets has been presented. As for roads and railways, the Highway A30 (Caserta–Salerno), two national roads (SS268, SS268 BIS) and two metropolitan/regional railways (the Circumvesuviana and the Cancello–Torre Annunziata) are located in the affected area.

Regarding point-shaped elements, it has to be highlighted that 18 railway stations, 1 hospital (Palma Campania) and 2 LPG plants are included in this area, one in Ottaviano and the second one in Palma Campania. The latter one is located at only 2 km distance from the hospital, entailing significant potential secondary and enchained effects in case of eruption.

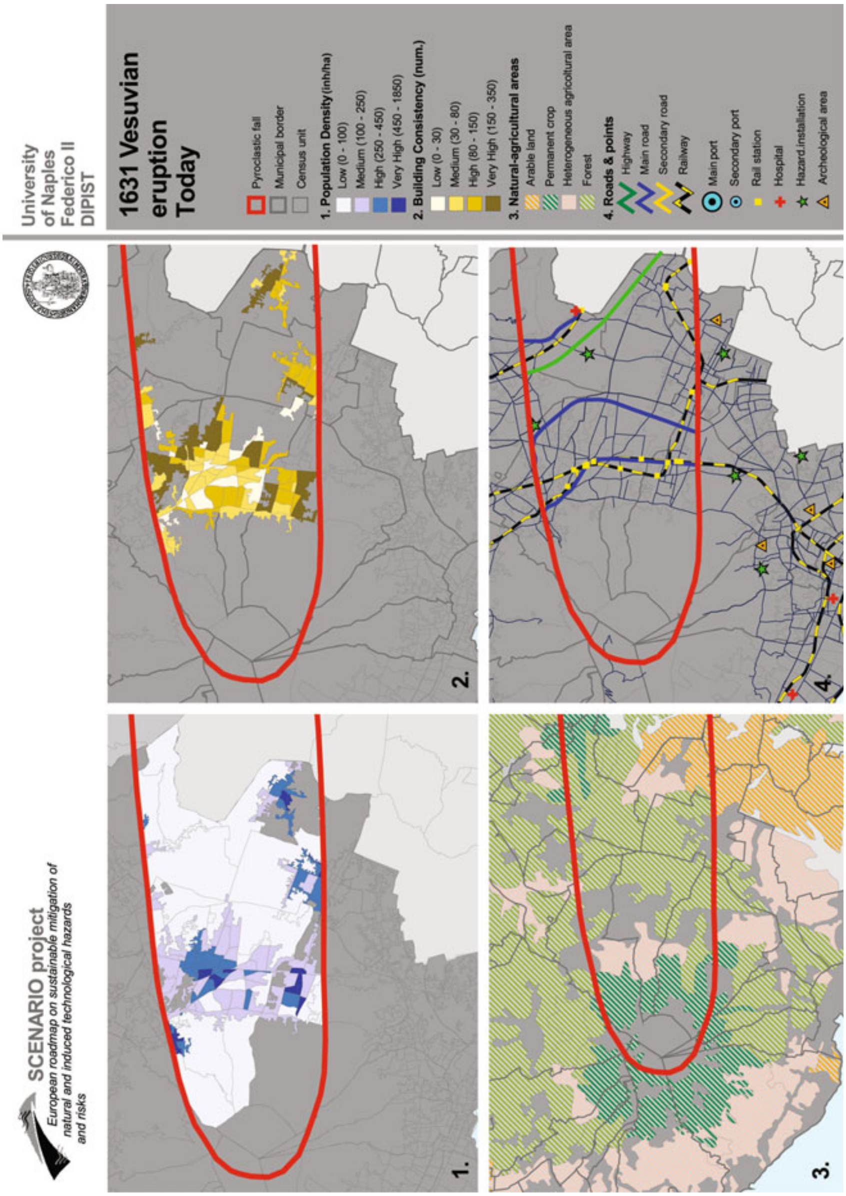


Fig. 6.14. Exposure to ash falls (1631 eruption)

Systemic Damages

Past Vesuvius' eruption, such as the 79 A.D. one, severely affected buildings and population in the Vesuvian area, but they caused also long-term damages involving the whole Campania Region and, in some cases, a wider geographical context. For example, ashes and pumices fall down halted agriculture in a large area for long time. The regional economy was damaged and in particular wine production as well as garum export stopped.

It was not by chance that, after the eruption, Rome began to import wine and other products from Gallia instead from Campania.

Therefore, as largely demonstrated also by recent volcanic eruptions (as the mentioned Icelandic one) systemic damages can be very relevant in case of eruptions and can arise not only as a consequence of physical damages (as in case of other natural hazards) but also as a direct consequence of the event.

Hence, the potential systemic impacts due to the selected reference event and some of the more relevant systemic damages which can be caused have been sketched. The main systemic damages which might occur in the different phases of the eruption and their duration have been outlined in Table 6.10 and are briefly described in the following pages.

Interruption of Flight Connections

The interruption of the flight connections due to volcanic ashes is one of the main systemic impacts which might occur along the entire eruptive duration, causing not only the closure of Naples International Airport, but also the interruption of all South-North flight connections between the Southern part of Mediterranean area and Central Europe.

As mentioned in historical texts, during the 79 A.D. eruption the Vesuvius ashes reached Africa, Syria and Egypt. Much more recently, during the Etna eruption in 2002, the Catania and Reggio Calabria civil airports and the military airport of Sigonella were closed for several days due to the volcanic ashes: the mentioned eruption was an effusive one not comparable with the features of the eruptive event selected as a reference event for developing the scenario presented here (VEI 4).

To better understand the potential consequences of such an event at national, European and global scale, it is worth referring to the recent eruption of the Eyjafjallajökull volcano in Southern Iceland, since no comparisons with past Vesuvius' eruptions can be made since flight connections have become a routine habit for society.

In the Eyjafjallajökull eruption, indeed, after the second eruption, on the 14th of April 2010, the ash plume has grounded flights all over Europe for one week, inducing severe consequences at European and global scale, as a direct consequence of the hazardous phenomenon itself. In detail, ash particles which may induce relevant failures in engines and in other essential systems of the aircrafts (such as sensor systems, hydraulics, pilot windscreens). Due to its

Table 6.10. Potential systemic impacts during the eruption temporal phases

Phases/Targets	First Phase	Second Phase	Peak Phase	Phases/ Targets	Post-event Medium Term	Post-Event Long Term
Agricultural areas	*Agricultural activities stoppage*				*Export of agricultural goods stoppage*	
Forests				*Air pollution due to CO_2*		
Network Infrastructures	*Interruption of flight connections*	*Breakdown in communication*				
Transport Nodes and Other Infrastructures		*Interruption of passengers and freight flows*				
Commercial and Industrial Areas		*Commercial and industrial activities stoppage*			*Food industry stoppage* *Export activities stoppage*	
Historical Heritage	*Interruption of tourist flows*		*Loss of world heritage*			
Climate				*Change in climate condition*		

chemical and physical features and to favourable meteorological conditions, the ash cloud has reached rapidly the height that aircraft generally fly and in few days has moved from Iceland to Europe up to Canada. The first relevant consequence of the ashes propagation has been the closure of most of the European airspace for several days. The closure of several European airports has provoked, besides relevant troubles for passengers all over the Europe, relevant economic losses for airline companies. Official data are not available yet, even though the media have reported a loss of about 200 million of dollars per each day. The total amount of economic losses on the 21st of April, is estimated in 1,5 billions of dollars. Furthermore, even though the hazardous phenomenon has directly affected European airspace, also airplane companies based far from Europe have faced relevant economic losses: the Thai Airways, based in Bangkok, has estimated that ash cloud has cost $3 million per day and has stranded 6,000 of its passengers.

Due to the closure of air space, relevant secondary impacts have been recorded too, so that a "butterfly effect" of the Icelandic eruption has been largely mentioned. The most relevant is the stop of freight flows: even though only a small percentage of freights travels by air, relying more on road, sea and rail, it has to be taken into account that fresh and perishable goods mainly depend on air freight.

Therefore, besides the problem internal to European freight flights, relevant repercussion on exports of fresh food and flowers from Africa have been reported: for example, Kenya normally exports up to 500 tonnes of flowers daily, the 97% of which is delivered to Europe. Therefore, Kenyan farmers have been forced to dump stocks of fresh food and flowers destined for European consumers and, according to a report in Kenya's Daily Nation newspaper, the Kenyan economy is losing $3.8m a day as a result of flight cancellations to Europe. The latter is a relevant consequence for a national economy largely dependant on export activities.

Other relevant failures, with consequent further economic losses, have been determined, for example, by the cancellation of political and business meetings, of relevant cultural or sports events and, also, by the relevant delays to air mail.

The Eyjafjallajökull eruption has clearly highlighted how a given hazard, occurring at a local scale, may cause consequences across a very large area; the extension of the latter largely depends on the increasingly large connections among territorial systems, and activities.

Even though the eruption occurred in an area which does not hold a strategic position in the global economic contexts (and which can be defined as lower than the one hold by the Vesuvian area), it has affected a strategic activity ± the air freight – reverberating on activities and economies all over the world with relevant economic losses.

Nevertheless, although in case of Vesuvius ashes should propagate in a smaller area, it is worth noting that the International Airport of Naples is one of the most important in Southern Italy and is connected with many

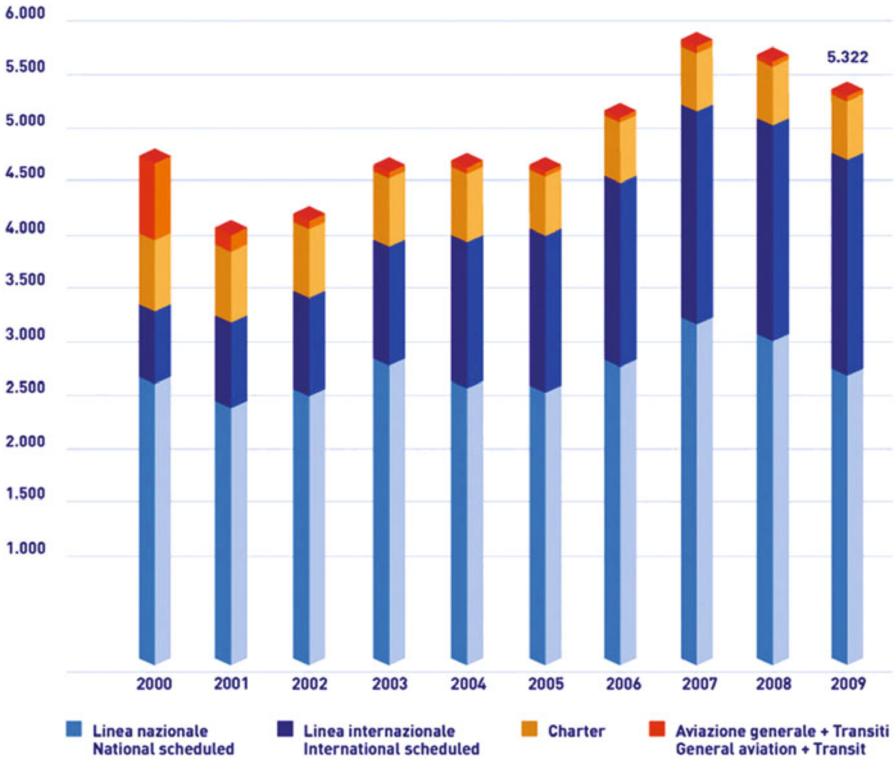


Fig. 6.15. Passengers traffic 2000–2009 in the International Airport of Naples

international and European destinations, such as Barcelona, Madrid, London, Paris, Athens, Berlin, Bruxelles, etc.

In 2009 more than 64.000 movements (take-offs and landings), were registered and the total amount of passengers has constantly grown between the 1997 and the 2007 (Fig. 6.15), though slightly diminishing in the last two years (2008–2009). The total amount of passengers in the 2007 was about 5.8 million, with an increment of 13% with respect to 2006, while the international scheduled traffic in 2007 recorded a 16% increase over the figures for 2006.

In the period 2000–2007 a relevant growth of international flights was recorded (+188%), thanks to significant enhancement of the international flight network and the inauguration of new routes. In 2009 the total amount of passengers was about 5.3 million.

Thus, just the closure of the airport of Naples might cause relevant economic losses both at local than at regional scale.

Interruption of Passengers and Freight Flows

Besides the burden imposed on flight flows, the consequences on the land transport system must be accounted for as well, as the most relevant roads and railways connecting the Southern Tyrrhenian regions and Northern Italy are located in the hazardous area. Hence, taking into account that most of the freights arriving at the harbour of Naples are then sorted towards several European destinations by road or railway, it is clear that the potential implications of such an event may be very significant.

Moreover, it has to be taken into account that in the peak-phase of the eruption one of the characterizing phenomena is the tsunami, which could affect most of the Campania coast, inducing relevant problems to the maritime traffic and the consequent interruption of the freight and passengers maritime flows. The harbour system of the Campania Region plays a central role in the Euro-Mediterranean context and it is the third one in Italy (following Genova-La Spezia-Savona-Livorno and Venezia-Trieste- Ravenna). Among the main Italian ports (15), Naples is placed in the sixth position for freights flows (about 500.000 TEUs in 2008) (Twenty foot equivalent unit) and Salerno is at the eight place with more than 370.000 TEUs). The Naples' harbour covers a surface area of 1.336.000 square metres and it is one of the main Mediterranean ports in terms of the quantity and variety of traffics. The harbour holds commercial and passenger traffics and shipyard facilities. In the area of the harbour devoted to passenger traffic there are mooring places for large cruisers and the area for links to the Naples' islands, Sorrento and other coastal towns, and to the Aeolian islands. In detail, from about 400 ships and 400.000 passengers in 2000, in 2008, more than 650 ships and 1.2000.00 passengers have been registered (Harbour Authority data).

Other harbours are located in the area potentially hit by the eruptive scenario, including those of Torre Annunziata, Castellammare, Torre del Greco and Portici, which play a relevant role for the local economy and productive activities, and many smaller ports, which have a relevant role in the tourism economy.

Interruption of Tourist Flows

The potential damages to tourism sector are largely linked to the interruptions of flight, railway and sea connections, already mentioned in previous paragraphs.

Furthermore, it has to be underlined that tourism is currently one of the driving sector of the Campania Region economy and is particularly relevant in the area at stake: in the Vesuvian area, the UNESCO site including Pompeii, Herculaneum and Oplonti (Torre Annunziata) archaeological areas is located and in 2009 more than 2.000.000 people visited the Archaeological sites in this area. Besides, the area is characterized by many historical centres and famous historical buildings. Moreover, the whole Vesuvius' ecosystem, protected by the Vesuvius' National Park and characterized by the Mediterranean-type vegetation and fauna, has a relevant environmental value and the Vesuvius' "Gran Cono" is one of the main tourist destination in the Campania Region.

Blockage of Export Activities

Another potential systemic impact is the stop to export activities, which are significant for local and regional economy. According to the data on export activities in the Province of Naples, they have been constantly growing since 2005, although a light decrease has been registered between 2007 and 2008. In detail, the total amount of the export in the Province of Naples was about 4.228.948.260 Euros in 2005; it reached a value of 5.009.752.510 in 2007 and has decreased to a value of 4.822.708.342 in 2008 (Bulletin of Statistics of the Naples Chamber of Commerce, Naples, 2009).

In the 18 Municipalities of the red zone (the main affected by pyroclastic flows) more than 44.300 firms were registered in 2008, which represent about the 17% of the provincial value. Among them, about 300 are export based firms; they represent about the 19% of the provincial export firms.

They are mostly characterized as *small and medium firms* (PMI) and the main economic sectors they belong to are: *textile and clothes* sector (27%), *jewellery, coral, cameo factories* (21%) and *food industries* (9%). According to the provincial trend, only the textile and clothes sector has registered a decrease in 2008.

Whilst the *textile and clothes* sector represents the 17% of Provincial value and the *Food* sector less than 20% of the provincial value, the sector of *jewellery, coral and cameo* represents the 79% of the export economy of the Province of Naples. A relevant role is played by goldsmith firms, as one of the Municipality of the Red Zone, Torre del Greco, is one of the main development pole in Italy for such activities. As regards the economic value of the Red Zone export, the total billing of the three economic sectors exceeds 140 million Euro (Table 6.11).

Table 6.11. Estimated values of the yearly export billing for each sector of economic activity (source: Elaboration on data 2007 (Chamber of Commerce, Naples))

	% Red zone/ province	*Provincial values (euros)*	*Red zone values (euros)*
Jewellery, coral, cameo factories	79%	15.415.488	12.197.006
Food industries	19%	382.152.386	72.472.225
Textile and clothes	17%	330.920.733	56.096.250
Total		**4.228.948.260**	**140.765.480**

Other Systemic Impacts

Finally other systemic impacts can be mentioned, even though they would require depper analysis. For example, although not normally depicted on hazard maps, atmospheric effects in the eruption column would generate frequent lightning strikes, which would in turn generate magnetic fields provoking breakdown in communications and, consequently, reducing the effectiveness of rescue activities.

Another aspect is related to the impacts of the Vesuvius' eruption on climate: the relation between volcanic eruptions and climate changes has been indeed largely discussed since the beginning of the 19^{th} century. As mentioned by some authors (Crowley, 2000; Shindell et al. 2003), a major volcanic eruption not only may have an impact regionally but it may also affect the global climate. For example, climate computational models and satellite observations showed that, after the Mount Pinatubo eruption in 1991, not only regional but all the world climate was influenced. The 1992 winter temperatures, in North America, Europe and Siberia, were some degrees above the seasonal average values. On the contrary, in Alaska, Middle East and China temperatures were below the average values. But such exceptional effects lasted for two years, so that it was assumed that Mount Pinatubo eruption forced world climate in a short-time period.

In conclusion, the Vesuvius' scenario highlights that the selected reference event (a VEI 4 event) occurring today would be surely devastating for the Vesuvian area, but it would cause also the disruption of the regional economy, inducing lasting effects for the entire South of Italy and provoking consequences at European or global scale too (loss of world heritage, interruption of freight flows, etc). Thus, even though largely qualitative, the description of a "logic" chain of events, impacts and damages provided in the two reference scenarios is useful to highlight the growing interdependencies among local and global scales, showing how difficult it may be to label a severe natural extreme as local when it hits a megacity or some vital systems.

7

Shift in Thinking

S. Menoni, C. Margottini, A. Galderisi, G. Delmonaco, F. Ferrara,
J.P. Kropp, J.F. Esteban, J. Lopez, A. Pugliano, O. Mejri, P. Plebani

7.1 Challenges of the Scenario Project

The Scenario project has set a rather ambitious and even risky goal: to lay down a roadmap for future research in natural risks and mitigation policy in the European Union, drawing on ten years of research on natural hazards, mainly funded under the V (1998–2002) and VI (2002–2006) Framework Programmes. The goal is not only ambitious, but could be easily labelled as unrealistic and even arrogant. Initial meetings of the project set the stage for harsh discussions on methodology, specific steps and basic definitions to be followed by the research teams. Despite initial differences, many of which persist, between diverse hazard communities, and between climate change and natural hazards scholars, it is interesting to note that it was possible to achieve some commonalities and convergence points.

Such a surprising result, even astonishing for the external observers who were testimony to the difficulties and the conflicting perspectives that arose throughout the project's development, was possible thanks to a couple of favourable conditions. The first stems from the decision to invite a group of experts to peer review the project documents and results. Those experts acted as a "governance body" of the research work. The second positive input derived from two workshops which constituted a unique opportunity for the project members to confront a wider, external disaster and climate change research community. The first workshop was organised in the mid-term of the project at Potsdam (October 2007), in the form of a conference where scientists in climate change and disasters met and held discussions. The second one was held in London (February 2008) at the end of the project with the main aim of establishing the foundation for the development of the last chapter of this book.

Efforts to assess the current situation in risk research may end up with rather pessimistic views, as those expressed by White et al. (2001), in their article titled "Knowing better and losing even more ...". But they may also look at future endeavours in a more optimistic way, recognising the significant

Menoni S. and Margottini C. (Eds.): Inside Risk: A Strategy for Sustainable Risk Mitigation

achievements not only in understanding natural phenomena but also in highlighting social factors and the interconnectdness of the latter with natural and technological systems. Recognition of crucial key themes, moving from a reaction mode strategy to a more proactive one, from emergency-driven responses to a more comprehensive "risk governance" or "governance of preparedness" (Weicheselgartner and Obersteiner, 2002) may account for an optimistic view. Of course, the picture is rather heterogeneous, as progress is not equally distributed in the world, or in the European Union. Discrepancies remain not only between countries, but also within countries, between regions. There are in any case interesting research and risk mitigation practices to build on. Probably an important shift has occurred from negative consideration of risks to a more positive perspective, acknowledging that zero risk and hazard elimination is an unreachable goal. In this sense, the call for sustainable risk mitigation has being conceived, as suggested in the first chapter of this book.

Risk mitigation and sustainable development share some common relevant points: the need to avoid the externalization of damage in space (to other geographical areas) or in time (to future generations); the recognition that unsustainable practices may exacerbate some hazards; the idea that risk mitigation constitutes a public good (Reddy, 2000). Prevention shares with other public goods the fate of being poorly managed by the free market, thus requiring intervention by public organisations. Most risk control measures, including natural hazard insurance programs have a public body as a fundamental participant.

Coupling risk mitigation and sustainability may produce rather positive outcomes, thanks to the feedback each one can gain from the other. Practices seeking sustainability that do not consider risk mitigation are likely to fail in the short run, particularly in areas where either hydrogeological or meteorological hazards have shown large variability in recent years and/or where exposure and vulnerability have noticeably grown as a consequence of fast economic development and urbanisation. On the other hand, risk mitigation strategies can gain momentum by being included in sustainability. Two advantages would result: an emphasis on the positive aspects of the safety, rather than on the negative connotation of risk, and the inclusion of mitigation into ordinary policies.

One fundamental question that is worth asking is whether or not, and to what extent, available science and expertise in the field are sustainable, i.e. if it can contribute to foster policies and practices aimed at guaranteeing the main objectives of sustainability as well as sustainable risk mitigation. We claim that presently the advancements and gaps in risk related research cannot be assessed only as far as theoretical and applied science are concerned. A very relevant issue is how current scientific practices perform in terms of mandated or regulatory science (Salter, 1988; Jasanoff, 1990). At the delicate interface between science and policy (Funtowicz and Strand, 2007), science is required not only to be credible, but also salient, that is relevant for concerned stakeholders as well as legitimate, that is developed within a process perceived as fair (Mitchell et al., 2006). These relevant issues have been raised in writing and revising every single chapter of this book, acknowledging the difficulties and challenges implied in any clear cut answer.

Last but not least, clearly the project results, as questionable as they may be, derive from analyses of European Commission-funded research against a larger world literature. These analyses are enriching and allow the identification of gaps in the EU perspective, which has matured in recent years. They also shed light on areas and domains where new ideas and original methodologies have been developed.

7.2 Images of Europe at Risk: Emerging Threats, Changing Vulnerability Patterns, Interscalar Relations

Capitalising on previous research has been always important to advance knowledge. Fragmentation and sectoral approaches have reached extreme levels in the last century, permitting advancement in individual sectors but leaving unsolved the question of how to recombine the different expertise needed to tackle complex issues and problems that originate at the border of two or more competences. As the report "Taking European knowledge society seriously" correctly puts it, along with a process of learning and building on previous studies, there is also a parallel process of unlearning, either because potential paths are neglected, which could have instead led to fundamental new findings in the future, or simply because previous knowledge is forgotten. As Cipolla (1996) showed, many times in history the technological capacity and knowledge for a given innovation were available, but the social, cultural and political conditions were not ripe for them to emerge. Similar situations may well occur today: future generations will tell to what extent this unlearning process has occurred in our time.

What can be argued is that the speed at which changes are taking place today challenges our capacity to reflect and think about the learning process.

In the context of risk studies, past knowledge is relevant not only as "information", but also for its operational content. Because risks can be mitigated only thanks to the synergic activity of various groups, agencies, administrations, community and individuals, what has to be preserved and passed to future generations is not only content information but also how things have to be done, what are the potential failures ahead, and what have been successful or unsuccessful ways to deal with them.

In this respect, past knowledge takes the form of "collective remembering" necessary for collective action, as required to mitigate risks. Operational documents like contingency plans for example should serve as artefacts through which an "unlimited number of individual and group actions are connected" (Engeström et al. 1990). When the contents of such artefacts is forgotten, the people operating in a given field, civil protection in our example, can no longer see how their actions derive meaning from collective activity and how they can influence that activity through their own actions.

Quarantelli (1998) makes an important point in addressing the "computer revolution", suggesting that it may lead to the abandonment of "paper" recording in favour of virtual exchange of messages and information. This way though, important information may be lost much more easily and it will become increasingly difficult to keep a record of what occurred in given emergencies.

In the absence of suitable tools for transmitting such memory and preparing accordingly, response is governed just by the ability of agencies, organisations and communities in the particular contingency at stake, without any guarantee for a similar or better response in the future. In fact, a very limited part of what is acquired during emergencies is transmitted to operators and officials who will have to tackle one in the future. Small findings, expertise, tailored tools that have been designed, and particularly the method that has been eventually developed to create solutions are being lost: an immense capital that would significantly enhance the performance of contingency and rescue teams facing future calamities.

In this regard, it should be noted how potentially relevant projects like the Nedies (http://nedies.jrc.it) are, which permit a wide range of experience in tackling natural extremes to be covered.

As mentioned in Chapter 4, lessons learnt within the Nedies project address both long- and short-term mitigation measures, showing when and under what conditions the latter have worked well and when they have not been implemented adequately, thus leading to failures and damages. It would perhaps need some reshaping and restructuring, particularly with respect to the part of the project where lessons are summarised and elicited. Unfortunately, in fact, the summaries provided do not always include the most relevant aspects emerging in each event. A cross-reading of the Nedies reports in their full length, as summarised in Chapter 4, permitted the identification of crucial pitfalls in managing risks that the described events clearly manifest. Those can be grouped into three categories: failure to comply with existing building codes; lack of compliance or absence of norms and regulations in land use planning; and finally communication failures before and during emergencies between relevant agenciees and with the public at large.

Similarly to the Nedies, the Espon project has also started work that deserves to be continued. In fact, it is one of the few sources providing a European view on risks, including maps constituting a first draft of vulnerability and exposure representations.

Despite the many limitations of the Espon project, it is a fundamental reference for anyone attempting to sketch an image of Europe at risk, as shown in Chapter 2. Limitations can be at least partially overcome in future editions, working on both data entry and methodological aspects. As written by Schmidt-Thomé in the executive summary report of the Espon project on natural and technological risks, "most data were obtained from freely available sources, indicated in each of the maps. Many data requests were sent to international and European research institutions as well as other transnational project groups (TPG), but only very few were responded to or the geographical coverage of gained data was poor. [...] Better data availability and more resources could easily enhance the project's results. In future research approaches on natural and technological hazards all indicators developed by this project should be revised. The main obstacle for indicator development was the required large geographical coverage. [...] Another obstacle was the compulsory reporting on NUTS3 level, as hazards usually do not respect political boundaries, also vulnerability and resulting risk patterns are difficult to produce on man made limitations. Future research approaches financed by the European Union on such an extensive scale should also ensure a good cooperation between relevant EU funded research institutions and projects" (p. 23).

Initiatives such as the Inspire directive go in the direction to encourage more access and sharing of information, by forcing technologies to reach the maximum possible interoperability between a variety of archives and information storage systems. The point is that technology can certainly provide a very strong impulse to data sharing and in some cases even force restrictions and boundaries. The internet constitutes in fact a formidable vehicle of information, but the main drawback remains the quality of information that is freely circulating on the internet. Because of the sensitivity of data and issues related to safety and risk, it is questionable whether unchecked information can constitute a reference for decision makers and organisations in charge of public protection. Therefore there is significant work to be done in this area of concern in order to obtain risk maps and assessment with European coverage and relevance.

With respect to the methodology, a stronger connection between the various sections of the Espon project as well as with other projects looking for a European perspective should be sought. It is important for example that information on the European space be available for further manipulation in terms of exposure and vulnerability.

Technology can significantly contribute in this regard. The Espon Webgis platform should become a more complete archive, permitting some operations and combinations of layers for new information to be produced by end-users. This platform should become an operational one, similar to those made available by FEMA in the US to be used in software like Radius or Hazus. In spite of the limitations of the latter, it is certainly useful for decision makers, particularly at the regional and the local level, to be able to carry out their own risk assessment, combining maps and information that are provided by organisations that have the power and the capability to collect and prepare them at adequate scales and formats.

7.2.1 Information Needs at the European Scale

In an attempt to capitalise on past research, a further effort was made to represent findings at a European scale, interpreting the call for European relevance that was introduced since the FPVI. According to De Elera (2006), such relevance is still a weak concept, loosely defined, open to a wide range of interpretations. As discussed in the previous paragraph, the attempt made within the Scenario project was to define Europe as a political and social entitity comprising the 27 Member States adhering to it, and consequently to look for risk assessments, maps and strategies that either are relevant for Europe as a whole entity or take place in one or more countries, but with tangible effects at the higher Community scale.

As already mentioned, obstacles have been faced: very few projects have produced results that that genuinely refer to Europe in the sense just described. This *per se* constitutes a challenge ahead: to first define what type of European relevance can be sought in a given research project and then how it can be tackled from a methodological and practical point of view. Difficulties are clearly significant, as many initiatives have been striving to achieve interchange and harmonisation of data and result representation. A discussion should be held on perhaps what is actually needed in terms of information to support European mitigation efforts.

In particular, knowing the risks, or at least those that have always affected human societies, implies also a quantitative recognition of past disasters and associated losses so as to identify trends in recent decades, and to compare between more and less recent events.

Virtually any article aiming at a global assessment of some kind of natural risk provides a table or a graph with such numbers. The problem is that sources of data are either inaccessible or scarcely reliable to accomplish the task. As thoroughly discussed in Chapter 3, several databases exist at various scales: national, regional, worldwide. Again the scale factor becomes crucial, as for any territorial phenomena. Because of substantial differences in sources, in criteria for data selection, aggregation according to categories and manipulation, databases at different scales cannot communicate. Here is a field where ICT could also be used to achieve substantial improvement, but the fundamental problem of differences in criteria, formats and standards will remain and constitute a significant obstacle to overcome.

International databases are also not easy to compare. As shown, data from EM_DAT and Munich-Re regarding the same event are often diverging, sometimes by an order of magnitude. Among other reasons, this is due to the different rationale of the two databases. The first has a more "humanitarian" perspective, as it is run by an institution with interest in epidemiological aspects and in the domain of assistance and care for disasters' victims; as for data reliability, the EM_DAT database relies on governmental sources, but with little possibility to countercheck with independent sources.

The second database is certainly more accurate as far as the input data are considered, as the latter come from insurance companies and have been gathered presumably more in the field. Nevertheless, the main focus on economic losses and among the latter on insured ones, restricts its validity and coverage of other aspects of disasters.

As a consequence of the shortcomings connected to those freely accessible databases, numbers associated to losses, death toll, victims and homeless are biased; they do provide an indication and they can be considered as a reference, but with relevant limitations.

Apart from the latter, there are a couple of other considerations to be made, mainly referring to the potential use of disaster information to support risk mitigation. In fact, few if any available databases allow for correlations between surveyed damage and root causes. In other words, damage information is poorly geo-referenced or localised, limiting the possibility to recognise vulnerability factors that may have generated them. Actually, existing data cannot even be correlated to hazard factors in a satisfactory way, as in some cases basic information such as the exact location of the event core/epicentral area or the magnitude is missing.

Finally, in order to be able to use damage data for mitigation purposes, it would be necessary to go beyond physical damage. In fact, secondary, induced and indirect damages are not reported in available databases, while it may be the case that their total amount far exceeds direct physical damage. Furthermore, secondary and indirect damages may sometimes significantly influence social ability to cope and recover.

It was therefore suggested (Chapter 3) that a European database of disasters should be created to permit comparison of future losses occurring in different countries. Data should be gathered and organised according to standard criteria, clearly identify selected information sources and provide more complete information as depicted in Table 7.1.

Such a database could be also used as a valuable source complementing more qualitative information such as that provided by projects like Nedies or by other databases like Mars for technological accidents.

7.2.2 Emerging Threats at the European Scale

As for emerging new types or modified threats, three main issues stand out from the analysis carried out in the Scenario project (see in particular Chapter 2): the potential consequences of climate change, spatial factors and hybrid/enchained hazards.

As for the first, even without considering the broader climate change issue, the climate variability registered in recent decades has already brought consequences in terms of heatwaves (the 2003 heat wave was the most deadly event in the aftermath of the Second World War in Europe) and influences on hydrogeological and meteorological hazards, that can be tracked in various databases and numerical trends analysis of events. It is important to appraise the extent of those changes and particularly the response capabilities of governments and societies in Europe. Uncertainties and difficulties arise not only in attempts to regionalise the global threat posed by climate change, but also in measuring the degree at which it may affect a rather wide range of other phenomena.

Table 7.1. Suggested structure of damage database at the European level

Disaster location	*Event severity*	*Time of occurrence*	*Duration*	*Spatial effects*	*Victims*	*Injured*	*Temporary evacuated*	*Damage to infrastructures*	*Damage to public facilities*	*Damage to residential buildings*	*Damage to economic activities*	*Insured losses*
Exact area	Depending on the hazard	Time of the day/exact date(s)	Duration of the event	Affected areas, description	Death toll	Number of injured	People temporarily displaced	Physical and functional damage to power, gas, etc.	Physical and functional damage to schools, hospitals	Physical damage to houses	Physical damage to structures, machines and loss of work days	Reported by insurance companies

Fig. 7.1. Damage to buildings due to a flash flood in Italy in Val Chisone, 2008

Fig. 7.2. Damage to an industrial site in Val Chisone, Italy, 2008

Fig. 7.3. Damage to infrastuctures in the Val Chisone, Italy, flash flood 2008

As for the spatial aspects, assessors and legislators should not restrict their concern to regional events, which may imply highly transboundary effects, as in the case of major floods or storms, but increasingly consider the challenge posed by events that can be defined as multi-site. The latter are otherwise local events which may nevertheless occur simultaneously and be scattered over large surfaces, imposing tremendous demands on responding organisations. It is not just a matter of labelling, but rather of recognising that fires or landslides occurring in the meantime in various European regions require extraordinary control over existing resources, be it in terms of civil protection forces or financial aid for reconstruction.

Regarding na-tech, it is clear that since the term was introduced in the disaster literature (from Myers and Showalter, 1992), a constantly increasing number of accidents in hazardous plants and installations triggered by natural disasters have been recorded, particularly in cases where large metropolitan, fully equipped areas have been stricken. Those hybrid risks have been indicated already in the work by Mitchell in 1999 as deserving further attention in the coming years. This implies lowering the barriers between technological and natural risk studies, while acknowledging the potential of such threats also in the application of the Seveso Directive. In fact, despite the theoretical appreciation of na-tech, very rarely have safety reports of hazardous installations actually accounted for natural extremes in their risk analyses, discounting such scenarios as highly improbable.

The three points mentioned above seem to share in common the call for multi-hazard and multi-risk approaches, which are needed when complex environments are analysed.

7.2.3 Changing Patterns of Exposure and Vulnerability

A core question for developing future scenarios is estimating how changes in the built environment, in infrastructures and in society in general may change patterns of exposure and vulnerability.

Europe is already a diversified and heterogenous society, where several languages are spoken and a variety of cultural identities coexist. Such fragmentation has been growing also internally, together with the increase of international exchanges and immigration from poor countries, inside and outside the Union. In the meantime, Europe is experiencing an increasing ageing of its population, unprecedented in history. These two factors translate into challenges for risk mitigation. The mobility of people, settling in areas far from their origins, means choosing areas that may be prone to hazards, sometimes as a consequence of deliberate choices made by developers, sometimes putting at risk people who have little or no knowledge of and familiarity with local environments.

Secondly, in times of crisis, both populations (newcomers and the elderly) have specific needs that must be addressed by civil protection. Language constraints, limiting the ability to understand warnings, and instructions are an

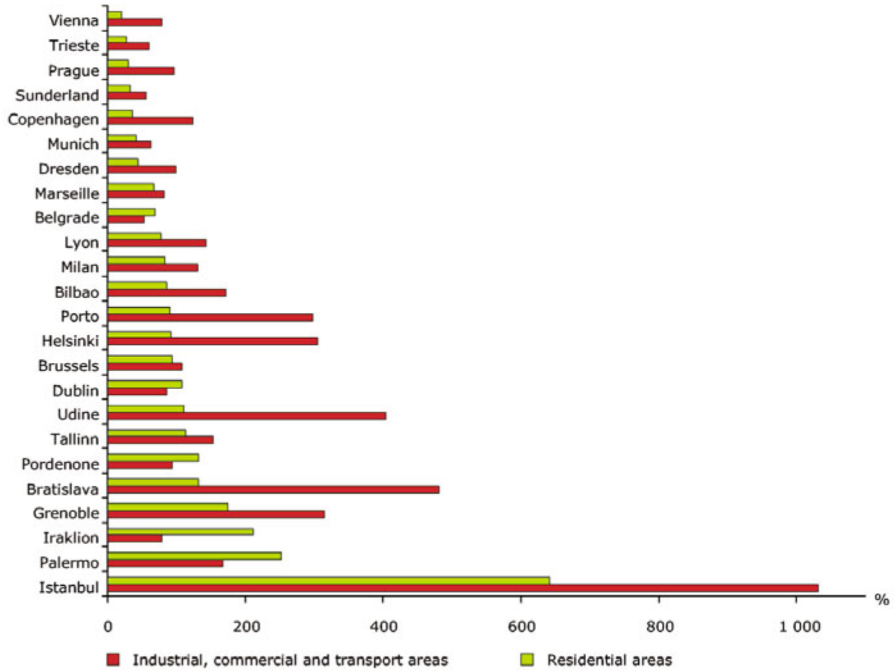


Fig. 7.4. Growth rates of residential areas and industrial, commercial and transport areas from the mid-1950s to the end of the 1990s, selected European cities (European Environment Agency, 2006)

example; another is provided by people with mobility impairment, who may encounter more difficulties in escaping, surviving in temporary shelters, etc. In general, it can be said that emergency planning is still missing relevant targets, such as special buildings and facilities (like retirement houses, prisons), which rarely develop credible contingency plans for mass disasters, and are almost never embedded in more general plans prepared by authorities.

Changes in the European space are no less relevant, particularly when social changes are considered in their entirety, including the potential consequences in terms of land uses and regional development. Three elements have been highlighted as far as the impact of natural and na-tech hazards is concerned.

The first relates to the urban sprawl that has been characterising virtually all European countries. Sprawl means, on the one hand, increasing increasing pressure on the environment, with direct and indirect consequences for hazards; on the other it implies a higher probability of occupying marginal and dangerous areas, in areas difficult to access, creating extra burdens on search and rescue teams.

The second aspect relates to lifelines, in particular energy supply and transportation networks, the current development of which is going to significantly modify mobility across Europe in future decades. Such networks may encounter areas threatened by natural hazards, the relevance of which is not always fully appreciated when the local implementation of such large megaprojects has to be carried out. In addition, as shown by Flyvbjerg et al. (2003), problems related to natural hazards that have been underestimated in the design of large projects delay construction and incur extra costs or works that constitute a financial risk *per se*, especially for governments.

Furthermore, new infrastructures are likely to impact on development, particularly in areas where accessibility will significantly increase, and extra care should be taken to avoid new settlements in hazardous locations (Bolton et al. 1986). As infrastructures create a magnet effect for development, attention should be paid to where they are made to pass through and where crucial connections, stations and connection nodes are built.

Transport infrastructures will make some places much closer than they have been up to now, but regional and national conditions will not change. As a result, today's remote places, such as mountain areas or islands, will continue to be remote, demanding extra efforts, for example, in managing crises.

The third aspect, referring to interscalar relations between places and regions in Europe, has been searched through event scenarios. In particular, the objective was to understand on the one hand how global threats, such as climate change, may have rather diverse impacts, particularly when factors like adaptation and coping capacity are considered, and on the other how a local event, for example a volcanic eruption, may have a ripple efffect on the European economy and society.

Box 7.1
Illegal and Informal Settlements: A Future Challenge for Europe

Informal and illegal settlements may constitute a significant problem for Europe in the future. The latter are the result not only of traditional attitudes to eluding compliance with urban plans in some Southern European countries as well as in recently integrated Eastern European ones, but also of the increasing demand for dwellings arising from recent immigrants.

Furthermore, as stressed by the EEA Report (2006), the same urban sprawl, which is increasingly affecting Europe, is very often synonymous with unplanned incremental urban development, characterised by a low-density mix of land uses on the urban fringe.

Informal settlements are very often built up in hazardous areas, worsening risk conditions, increasing exposure, and physical and systemic vulnerability, and inducing relevant problems even in the emergency phase, due to the need to evacuate populations, in many cases illegal, characterised by extreme conditions of economic and social degradation.

Hence, a sustainable approach to risk prevention and mitigation cannot ignore that an effort towards effective integration of informal settlements "in the social and economic, spatial/physical and legal framework" (Vienna Declaration, 2004) has to be made.

Some steps towards the integration of informal settlements have already been undertaken at both national and international levels.

For example, in Italy national and regional laws introduced, starting in the mid-1980s, specific plans for the recovery of existing informal settlements that had already been legalised, while for settlements in Rome an "Action Plan on Improving the Situation of Roma and Sinti Within the OSCE Area" was issued in 2003. These experiences, however, are not specifically addressed to risk prevention and mitigation.

Thus, in order to build a sustainable approach to risk prevention and mitigation at a European scale and based on the experiences already developed for Southern and Eastern European countries, some main aspects must be addressed.

As far as research needs are concerned, a knowledge framework of the informal settlements at European scale, based on national surveys for monitoring the phenomenon and providing reliable estimates of dimension, typologies and risk features of informal settlements, has to be developed. The need for such in-depth studies has already been mentioned in the "Discussion Paper on Challenges and Integrated Policy Responses for Informal Settlements" (2007) and it should represent a relevant supporting tool for policy implementation at the European level.

As far as policy needs are concerned, reccommendations for driving current policies for the recovery of informal settlement in European countries – in cases where they do not threaten environmental or cultural heritage protection – towards risk prevention and mitigation issues and effective rules for preventing informal settlements in the future should be provided. For example, in order to reduce their physical and systemic vulnerability, policies aimed at their legalisation and integration into urban areas should be accompanied by actions to retrofit buildings or to provide basic infrastructures and services.

Those scenarios highlighted some aspects that should not be disregarded either in future research or in risk governance. First, it will be increasingly difficult to state that some disasters, even if their direct impact is limited, are truly local. Whenever the magnitude of events is large, particularly in cases where metropolitan areas or important economic centres embedded in international networks are stricken, events may have an extended impact on much wider areas, on tourism, economy, lifelines.

Another aspect worth mentioning refers to the articulation of European spaces, which cannot be simply divided between urban and rural, megacities and regional networks. In a relatively small area, Europe presents all kind of settlements: mountain, modern extensive agricultural lands, small islands, remote rural places, large, medium and small size cities, and coastal development (Klein et al., 2003).

7.3 Coping Mechanisms in Europe: Present Constraints and Future Challenges

The European Union has performed remarkably strongly in issuing legislation and in encouraging compliance in the field of environmental policies. The latter has grown in importance over the decades, evolving from scarce, if any, consideration in the earliest stages of the European Economic Community to the increasing concern shown by the Environmental Action Programmes (see McCormick, 2001).

In this context, legislation in the field of natural risks has not been as strong as in other areas, like waste management or pollution control, though it may be worth noting that the first field of legal intervention of the EU was grounded on the Euratom Treaty in 1957, "establishing uniform safety standards to protect the health of workers and of the general public". Thus the European initiative in the environmental field was triggered by safety concerns, though focussing on technological risks.

The reason for the scarce intervention in the field of natural hazards can be explained in various ways. First, the rather sectoral approach that has characterised mitigation policies, also nationally, as denounced by, among others, the Armonia project (see Fleischhauer et al., 2006).

Second, the intrinsic difficulties that still exist in entering the field of non-structural mitigation measures, in which European intervention would make more sense but is also difficult to sustain without competing with national diverse systems of education on the one side and land use and spatial planning on the other, the two pillars of non-structural measures.

Another significant obstacle is represented by the need to set a sort of European standard or level of "acceptable level or risk", while this would encounter different and even diverging starting points in the various countries, a problem that the adoption of policies for climate change also faces (see in particular the sea-level rise scenario in Chapter 6).

A no less relevant reason can be found in the at-best sectoral contribution of past research to the formation of a comprehensive risk mitigation policy. The latter addressed mainly specific sectors of hazard mapping or codes to reduce the vulnerability of buildings to some risks.

The Flood Directive certainly constitutes an important innovation and is perhaps a first step towards a more comprehensive policy for natural risk reduction efforts at an EU scale. In this regard, many aspects require futher investigation and prioritisation.

A crucial point is the achievement of more integrated policies supported by adequate legislation. In the same field of natural hazards there is the need to move towards policies that are simultaneously more comprehensive (embracing several risks in a multi-risk perspective) and more interconnected with other environmental policies as well as with decisions regarding the development of the European space. Secondly, in line with the ideas proposed in this book on a stronger connection between sustainability and prevention, important tools such as the Strategic Environmental Assessment (2001/42/EC) should comprise risk assessment. Mitigation efforts should be carefully designed to reduce the impacts provoked by human activities on the natural environment and also damages the latter may suffer from disasters, both natural and man-made. In the same vein is the intersection with the Seveso Directive, particularly concerning na-tech risk.

7.3.1 Emergency Preparedness and Contingency Planning

In the field of short-term mitigation, the legislative and organisational efforts of the EU Commission have been stable and constant since the introduction of the Community Mechanism. As stated in the introduction to the Legislation Working Programme 2007, "Environmental and health risks, communicable diseases and natural disasters, as well as threats from terrorist attacks require rapid and effective response capacity at the EU level". The forest fires affecting Southern European countries in the summer of the same year raised concern about the capacity to respond effectively to large regional or multi-site disasters. The Communication from the Commission on Reinforcing the Union's Disasters Response capacity mentioned in the resolution adopted in June 2008 represents an important document, drawing on past experiences and reports (see in particular Barnier, 2006), to look at the future. Among other aspects, strengthening of monitoring capacity and the creation of a European training network are discussed. Research has an important role to play in the training network as well as in providing the basis for disaster prevention and response capabilities, as explicitly mentioned in article 35 of the Resolution approved in June 2008. In particular, research can provide a systemic approach to crisis management and contingency plans, addressing a multi-risk perspective whenever needed and preparing experts capable of intervening and advising in emergencies. This type of expertise is not easy to develop and, among other training objectives, appropriate attention should be paid to training scientists to assist on issues like building usability after earthquakes, road and network safety conditions after or during landslides, and expected lag time for pick discharge to generate a flood in a given river section.

Whilst physical and particularly systemic factors are always important, social vulnerability becomes prominent for short-term prevention. Under this label, different aspects must be considered, such as:

- organisational vulnerability of civil protection agencies, with respect to problems in resources and coordination
- people's preparedness (or lack of) to face emergencies and their consequences
- people's inability to cope, because of some kind of constrain (physical but also cultural).

Additional stress on social systems may derive from transboundary events, when there is the need to coordinate efforts and resources among countries. The European Commission is taking initiatives in this regard as well as in enlarging the view towards regional and multi-site events and in recognising the differences in threats menacing the various European geopraphical zones.

Event scenarios are a fundamental tool for civil protection preparation and constitute a basis for contingency plans, as demonstrated in Chapters 5 and 6. The key message deriving from the Scenario project concerns the need to go beyond hazard scenarios, to integrate exposure and vulnerability factors. In this respect, scenarios set in the Barnier document (2006) may be too extensive while underestimating important eventualities. The decision on what to prepare for should derive from an imaginative effort to understand how old and new threats in a changing European society and space may interact, producing specific types of damages and challenges to rescuers and to those in charge of rehabilitation.

Without such efforts, the type of resources, human and technological, that will be taken into account are of the most traditional type, while what is required is perhaps much more an assessment of how well and quickly unexpectedly needed tools and expertise can be mobilised (Guilhou and Lagadec, 2002). According to Boin and Lagadec (2000), "the required response is not just local and technical: it is an executive task to help systems re-orient amidst severe turbulence".

In the context of short-term measures, early warning systems play an important role, particularly for those hazards for which pre-alerting and forecasting is possible on the basis of existing knowledge, models and monitoring techniques.

Recently, some experience has been developed in the use of monitoring systems as a mitigation system, in areas where climate change effects are likely to trigger the occurrence of gigantic and deep landslides, during prolonged rainfall and where stabilisation costs are so high as to become unrealistic (Cardellini and Osimani, 2008)

Early warning systems have long been considered a technical problem, related to monitoring devices and to control variables in order to forecast extremes in a short time. The newest approaches to the issue have overshadowed this way of interpreting things, showing the limits of a uniquely technical approach to the question (see also Third International Conference on Early Warning, 27–29 March 2006).

In the absence of careful consideration of the various links between the steps just mentioned, the institutions in charge of them, and a strong network connecting those institutions, authorities and the public, it will be impossible to transmit an alarm which, by the very nature of the involved phenomena, may rely on a narrow, albeit sufficient, time window.

Furthermore, it must be recognised that even limiting the analysis to very technical matters, the interpretation of premonitory signals is by no means simple and often requires the use of models developed by experts from different disciplines.

Therefore, there are at least two crucial fields to be explored in the attempt to develop better early warning systems: the first relates to the development of scientific knowledge to be used in forecasting reliable models, particularly whenever multi-hazard or multi-site events are at stake; the second concerns the connection between these technical and scientific tools and the social networks through which the alert message can be propagated in appropriate ways to save lives (see Parker and Handmer, 1998).

As for the first point, research should focus on aspects such as the following: the evaluation and selection of the most appropriate models providing as an output crucial information regarding an imminent event; the development of monitoring systems feeding models with reliable data at scales and time intervals compatible with decision-making and contingency management activities; the uncertainties involved in current knowledge embedded in prediction models. Being aware of uncertainties is crucial while taking decisions on evacuation or any other mitigation measures implying high social and economic costs. False and missing alarms involve questions that cannot be answered only technically; nevertheless they require technical experts to provide enlightening insight to make the best decision.

Even though also scientific and technical aspects of prediction require further research efforts, the interface between the latter and their translation into a "social fact", strong enough to mobilise collective and individual actions of protection and self-protection, remains the least investigated issue.

There have been studies concerning different warning systems designed in Europe (see Parker and Fordham, 1996) that would deserve to be updated today and extended to a larger number of countries, including those adhering to the Union more recently. The study identified a grid of criteria against which the performance of early warning systems for floods was assessed; its application showed a rather diverse situation not only comparing nations, but also regions within the same state. In a more recent article Handmer (2001) states that "unfortunately, European flood-warning systems often do not seem to have fostered the empowerment of potential victims, and with some exceptions, neither they achieved integration across the many functions, organisations and countries".

What is still missing is a clear codification of the different technical and social elements that contribute to an efficacious alarm system, connecting in a unique path the knowledge regarding given hazards, monitoring systems, information transmission and contingency plans.

Box 7.2
Climate Change: New Challenges for Civil Protection Agencies

"It is now clear that in coming decades natural disasters are broadly expected by members of the scientific community to intensify due to climate change. Emergency managers, planning agencies, private companies, and communities especially affected by climate change will be challenged to adapt their planning to take into account an increase in the type, extent, and intensity of natural hazards". This quotation is taken from the draft of the Multihazard Mitigation Plan of California, open to the public for comments. With respect to the previous 2007 version, the more recent one devotes more room to climate change and related hazards. For some years this idea has been circulating also among civil protection officers and firemen, like me, in Europe, although not in official formats and settings. A recently concluded project, involving universities from the Netherlands (coordinators), Norway, Sweden and New Zealand, was titled "Climate change and climate vulnerability". Its main goal was "to investigate which factors determine the capacity for local adaptation to climate change by studying long-term institutional learning within civil protection institutions in the wake of extreme weather events".

In fact this is the main issue at stake: how organisational learning can take place effectively in the face of new and emerging threats that are not yet fully recognised by the majority of officials and agencies dealing with contingency planning and crisis management. In general it is said that the time horizon of such organisations is too short to include a threat which is still to come, even though some evidence of changes in climate-related hazards has been observed even by interveners and responders in recent decades. In particular, the frequency and the intensity of extreme events seem to be on the increase, even in areas that were less affected in the past. The question is how to integrate into ordinary activities and the traditional way of conceiving protocols and procedures information and knowledge which is continuously progressing and regarding which large uncertainties still exist. The latter are particularly relevant when local and regional potential consequences of climate change have to be forecasted, as those are the scales at which preparedness by agencies and organisations can take place in operational terms.

Two interacting but still independent aspects should be considered: on the one hand climate change *per se*, as a new hazard implying consequences such as increasing heatwaves and sea-level rise, and on the other as a trigger of other hazards like floods, forest fires and drought, for which the intervention of firemen in many European countries, certainly in Italy, is considered vital. The challenges ahead are therefore multiple: they consist in the need to better integrate scientific expertise in professional and operational practices, something that has seldom been systematically pursued in some of the aforementioned organisations, in the need to prepare means and personnel for potentially more frequent and more severe storms, floods, particularly flash floods, and fires, and in the need to identify the most exposed and vulnerable areas for pre-allocating materials and personnel, for example in coastal areas or islands.

However, the challenges do not only pertain to national and regional civil protection forces, they also involve international organisations and in Europe the Community Mechanism, which is likely to increase the number of interventions in coming years both to respond to internal calls and for humanitarian purposes in countries outside the EU. The Community Mechanism has been growing steadily since its creation in 2002, with 3 interventions to 2008, when 20 interventions were recorded. Those interventions require the training of personnel in individual countries, not only to face a larger number of aid requests but also to be prepared for some of the "security" challenges mentioned in the document prepared by the European Commission on the issue in 2008 (S113/08, 14 March 2008). Among the latter, environmental migrations are quoted as reported also in the Scenario project.

In summary, the main task ahead is to build a cooperative system fully acknowledging the issue of climate change and related hazards, not only for rescue purposes but also to provide support and assistance in all phases of crises, including warning, mitigation and return to normalcy.

7.3.2 International Cooperation and Humanitarian Aid

DIPECHO, the special unit for disaster assistance within the framework of European humanitarian aid, releases an evalution report every year, summarising the developed activities and assessing future needs.

With respect to emergency management issues, considerations made previously regarding short-term mitigation strategies inside the EU apply also to international cooperation. The Community Mechanism, in fact, was created with the dual intent to assist countries inside and outside the EU facing severe emergencies. In this case the intervention occurs in compliance with the EU humanitarian aid policy, comprehensively stated in the European Consensus on Humanitarian Aid, signed in December 2007 by the EU Parliament and Council.

It would be therefore extremely beneficial to integrate knowledge and experience gathered in disaster management outside and inside the EU. Comparison of difficulties, failures and successes encountered in efforts in both arenas could provide important lessons to improve for the future. In this regard, a cross-analysis of the Nedies report on the one hand and the Dipecho on the other should be carried out. For example, the Dipecho report on the South East 2007 recommends that more effort be put into documentation dissemination of lessons learnt in disasters and risk reduction. Another integration effort should be made between scientists working on various disaster aspects and those active in humanitarian projects in contexts at risk. This would avoid the initiation of projects in developing countries without adequate understanding of the positive and negative consequences of similar rehabilitation/reconstruction processes that have been made in the past within and outside the EU borders.

Reporting the results of an expert workshop organised by the Centre for Research on the Epidemiology of Disasters (CRED) and the ECHO in 1997, Twigg (2002) has identified, among others, the following critical issues:

- "Lack of standardisation not only between countries but even in the assessment of different types of disasters within a single country
- lack of training for assessors
- limitation in coverage (e.g. assessors focusing on their institutions' areas of interest, and overlooking damage that is not eligible for government assistance; political pressures to over- or under-report)
- pressure to carry out assessment soon after a disaster, and quickly (while this is important in addressing relief needs, there is often no follow-up and hence no assessment of disasters' long term consequences)".

Difficulties in achieving satisfactory data for assessing past interventions often "add strength to the argument for rapid engagement without waiting for the data" (Twigg, 2002), while as Quarantelli (1977, p. 106) suggests: "it is far more important in disaster to obtain valid information so as to what is happening than it is to take immediate action. [...] Planning in fact should help to delay impulsive reactions in preference to appropriate actions necessary in the situation".

Furthermore, insufficient attention has been devoted to vulnerability factors to assess how poverty, underdevelopment or unsustainable development translate into specific weakness and fragility (Buckle, 2000). In the meantime, lack of attention to local history, political and social aspects lead to underestimating or ignoring the resilience and coping capacity available to overcome crises, while providing answers to incorrectly interpreted needs or even being counterproductive, for example in a conflict situation (Christoplos, 2006).

7.4 Issues of Future Research

Figure 7.5 is organised so as to represent the intersections between key research themes on the one side (the x axis) and policy key issues on the other (the y axis).

Describing in further detail the scheme, along the horizontal axis, three main aspects have been identified:

- a more general one, related to the kind of knowledge that must be further developed in the field of natural hazards
- a second one, addressing the requirement to produce a vision for Europe as an entity and not only as the sum of individual states
- a third one, addressing risk assessment needs in more depth, in the light of a broader definition of risk (therefore including vulnerability and exposure) and acknowledging the large variety of conditions existing in Europe (as in other regions of the world), comprising multi-risk conditions, hybrid risks (Parker, 1999), domino effects, and emerging and insidious threats.

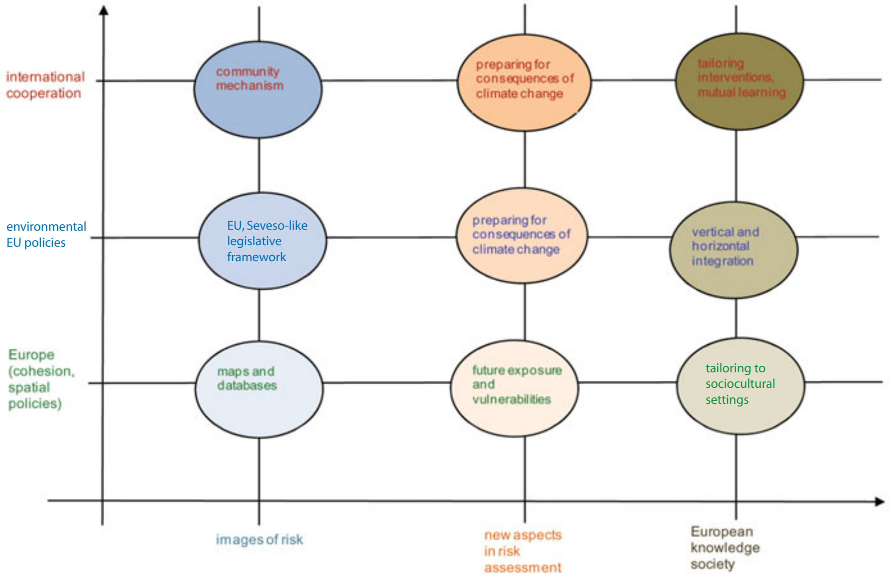


Fig. 7.5. Future research needs addressing theoretical and risk governance aspects

Looking at the vertical axis, the following aspects have been highlighted:

- first the "political" definition of Europe, suggesting that the latter is relevant for setting priorities among hazards and risks
- second, the level of international cooperation, as Europe is currently acting in this field at least at two fundamental levels: providing a Community Mechanism of civil protection to be displaced in third countries whenever required, and scientific cooperation, for example with Asian countries and Latin America
- finally room for innovation within the rather large body of environmental policies in order to integrate risk mitigation more satisfactorily than pursuing it in the usual sectoral fashion.

Not all the nodes that have been drawn in the figure will be extensively developed. Some will receive significant attention as they are considered key questions as derived from previous chapters and collective discussions.

Learning from the Past

As Hewitt wrote (1983), the fact that it is not possible to forecast precisely when and where an extreme strikes cannot be an excuse for not preventing it, as if there were no knowledge about the existence of hazards in a given site.

History is a precious archive where past events have been recorded, constituting an indispensable basis for future forecasts. For some hazards, historic data are used to draw statistics about frequencies and exceeding probabilities as well as to identify areas that have been hit in the past. Europe holds an immense patrimony of documents and data stored in parishes, state archives and private collections.

The catalogues of historic earthquakes are certainly the most eminent product of this type of study. To compile these catalogues, it was necessary to shift from an anecdotic description of events to a systematic, analytic grid, permitting the classification of reports that can be obtained from historic documents by location, extrapolating exact references to dates, numbers of affected people, damaged houses and infrastructures, etc.

In carrying out such analysis, vivid testimonies of past dramatic disasters can be found and have occasionally been published (Boschi and Guidoboni, 2001). Unfortunately, the potential of these storytellings for other aspects of risk assessment and management has not been appreciated as in the case of hazard statistics.

Instead, a deeper understanding of how past societies have coped with disasters, emergencies, recovery and reconstruction is extremely useful in making sound decisions for the future.

Descriptions of past events would enhance our comprehension of constraints, opportunities, and successful and wrong decisions that have been made, constituting a reference for complete event scenarios. As "scenarios are futures seen in the past" (Schwartz, 1991, pp. 36), past reports are an important and often unique source of inspiration to envisage what may occur in the case of a similar extreme event in the future.

Last but not least, history is important to investigate the underlying drivers of present levels of vulnerability, which may still be at work in modern times. Vulnerability, as well as resilience, in both physical and systemic components is the result of historic processes, which have made settlements, infrastructures and buildings develop and grow in given ways, according to specific dynamics and patterns. Being able to recognise those is crucial to understanding the causes as well as social, political and economic roots of vulnerabilities. Examples of such use of historic analysis have been attempted in some studies, more or less systematically (Tropeano, 1989; Tobriner, 1988).

Certainly a stronger cooperation between historians and scientists is required: the former are mainly interested in understanding the social, cultural, political and economic processes, and are less aware of the information potential of documents for scientists and technical purposes. In their turn, scientists would misinterpret historic documents without the necessary expertise including the geographical, situational and temporal context to reconstruct the meaning of words and texts (see Massard-Guilbaud, 2002).

Dynamism

The instrinsically dynamic nature of risks and processes that they generate or that are designed to manage the latter is a key concept that only appears to contradict what has just been discussed in the previous paragraph.

In many instances, dynamism is inherent to the hazard itself in one form or another, because changing factors in the environment (including human interventions) may worsen the severity or the frequency of natural extremes. In others, dynamism is a key feature of exposed systems, for example technological plants or lifelines. On some continents (particularly Asia and Latin America), a strong dynamism characterises the growth of urban areas.

Certainly, the world as a whole has undergone a dramatic change in the last few decades, experiencing for the first time a condition in which the majority of the population lives in cities.

The dynamism in technology, the growth of cities and population trends of recent years makes it increasingly difficult to recognise in the past the seeds of the future and enlarges the gap between what we know and can infer from experience and forecasts, visions of the future.

Despite those obstacles, the only good way to trace scenarios is to continue to learn from the past, merging together information and analysis of past events, past societies' strategies for coping with disasters on the one side and their capacity to recognise crucial trends and factors in the present on the other.

Dynamic processes interfere with our ability to forecast and contribute to create uncertainties in the following dimensions:

- whenever dynamic natural processes are at stake, which are difficult to model, particularly in the case of enchained hazards, such as earthquakes triggering landslides or the latter carrying sediment to rivers
- whenever new technologies change the facets of some particularly vulnerable systems, such as factories or lifelines. Na-tech are important examples in this regard, as their number is going to increase on the one side as long as metropolitan areas are involved in disasters on the other as a consequence of the same development of new technologies.

Vulnerability and Resilience

The concept of resilience was introduced at the beginning of the 1970s to indicate the capability of natural systems to absorb perturbations, preserving their structure and function. Thus, resilience referred to the "load" that a natural system can sustain before changing its structure, modifying variables and processes which control its behaviour. A resilient system was interpreted, therefore, as a system's capability "to absorb change and disturbance and still maintain the same relationships between population or state variables" (Holling, 1973, p. 9). In the last few years, the concept of resilience has been investigated in more depth with respect to complex systems, focusing on the capacity of those systems to face external stresses, like extreme events, renewing and reorganising themselves and reaching a new state of equilibrium (Gunderson and Holling, 2002). In particular, as regards complex systems, resilience refers not only to their self-organisation capability but also to their ability to learn. from experience and adapt to external stresses (Carpenter et al., 2001; Folke et al., 2002).

Meanwhile, the term "vulnerability" generally refers to how prone people or structures are to damage in case of extreme events: thus, it represents a measure of fragility, and the inability of people, structures and networks to cope with severe external stress.

As for the relationship between resilience and vulnerability, at least three main approaches or schools of thought can be currently identified:

- Resilience as the flip-side of vulnerability (Fortune and Peters, 1995, Folke et al., 2002).
- Resilience as a component of vulnerability. For example, McEntire (2001) identified resilience as one of the four variables determining vulnerability, together with proximity to hazards, susceptibility and resistance. Similarly, Pelling (2003) recognized a priority role of vulnerability with respect to resilience and suggested an interpretation of vulnerability as resulting from exposure, resistance, and resilience.
- Resilience and vulnerability as separate concepts (Paton, 2008). According to those authors, resilience and vulnerability are considered as independent, acting in different phases after the event (readiness, response and recovery) at individual, community and institutional levels in order to contribute respectively to improve adaptation and minimize disruptions (Paton, 2008).

Some scholars identify adaptability as the overlapping part between vulnerability and resilience (Chapin, 2009), highlighting that the two concepts cannot be interpreted neither as opposite nor as included one into the other, but as separate, only partially overlapping.

According to both the second and the third interpretations resilience and vulnerability play a different role in the capacity of a territory or a community to prepare and respond to extreme events. Both share the idea that strategies aimed at reducing vulnerability do not necessarily contribute to improve resilience in a given system and viceversa.

It should be pointed out that the concept of resilience has an active and highly dynamic dimension as it represents the capacity to face disasters and rebuild and, also, to take advantage of experienced burdens to build up the future. The capacity to store knowledge and experience produces flexibility in solving problems, improving the adaptability and, ultimately, the resilience of social systems (Folke et al. 2002). Being able to anticipate and plan for the future may increase a system's capacity to resist and recover from changes and this has to be considered (Kasperson et al., 1995) in risk analysis. Social and territorial systems vary significantly in their capacity to react to and recover from extreme events (Comfort, 1999), to reorganise without undergoing decline, to keep crucial facilities functioning and to take advantage of the change by transforming it into an opportunity for further development.

According to some authors, several cities in history have manifested this capability in past disasters (Vale and Campanella, 2005).

Therefore, a distinct objective has been identified as the need to build resilience into communities and the built environment, reduce expected losses and in the meantime be prepared for recovery. Systems are not just required to overcome extreme events with no damage, but also to prepare tools and plans to respond adequately to losses and failures, maintaining basic functioning of critical facilities and community activities. This process can now be identified with the implementation of "empowerment", slightly revising the current approaches to sustainable development. Empowerment is a lifelong process whereby an individual, a population, a community, a venture, a region or a country gain knowledge and deliberately learn how to shape the latter and make it consistent with the community's aspiration and identity, with the natural and cultural heritage, coherent with historical course and development (Di Castri et al., 2005). Through empowerment information loses its traditional vertical hierarchical arrangement to achieve a cross-disciplinary character that rules over communication, spatially diffused (as opposed to concentrated) initiatives, and the possibility for any individual to embark on such initiatives. Building resilience into local communities is then a process which includes the empowerment of the public, but in a more participative, collaborative and responsible way also at an individual level, for a general advantage. Resilience has the potential to become an important concept to be searched in future research, to clarify its specificity compared to other fundamental concepts that have been used in both the disaster and the climate change communities. Equally relevant, though, is the question of how to operationalise concepts like vulnerability and resilience, providing both qualitative and quantitative indicators to identify deficiencies, and strengthen the basis for mitigation on the ground.

In the last few years, the concept of resilience has been investigated in more depth with respect to complex systems, focusing on the capacity of those systems to face external stresses, like extreme events, renewing and reorganising themselves and reaching a new state of equilibrium (Gunderson and Holling, 2002). In particular, as regards complex systems, resilience refers not only to their self-organisation capability but also to their ability to learn from experience and adapt to external stresses (Carpenter et al., 2001; Folke et al., 2002).

Meanwhile, the term "vulnerability" generally refers to how prone people or structures are to damage in case of extreme events: thus, it represents a measure of fragility, and the inability of people, structures and networks to cope with severe external stress.

The correspondence between resilience and vulnerability appears more clearly in recent definitions of vulnerability. Although they specifically refer to social systems, these definitions widen the concept from the propensity to be damaged to the "characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural hazards" (Wisner et al. 2004). Therefore, systems' vulnerability can be viewed as the opposite of their capacity to absorb perturbations; hence, as the opposite of their resilience (Fortune and Peters, 1995; Adger et al. 2005).

Thus, an ecological, social or territorial system becomes vulnerable when it loses its resilience or, in other words, its capacity to absorb change. In a vulnerable system even small changes can be devastating (Folke et al. 2002).

In order to embed the concept of resilience into risk analysis, the diversity of both natural and social systems must be fully appreciated as a fundamental quality providing resilience. Diversity, in fact, assures a much greater functional "redundancy". Some authors (Low et al. 2003), based on the analogy between ecological and social systems, stress the larger capacity of systems characterised by diversity and redundancy of functions and institutions to absorb changes and, above all, to reorganise after a crisis.

It should be pointed out that the concept of resilience has an active and highly dynamic dimension as it represents the capacity to face disasters and rebuild and, also, to take advantage of experienced burdens to build up the future. The capacity to store knowledge and experience produces flexibility in solving problems, improving the adaptability and, ultimately, the resilience of social systems (Folke et al. 2002). Being able to anticipate and plan for the future may increase a system's capacity to resist and recover from changes and this has to be considered (Kasperson et al. 1995) in risk analysis.

Social and territorial systems vary significantly in their capacity to react to and recover from extreme events (Comfort, 1999), to reorganise without undergoing decline, to keep crucial facilities functioning and to take advantage of the change by transforming it into an opportunity for further development. According to some authors, several cities in history have manifested this capability in past disasters (Vale and Campanella, 2005).

The final document of the World Conference on Disaster Reduction held in Kobe in January 2005 considers "the development and reinforcement of institutions, mechanisms and capacities at all levels, mainly at community level, which can contribute to build up the resilience to hazards" as one of the strategic issues for risk mitigation.

According to Birkmann (2006), "the term resilience gained high recognition in the Hyogo Framework and the debate thereafter" even though the "current literature" still "reveals different interpretation of the term, especially concerning the question of whether resilience is defined as the capacity to absorb disturbances or shocks, and is thus more linked to the understanding of resistance, or whether the term refers to the regenerative abilities of a social or an ecosystem, encompassing the ability to learn and adapt to incremental changes and sudden shocks maintaining its major functions. This meaning is more related to the coping and adaptation phase".

Resilience has the potential to become an important concept to be searched in future research, to clarify its specificity compared to other fundamental concepts that have been used in both the disaster and the climate change communities. Equally relevant, though, is the question of how to operationalise concepts like vulnerability and resilience, providing both qualitative and quantitative indicators to identify deficiencies, and strengthen the basis for mitigation on the ground.

Integration

In an article whose title paraphrases a previous one by White et al. (2001), "Knowing sufficient and applying more: challenges in hazard management", Weichselgartner and Obersteiner (2002) propose a table in which necessary shifts are recommended from an old method of tackling risks to a newer one that is more suitable for the present challenges. Among the latter, the authors emphasise the need to refocus disaster research interests from a hazard-centered approach to one embedding the vulnerability and resilience concepts, moving objectives from response to mitigation, from reactive to proactive management. Furthermore, they have correctly stressed the need to integrate the various risk factors, and as a consequence, the disciplines dealing with the latter.

Investigating the possibility of integration between disasters and climate change fundamentals was one of the objectives of the Scenario project. Currently crucial issues seem to separate the two communities with little chance for such an integration. Nevertheless, some advancement in this respect can be foreseen on the basis of research that has been carried out, particularly in recent years.

Arguments challenging the notion of no match points can be put forward. The reasons for lack of common ground as summarised by Pelling and Schipper (2006) can be counterbalanced as follows:

- Climate change policy deals exclusively with climate-related hazards and their impacts; nevertheless, climate change is not only a hazard *per se* but may significantly influence several other natural hazards, like hydrogeological and forest fires, as shown in Chapters 2 and 5 of this book.
- The time frames for reactive adaptations to climate change and disasters are distinct; disaster impacts are relatively immediate and concentrated, whereas the consequences of climate change may evolve, along with social change, over a longer timescale. This position can be held only by limiting the focus on the impact and emergency phases. As demonstrated by decades of research and discussed in the project development, the time before the impact as well as that of reconstruction and rehabilitation have to be considered. Vulnerability development or reduction must be viewed in a historic perspective, as several decisions and processes of different duration are implied. The dynamic character of many natural disasters should not overshadow the latent conditions creating vulnerability to the physical stressors as well as in the form of systemic consequences for losses and damages.

- The scales addressed by disaster studies on the one hand and by climate change research on the other are rather diverse: the former generally focus on the local and regional scales, while climate change analysis has privileged assessment of root causes of human vulnerability emanating from the global political economy. Chapter 6 has challenged this view as well, showing that the interplay between different scales is vital to understand the interaction of nature and society in phenomena caused by both climate change and natural hazards. A rather local event may entail global consequences through the ripple effects across interconnected economic, social and territorial systems.

In Section 7.5, a new logic chain will be proposed in order to show how the concepts used by the two communities might be part of a common and shared methodology, investigating how both stressors and vulnerability/coping capacity of exposed systems and communities can become part of a preventative strategy.

Integration Between Qualitative and Quantitative Models

Risks challenging todays' societies are complex and require much stronger integration between qualitative and quantitative analysis, between the understanding of the physical processes behind phenomena and the social and economic systems that must react and respond to these.

Such an integration should occur at various levels, and start by bridging between social and "hard" sciences, as commented by Jasanoff (1993). Quantitative analysis, modelling of hazards and, whenever possible, vulnerabilities on the one hand and qualitative or semiqualitative assessments of vulnerability, particularly those referring to social and spatial contexts and the built environment on the other, are necessary to achieve the kind of complex understanding recommended by Weichselgartner and Obersteiner (2002). Such a complex, multi-layered approach would help overcome barriers between stakeholders toward a more democratic recognition of the role of the so-called lay public, often the victim and in the meantime creator of exposure and vulnerability.

Integration Between ICT and Disaster Assessment and Management

Links between the ICT and disaster communities should be strengthened, so as to achieve tools that not only perform well but are also a better fit to the variety of tasks implied by risk management.

In this regard, the contribution provided by ICT in the last decade can be grouped into three main categories (Fabbri and Weets, 2005): monitoring, mapping technologies, used to support both long- and short-term mitigation strategies, and devices for crisis management. The latter range from telecommunication to search and rescue means. ICT offers a large variety of solutions which need nevertheless to be checked and tested against emergency conditions, when basic resources (like electricity) may be missing. Interoperability and harmonisation are crucial goals to be achieved whenever a European perspective is taken. Nevertheless, also improvements to tailor solutions to the so-called "end-users" are required.

Box 7.3
ICT for Emergency Management

Needs in the Field
Emergency Management Information Systems (EMISs), usually employed in Emergency Operation Centers (EOCs), provide a set of ICT tools for supporting the emergency management process during its entire lifecycle: mitigation, preparedness, response and recovery phases. More specifically, during the pre-event phases, emergency operators can take advantage of an EMIS for designing a contingency scenario and deriving the related contingency plan. Likewise, during an emergency, information systems guide the involved EOC operators through the execution of the contingency plan workflows. At the current stage, the presence of diverse EMISs accessible to heterogeneous users and stakeholders both in expertise and in specialisations generates in a non-crisis time the collection of a huge amount of disaggregated data and misaligned procedures that may cause, in an emergency context, failures (Lagadec, 2005). In addition, in multi-hazard and multi-risk scenarios, the collection of disaster agent-generated requests changes as time passes from the time of impact; requests associated with initial impact may decline while new demands arise from secondary threats. These changes occurring over time may be associated to information and/or operation management needs.

ICT solutions for emergency management need to cope with these dynamic scenarios by proposing methods and tools for integrating heterogeneous systems, as done for instance in the EU INSPIRE directive and EU FP6 Orchestra project. Generally, two main objectives related to ICT applications deemed to support emergency management can be underlined (Hooran and Schooley, 2007; Manoi and Baker, 2007). On the one hand, crisis and risk management require a *flexible EMIS architecture*, easily customisable, to support people on the field by considering the actual characteristics of the disruptive event that has occurred. This architecture needs to involve the adoption of emergent technologies, such as lightweight and highly configurable multi-agent systems (Friedrich and Burghardt, 2007), service-oriented solutions in mobile environments (Dwarkanath and Daconta, 2006) or ad hoc sensor networks. On the other hand, it is fundamental to have *enriched information management* that allows the collection, the classification and the extraction of data throughout the overall amount of information inflowing into the process. Such information regards data not only coming from sensor networks and connected EMIS, but also gathered from external and non-supervised data sources such as websites and social networks.

Flexible EMIS Architecture
Usually EOCs are organised according to a hierarchical structure: a central EOC responsible for the entire country, some regional EOCs controlling specific areas and local EOCs responsible for smaller areas. This configuration reflects the organisation of emergency operators during an emergency according to the usual *chain of command* pattern. In the same way, workflows running on the EMISs are designed reflecting this hierarchical organisation. Even though this structure usually works, the design and execution of the workflows deployed on the EMIS suffer from a lack of flexibility. More specifically, the hierarchical structure is particular to a given entity: e.g. civil protection, fire departments, medical emergency. Actually, during an emergency the contingency plan involves more entities and the global workflow needs to involve different EMISs belonging to different hierarchies. In addition, even considering the same hierarchy, the contingency plan might change over time. Thus, the EMIS needs to be redesigned with respect to the new requirements and the lack of flexibility requires some effort to redesign and reimplement the workflow that supports the evolving contingency plan. At this stage, such an effort is made by tech-savvys and requires a sine time for the release of a new operating version.

To overcome these limitations, Service Oriented Architectures could facilitate the definition and the adaptation of various contingency scenarios and plans involving different EMISs. This type of architecture separates the infrastructure from the provided services. As a consequence, all the EMISs installed in the EOCs could be considered as members of a peer-to-peer network where each node provides a set of services and can potentially communicate with all the others.

To make the presence of interacting heterogeneous sytems possible, an effort of integration will be needed in the future. More specifically, two kinds of integration may be identified: horizontal integration aims to make different pervasive technologies interoperable, while vertical integration aims to develop high-level abstractions of devices into information systems, hiding interactions with the physical device. There are many database-like approaches for both horizontal and vertical integration. These approaches abstract the pervasive space whose data is gathered as if it were a database. One of the first approaches in this field is TinyDB (Madden et al. 2005), concerned with Wireless Sensor Networks, while recently some similar approaches have been developed taking into consideration quality-of-service aspects, interoperability between different kinds of devices and the existence of actuators together with sensors (Xue et al. 2005).

Besides the technological issues regarding the implementation of the infrastructure, the definition and the implementation of the organisational policies regulating the information flows among EMISs need to be considered in future research.

Integration Between Different Government Levels and Sectors

Many legal instruments that have an environmental impact already exist although they were not designed to address climate change or disaster prevention.

Horizontal integration is important here, since these kinds of assessment require not only administrative and legal knowledge, but also information on how a stressor might be propagated throughout several sectors/regions and what the potential consequences could be.

In this context, close consideration of cost-benefit schemes could help decision makers, keeping in mind the difficulties and constraints that may be encountered and which make them an important reference for decision-making but certainly not the only one. Those schemes require, first, impact studies, to estimate how effects will be distributed across different sectors of society. Second, not all values can be quantified adequately, for example natural and cultural heritage. Identifying risk-prone areas is only a first step, since, from a broader European perspective, regions are unevenly exposed to climate change impacts and to natural hazards, not only in physical terms but also as far as social and economic factors are concerned.

Some adaptation strategies can have contrasting effects in different sectors or regions. For example, the re-fortification of dikes can protect one area against the threat of floods whilst possibly increasing the risk of flooding in other areas downstream. Therefore trans-sectoral and interdisciplinary perspectives are vital in the development of adequate strategies. Cooperation and integration are necessary across regions, countries, sectors and administrative levels. Actors need to be aware of the benefits of cooperation to gain positive long-term effects instead of decisions focusing only on short-term benefits. But the discussion on natural hazard consequences and on climate change impacts is also driven by different interests and values. A *conflict of interests* between different stakeholders and sectors on future development priorities is inevitable in pluralistic societies. Therefore, adaptation to climate change and vulnerability reduction in the face of natural hazards is a cross-cutting issue – not only across sectors or administrative levels, but also across different groups in society and national borders. It therefore requires a much higher level of cooperation than has been the case until now among a variety of social groups, administrations and governmental sectors.

Tailoring

One for all solutions will not function. The complexity of issues at stake, and the variety of natural, technological and social systems contrast with the wish to provide uniform, standardised responses. In addition, the diversity of European society should also be taken into account. Risk mitigation strategies must encompass a variety of spatial contexts, including megacitites, medium to small size towns, coastal development, remote mountain and rural areas, and small islands. Different types of contexts, with their own social and economic systems, rely on traditions, identity and social arrangements to function and cope with changes.

Tailoring is therefore a crucial concept, even when basic methodological frameworks are followed. The general scheme including hazard, exposure and vulnerability assessments must be tailored to specific local conditions, with their histories and past experiences. Even within each of the territorial contexts mentioned above, significant differences can be encountered and consequently adapted for. Cities are not all the same, either socioeconomically or as far as their morphological patterns are concerned.

Historic centres and monuments are even more unique, as each represents the current step of an otherwise long evolution, with parts added and subtracted over centuries. Tailoring in this case means understanding first the technologies and practices specific to a given region over a period of time, recognising turning points, for example reconstruction following disasters, when new forms, materials and techniques were imposed on the built environment.

Uncertainty

It may be provocative and even trivial to state that uncertainty analysis should be more at the core of risk studies, as uncertainty is clearly an intrinsic feature of any risk condition.

Nevertheless, what is meant here is a rethinking on the entire issue of uncertainty treatment in both risk assessment and management as well as in the delicate interface between experts and decision makers, and between the latter and the so-called lay public. Several authors have highlighted the limits that restrict the use of probabilistic theory to the types of uncertainty implied by risks. Their critiques can be grouped into three main categories. The first relates to knowledge gaps influencing the risk assessment phase. Pielke (2003) distinguishes between probabilistic uncertainty intrinsic in the nature of aleatory events and epistemic ignorance deriving from gaps in our ability to understand and explain complex environmental issues.

Stirling (2007), building on previous work by Renn et al. (1995), establishes a further subtle difference between uncertainty and ambiguity, whenever lack of information and forecasting capability limit not only our capacity to predict the future occurrence and outcome of events, but also imply an intricate coupling of facts and values that cannot be solved either in a fully technical way or ignoring the technical and scientific content of the problems at stake.

Finally, De Marchi et al. (1995), building a checklist for risk managers, unfolded several other levels of uncertainty, including those related to the potential side effects of decisions made under pressure and urgency.

In their work, Salter (1988), Pielke (2003), Sarewitz et al. (2000) and Jasanoff (1990) all pointed out the traps originated by the interaction among different types of uncertainty, whenever regulation and decision-making are implied. A step forward can be made by recognising how uncertainties shape the debate when long-term mitigation measures, such as those concerning land use planning with relevant long-term impacts on risks, have to be taken or how uncertainties must be handled preparing for emergencies and facing them.

Reflection on uncertainties at different levels and in the interaction between social groups and stakeholders perhaps deserves further efforts, also in light of the recently published report "Taking European Knowledge Society Seriously" (EU Commission, 2007).

Implementation

Whenever complex projects and programmes are at stake, such as risk mitigation, real implementation is often hard both to measure and to achieve. In order to fully appreciate the degree of implementation (and to check the correctedness of taken measures), one has to wait for an extreme event to happen. On the other hand, following from previously discussed points, prevention can be only the result of a complex mix of decisions and plans tailored to the specific place for which they have been designed. Furthermore, routine controls must be set for mitigation measures that are conceived to prove their validity under extreme and rare conditions. Forgetting the risk and failing to implement controls on the presumption that those events will not happen again pave the way for future calamities, creating an "incubator" for future disasters, as shown by Turner in his pioneering work (1978).

However, as the intrinsic dynamism of risks involves not only several natural phenomena, but also the ever changing built environment, the final catastrophe is often the result of a long process in which wrong decisions were coupled with small errors or episodes of lack of compliance with norms and regulations.

The pitfalls that Thiruppugazh (2007) found for the Gujarat, Turkey, Greece and Taiwan earthquakes actually apply also to other countries in Europe and also as far as other natural hazards are concerned. Among other causes of vulnerability, "lack of building codes enforcement, lack of land use plans, design, inspection, plan review, material quality and lack of insurance" must be accounted for. Yates (2002) notes that "a common element of all those tragedies is a failure to enforce the actual spirit of the regulation". In fact, compliance is often just formal, without full appreciation of the subject matter, of the safety goals and thresholds that are set by regulations. Furthermore, as vulnerability builds across "interscalar" layers, also its reduction must be achieved at different levels: individual dwellings, single buildings, urban blocks and urban areas.

Recent disaster history outside and inside Europe has demonstrated that implementation does not come automatically from regulation: strategies have to be designed with the specific purpose to guarantee both formal and norms content compliance. Two aspects stand out from the work carried out within the Scenario project: the need to design policies addressing illegal housing

Table 7.2. Basic research needed to manage the various uncertainties as proposed by De Marchi (1995)

Critical research aspects / *Types of uncertainties*	*Increased interdisciplinary work*	*Increased work at disciplinary frontiers*	*Improvement of current models*	*Different procedures and protocols for data collection*
Scientific:				
– Epistemic	Necessary for enchained phenomena; for emerging threats; in the field of vulnerability	Necessary for enchained phenomena; in the field of vulnerability		
– Probabilistic			Better calibration of models to a variety of contexts	Framing of the problem prior to data collection Rethinking damage data systems
Legal	Necessary to support problems arising in complex environments	Necessary to define better cause–consequence relationships	Increased capacity to represent and make explicit scientific uncertainties and their origin	
Societal	Improved understanding of several facets of vulnerability	Improved understanding of the human/environment interface in terms of hazards and vulnerabilites	Increased capacity to represent and make explicit scientific uncertainties and their origin	
Institutional	Connecting various sectors of the public administration; enhancing coordination	Creating a new/better connection between "experts" and decision makers		Better definition of data requirements tailored to the problems at stake
Moral	Creating new/renovating tools to ascertain scientific quality	Creating a new/better connection between "experts" and decision makers	Guarantee transparency of proposed models	Increased openess of databases and free resources to allow officials and citizens to carry out their own risk assessment

and illegal urban fringes on the one hand and on the other the creation of economic leverage to provide incentives for implementation.

As for illegal parts of the built environment, two levels must be considered: at the micro and at the urban scales. As for the first, the myriad of changes in materials, structural components and use of buildings have to be accounted for, so as to check whether or not they are also creating or inducing fragility. At the urban level, pattern and density, access to resources, facilities and transport networks have to be appraised.

In cooperation efforts within the humanitarian framework, any attempt to increase the resilience of the built environment without tackling the complex issue of illegal housing and areas will be almost useless. In the meantime, criteria and indicators helping to refine analysis and find local specificities are required, so as to tailor solutions to the variety of contexts that can be found in otherwise similarly fast growing megacities in developing countries. This enforces the belief that not all developement, by reducing poverty, implies a reduction of existing vulnerabilities. Some development choices can be significantly counterproductive to safety, promoting new construction in dangerous zones and mixing hazardous industries with residential areas.

As for the economic tools, particular attention has been given to insurance programmes, coupled with requirements concerning both buildings and zoning, so as to couple insurability with measures aimed at containing, and eventually lowering, existing exposure and vulnerability.

As for insurance policies, the case of Turkey stands out with respect to earthquake risk management under the auspices of the World Bank. As shown by Linnerooth-Bayer and Amendola (2000), while it is often considered a solution for rich countries only, insurance against natural calamities can ease recovery without excessive fluctuations in economic trends in poor countries, where the immediate impact of a catastrophe can represent a high percentage of the total GDP.

7.5 Towards a Different Framing of Risk Research

Figure 7.6 provides a framework showing the chain of interconnections which characterise the organisation and logical pathways of established research approaches. Two main streams of research can be identified: one in natural hazards and the second in climate change.

These are concerned with different aspects of the natural and built environment, so that it is not surprising that the communities in the two fields perceive themselves as rather distinct and separate, reflecting contrasting, if not conflicting, views of the society–environment relationship.

For the sake of simplicity, the framework identifies three steps in the development of research in the field, although it should be underlined that in many instances not all the steps are covered by the same research project, which generally cover one or at the most two of the main steps depicted here.

As far as the natural hazard community is concerned, most projects (and we may suggest more broadly the general philosophy that underlies risk assessment and management) are positioned along the following general pathway (moving through the boxes on the left-hand side of Fig. 7.6):

- First hazards are identified, and analysed with respect to two main aspects: physical characteristics of the threat on the one hand, and the estimation of frequency/probabilities on the other, to account for the uncertainties involved in forecasting and prediction of the phenomena at stake.
- Second, some projects add to the study of the hazard itself some analysis of the physical vulnerability of some of the exposed systems/objects, prioritising generally the vulnerability of ordinary residential buildings, which often account for the majority of the most extensive damage due to natural events. One advanced field here is the seismic vulnerability of buildings, addressing both existing stock and building codes for new constructions.

Different scientific communities have developed tools to assess risks independently from each other, though often grounding their methods on similar fundamental assumptions. All communities use tools such as probabilistic

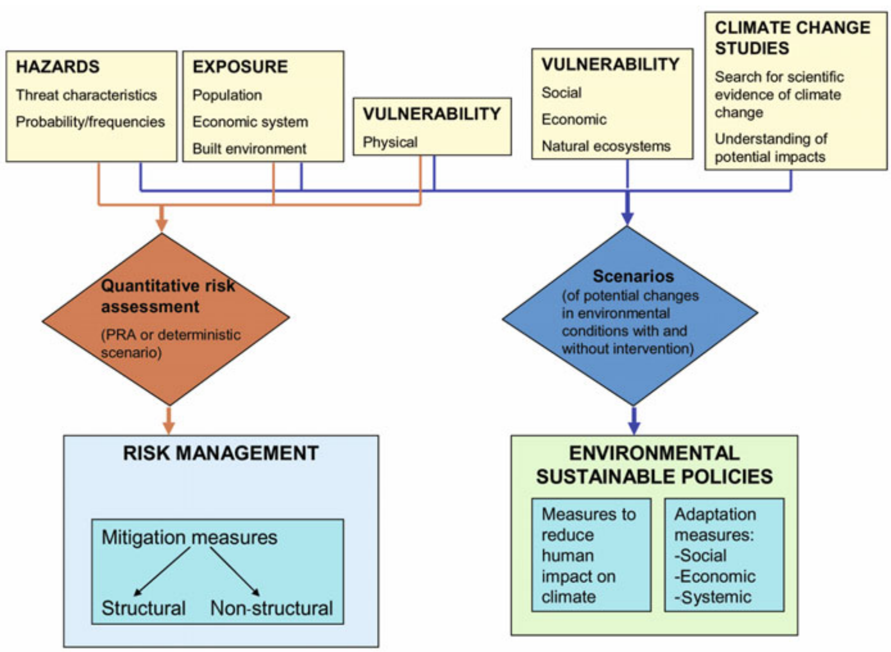


Fig. 7.6. Established approaches to natural hazard and climate change research

risks assessment and deterministic scenarios, and have developed some kind of severity-intensity scales to grade the destructive potential of phenomena in a given place. There are also differences, originating from the varying nature of threats and from the need to attune variables to the specific physical dimensions at stake.

Natural hazard studies have rarely considered other aspects of vulnerability, particularly social, economic and systemic. Studies in these fields generally are far less advanced and it is difficult to establish a picture of the exposed systems in Europe (as shown in Chapter 2). In order to provide quantitative risk assessment or deterministic scenarios, generally natural hazard studies have overlapped, combining the information relating to the characteristics of the hazard on the one hand, and numbers and the dimension of exposed systems on the other.

As has been noted, the type of risk mitigation that is adopted depends very much on the kind of risk assessment that has been carried out. In particular two types of mitigation measures are associated with such assessments. First, structural measures, aimed at reducing the hazard potential, for those phenomena where this is possible, and at reducing the physical vulnerability of exposed buildings and infrastructures. Second, non-structural measures, which can be generalised as those aiming to reducing exposure and vulnerability – land use planning, early warning and civil protection systems, and citizen training and awareness programmes.

In addition, most research projects to date have addressed one hazard at a time, are rather sectoral in their remit and very seldom address issues of multi-hazard and multi-risk. There are exceptions in a small number of projects that, because of their particular focus, have addressed a variety of hazards, though not necessarily according to an integrated multi-risk approach, but, rather, in terms of the collection of results deriving from separated analyses. Other exceptions are projects that have considered phenomena that may be induced by other hazards within an enchained sequence of events. An example is debris flows as a consequence of forest fires or landslides as a consequence of earthquakes.

Climate change studies have always taken a rather different approach to problems. To a certain extent they share, in principle, many features with natural hazard studies, including concepts of vulnerability, impact, uncertainty related to the threat and to the extent of foreseeable consequences, etc. Despite similarities, climate change studies developed differently, as can be clearly seen by the elements on the right-hand side of the framework in Fig. 7.6.

First it should be noted that climate change can be considered a hazard *per se*, but also a kind of phenomenon with many potential repercussions on other hazards. Clearly as a hazard it cannot be represented in probabilistic terms, because of the many complexities involved and the lack of historic records permitting any kind of frequency estimates to be established. In this regard, the chosen approach to risk analysis for climate change is rather similar to that used for industrial risk analysis. As in the latter case, a scenario approach is followed, adding a likelihood estimate to each potential final complex event, derived from the combination of individual probabilities (frequencies) associated to elementary events making part of the probability chain or fault tree leading to the so-called "top accident".

The inevitable impossibility of probabilistic assessment for climate change may also have potentially important consequences for other hazards, for example floods, for which a return period has been traditionally used as a fundamental reference point. Depending on how relevant the potential contribution of climate change to future floods is deemed to be, the meaning of a return period as a pivotal unit of measure tends to lose its centrality, even for the design of hydraulic structures and infrastructures (see Burlando et al. 1997).

Referring to Fig. 7.6 and starting from the elements that characterise the definition of climate change as a hazard, two main objectives have been pursued – producing increasingly refined evidence of the reality of climate change as a consequence of human activity; and identifying the potential impacts, direct or induced on other hazards.

As far as exposure and particularly vulnerabilities are concerned, climate change studies put a much greater emphasis on understanding potential response capacities and the resilience of systems and communities that may be significantly stressed by the consequences of climate change. As already mentioned, the key tool for depicting expected, potential futures has been found in increasingly sophisticated scenario modelling, depicting possible alternative futures following from different policies. The latter have two components. First those aimed at reducing the hazard itself (mitigation), through structural (action on energy production and use, action on mobility, on heating, etc.) and non-structural measures (those for example aimed at changing people's and industries' behaviour in the field of energy consumption and waste production and management). And second, those embedded in adaptation policies, aiming at reducing communities' and societies' vulnerability to direct and indirect consequences of climate change.

7.5.1 Proposing a New Logic Chain for Future Integrated Research in Disasters and Climate Change

The discussion within the Scenario project team between the two scientific groups studying natural hazards on one side and climate change on the other led us towards a thorough reconsideration of the pathways and chains of logic that are illustrated in Fig. 7.6. Our belief is that a more integrative approach should be developed and that solutions for both natural hazards and climate change concerns should be looked for within a more comprehensive and satisfactory framework of sustainability.

The new framework and logical pathways shown in Fig. 7.7 are proposed as a first attempt to present the development of ideas and concepts in the context of the Scenario project and the objectives of this book.

This framework advocates that an integrated, context-sensitive approach to risk assessment should be looked for, including multi-risk methods, when relevant in the area of study (see, for example, attempts made by the EU FP6 Armonia project).

Scientific understanding of risks could certainly benefit from more integrated research, successfully transferring experiences and solutions from one field to another. Not only each individual research community could take advantage of merging their experiences, but a common ground for tackling multi-hazard and multi-risk problems could be created.

Multi-hazard studies can be defined as those addressing phenomena that may be linked to each other in a potential chain of events in a given territory. Those hazards have been always known by experts, but only relatively recently they have been granted the status of a field of study deserving more in-depth attention. It is more a matter of how things are looked at rather than of how they intrinsically are. Many hazards can be triggers of others, like earthquakes and tsunami, earthquakes or fires and landslides, or volcanic activity which comprise a variety of different phenomena, including tephra falls, pyroclastic flows, lava and finally lahars as the ultimate combination of volcanic deposits

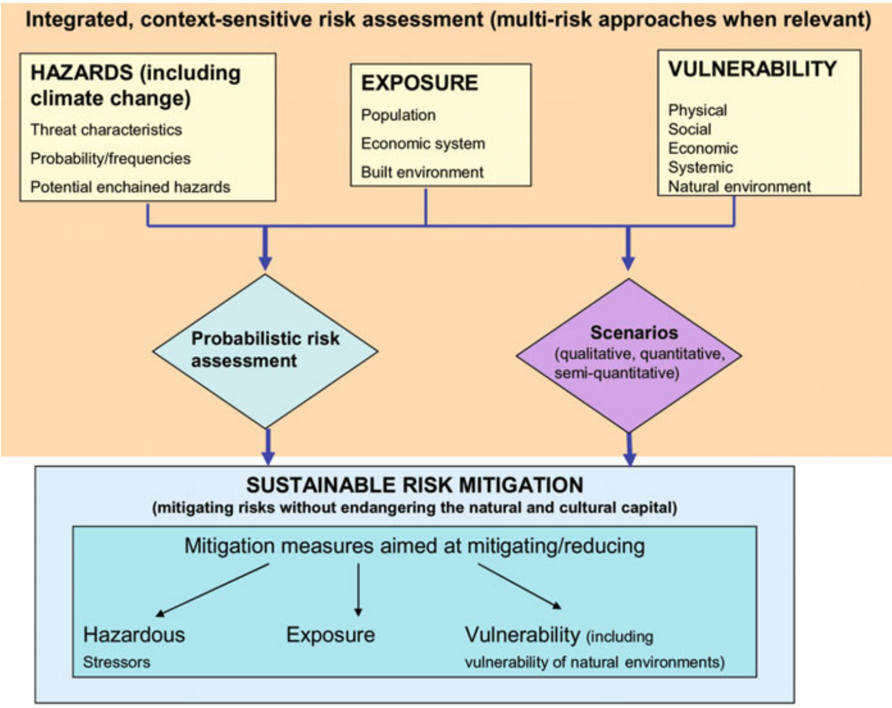


Fig. 7.7. A framework for a new integrated approach to risk research

and rainfalls. Some induced hazards can result in more destructive outcomes than the initial event, especially in the absence of adequate preparation.

Multi-risk studies, however, may involve a wider perspective on hazards in a given area, recognising the co-presence of several threats that may or not be combined in a unique macro-event, but which require the development of methodologies to tackle them in a coherent fashion, avoiding mitigation measures that, while beneficial for certain threats, may produce drawbacks for others.

Multi-risk approaches address the question of how vulnerabilities in the built environment may become induced hazards in their turn. In this regard, na-tech certainly deserve increased attention in the future, so as to identify indicators and units of measure to analyse them and forecast them in advance.

Climate change is considered in two respects: as a hazard *per se* and as a potential trigger of other hazards (enlarging the concept of potential consequent and simultaneous events summarised by the label "potential enchained effects"). With respect to the first the traditional view of "mitigation" is here included in "measures aimed at mitigating/reducing the hazards" while the traditional view of "adaptation" is comprised in "measures aimed at mitigating/reducing exposure and vulnerability". The vulnerability of exposed systems is articulated in multiplicity, considering the various components of vulnerability, not only for climate change studies or separately for other hazards, but as a general principle to be followed for any kind of risk assessment, be it probabilistic or scenario-based.

One fundamental question that has still to be answered by future research relates to the question of whether or not and in which cases deterministic scenarios are better than probabilistic risk assessment. The search for this question will benefit from multi-risk approaches, consisting not only in assessing all hazards in one place, but also opening the floor to the aforementioned exchange of experiences and tools.

In using scenarios, a variety of possibilities is envisaged in the proposed framework, ranging from quantitative to qualitative and semi-quantitative methods to account for the various ways in which expected futures can be represented and to enable the inclusion of all potentially relevant information – including that which cannot be represented in numbers. Risk assessment leads then to the selection of suitable sustainable risk mitigation measures, aimed at reducing, whenever possible, hazard potential, exposure and different forms of vulnerability (avoiding the potential harm mitigation measures may have on ecosystems and the natural and cultural capital in general).

7.6 An Open-ended Conclusion

It is not easy to provide a conclusion to this chapter while summarising the findings and recommendations resulting from the work carried out in the frame of the Scenario project. It may be appropriate to raise warnings, related to the two concepts that are at the core of this book and the work behind it.

The first concerns the concept of sustainability. The title of the project alludes to the need to find a stronger integration between risk mitigation and sustainability.

Perhaps, though, the same sustainability concept must be interpreted through a critical lens. As mentioned by several authors (Arrow et al. 1995; Costanza and Patten, 1995), it lacks an operational dimension, which would be essential for deciding what resources and what habitats cannot be further consumed or transformed without initiating a cascading, irreversible change that leads to uncertain, possibly but not necessarily disastrous outcomes. This operational dimension can be implemented through the concept of "empowerment" and the related development of identity of local involved communities by means of practical tools for growth and expansion in a safe way.

An operational dimension is also required to be able to measure to what extent prescribed actions (or limitations to action) are actually leading towards an ecological/biological status that is more compatible with the general goal of environmental preservation. The *Journal of Ecological Economy* hosted a rather animated debate on this issue in the early 1990s; authors such as Arrow et al. (1995), Costanza and Patten (1995) suggest that a way to operationalise the concept of sustainability is to refer to resilience as a key indicator of ecosystem capacity to change without undergoing disruptive stress in a dynamic environment.

Resilience is a key term for the disaster and climate change communities as well, though it is questionable that it can be measured and operationalised much more easily than sustainability. Nevertheless, such an interesting link suggests that the concept of resilience has gained a broader scope than in the past, embracing ecology, psychiatry, disasters and climate change research.

This is not surprising, as the target of investigations shifts from purely technical considerations of hazards to the characteristics of exposed systems, individuals and societies.

The climate change community has developed more consistently than others the interpretation of resilience (or vulnerability as its opposite) across time and space, thanks also to its closer links to biological and ecological research (see Turner et al. 2003).

Transferring those concepts to the natural hazards domain means that risk mitigation should not just consist in transfer mechanisms, which simply shift the risk in space (to other areas) or in time (to future generations).

In this regard Handmer (1999, p. 175) wrote: "Despite legislation that formalizes state responsibilities for incorporating environmental considerations into the planning system, degradation of most elements of the metropolitan biosphere continues. Among other reasons is the difficulty of shifting the orientation from events and projects to comprehensive and integrated long-term programmes. [...] The whole state budgetary process works to reinforce sectoral planning and existing agency boundaries".

A second set of critics of sustainability as defined and conceived in the Rio Declaration and in the Bruntland Report point at its scarce relevance for developing and poor countries.

In this regard, some authors (Aguirre, 2002; Smith, 1996 and 1997) have raised a couple of fundamental questions, one with respect to the *a priori* set against growth and the second requiring a wider range of tools and policy options, more tailored to the specific characteristics of the cultural and economic conditions of the countries where those should be implemented.

The latter argument is very well made also with regard to risk mitigation measures, particularly in Europe, which provide a wide range of hazards, exposure and vulnerabilities, as shown in previous chapters.

A final warning refers to the same term scenario. With a rather short past, the technique of scenario building and modelling has been rising and gaining in importance in the last few years, particularly in environmental studies. Pulver and VanDeveer (2009) show for example in their review of the Ebsco Environmental Index Database that in the period 2002–2006 500 articles were published regarding the scenario approach. The vast majority of them were produced in the disciplinary domain of Engineering and Ecology.

Some scenarios are extremely powerful, in envisaging the consequences of divergent futures. An example is provided by the Shell video and study regarding future energy policies. Similarly to what was attempted in the Scenario project, the Shell images of the future result from the complex combination of a number of crucial indicators, the combination of which, besides their individual values and trends, shape the possible framework within which decisions on energy supply will have to be taken. Our same project relies on previously built scenarios, within the IPCC or as part of the Espon project, as well as on European Environment Agency maps (http://www.eea.europe.eu). In a short time, we will be faced with a plethora of scenarios, mixing physical and sociopolitical facts sometimes in a rigid and opaque form.

Perhaps it is time to go back to the same scenario concept, finding ways to assess not so much reliability or likelihood as their usefulness in supporting risk mitigation decisions, accounting explicitly for the various components of risk, that is hazard, exposure and vulnerability according to a systemic approach.

> "Making projections about the future is always a risky enterprise, especially in an area as complex as risk analysis and management" (Pulver and VanDeveer, 2009).

References

ABI, *Coastal flood risk – Thinking for Tomorrow, Acting Today* (summary report). Association of British Insurers: UK, 2006.

Adger W.N., Hughes T.P., Folke C., Carpenter S.R. and Rockstrom J., "Social ecological resilience to coastal disasters." *Science* 309: 1036–1039, 2005.

Aguirre B.E., "Can sustainable development sustain us?" *International Journal of Mass Emergencies and Disasters* 20(2): 111–126, 2002.

AIRTRICITY, European Offshore Supergrid®Proposal, 2006.

Alcamo J., Bouwman, A., Edmonds, J., Grübler, A., Morita, T. and Sugandhy, A., "An Evaluation of the IPCC IS92 Emission Scenarios." In *Climate Change 1994, Radiative Forcing of Climate Change and An Evaluation of the IPCC IS92 Emission Scenarios*. Cambridge University Press: Cambridge, UK, 1995, pp. 233.-304.

Alcamo J., Döll P., Henrichs T., Kaspar F., Lehner B., Rösch T. and Siebert S., "Global estimates of water withdrawals and availability under current and future business-as-usual conditions." *Hydrological Sciences Journal* 48: 339–348, 2003.

Alcamo J., Moreno J.M., Novaky B., Bindi M., Corobov R., Devoy R.J.N., Giannakopoulos C., Martin E., Olesen J.E. and Shvidenko A., *Europe Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry M.L., Canziani O.F., Palutikof J.P., Van der Linden P.J. and Hanson C.E. (eds.), Cambridge University Press: Cambridge, UK, 2007, pp. 541–580.

Alexander L.V., Zhang X., Peterson T.C. et al. "Global observed changes in daily climate extremes of temperature and precipitation." *Journal of Geophysical Research* 111: D05109, 2006.

Aniello C., Morgan K., Busbey A., Newland L., "Mapping micro-urban heat islands using Landsat TM and a GIS." *Comput. Geosci.* 21: 965–969, 1995.

Archer D., *Global Warming – Understanding the Forecast.* Blackwell Publishers: UK, 2006.

Arrow K., Bolin B., Costanza R., Dasgupta P., Folke C., Holling C.S., Jansson B.-O., Levin S., Mäler K.-G., Perrings C., Pimentel D., "Economic growth, carrying capacity, and the environment." *Ecological Economics* 15: 91–95, 1995.

Aubin, J.-P. *Viability Theory.* Birkhuser: Boston, 1991.

Aubin J.-P., Saint-Pierre P. “An introduction to viability theory and management of renewable resources” In: J.P. Kropp & J. Scheffran (eds.), *Advanced Methods for Decision Making and Risk Management in Sustainability Science*. Nova Science Publishers Inc.: New York, 2007, pp. 43–80.

Bachmann A. , Allgoewer B., *The Need for a Consistent Wildfire Risk Terminology*. Proceedings of the Joint Fire Science Conference and Workshop, Boise (Idaho, USA), June, 15–17, 1999, p. 11

Ballantyne C.K., “Paraglacial Geomorphology.” *Quaternary Science Reviews* 21: 1935–2017, 2002.

Ballester F., Michelozzi P., Iniguez C., “Weather, climate, and public health.” *J. Epidemiol Community Health* 57(10): 759–760, 2003.

Bankoff G., Frerks G., Hilhorst D., *Mapping vulnerability, Disasters, development and people*. Earthscan: US, UK, 2004.

Barnier M., *For a European civil protection force: Europe aid*. European Commission, May 2006.

Barredo J.I., Lavalle C., Camia A., Hiederer R., Niemeyer S., De Roo A., *Towards an integrated assessment of weather-driven natural risk in Europe*. 1st ARMONIA Conference Proceedings, Barcelona 5–6 December, 2005a.

Barredo J.I., Petrov L., Sagris V., Lavalle C., Genovese E., *Towards an integrated scenario approach for spatial planning and natural hazards mitigation*. JRC Report, 2005 EUR, 2005b.

Barrett P., “Paleoclimatology – cooling a continent.” *Nature* 421: 221–223, 2003.

Bättig M., Wild M., Imboden D.M., “A climate change index: Where climate change may be most prominent in the 21st century.” *Geophysical Research Letters* 34: L01705, 2007.

Beck U., Risk society: towards a new modernity. Sage: London, 1992.

Beniston M., “The 2003 heatwave in Europe. A shape of things to come. An analysis based on Swiss climatological data and simulations.” *Geophysical Research Letters* 31: 2022–2026, 2004.

Benson C. Personal communication between Ben Wisner and Dr. C. Benson. Overseas development Institute, London, 4 June, 2002.

Bertalanffy von L. “La teoria dei sistemi aperti in fisica e biologia”, in Emery F.E. (ed.) *La teoria dei sistemi*. Franco Angeli: Milano, 1985.

Bissolli P., Grieser J., Dotzek N., Welsch M., “Tornadoes in Germany 1950–2003 and their relation to particular weather conditions.” *Global Planet. Change* 46, doi:10.1016/j.gloplacha.2006.11.007, 2007.

Birkmann J. (ed), *Measuring vulnerability to natural hazards. Towards disaster resilient societies*. United Nation University Press, 2006.

Bisping M., Bresch D.N., Lemcke G., *Storm over Europe: an underestimated risk*. Swiss Re Publishing: Zurich, 2000. Available at: http://www.swissre.com

Björnsson H., “Glacial lake outburst floods in mountain environments”, in Owens, P.N., Slaymaker, O., (eds.) *Mountain Geomorphology*. Hodder & Stoughton: London, 2004, pp. 155–184.

Blaikie P., Cannon T., Davis I., Wisner B., *At risk. Second edition. Natural hazards, people’s vulnerability and disasters*. Routledge: London, 2004.

Boardman J., Ligneau L., De Roo A., Vandaele K., “Flooding of property by runoff from agricultural land in northwestern Europe.” *Geomorphology* 10: 183–196, 1994

Boholm Å., Löfstedt R.E., "Issues of risk, trust and knowledge: the Hallandsas Tunnel case." *Ambio* 28(6): 556–561, 1999.

Boin A., Lagadec P., "Preparing for the future: critical challenges in crisis management." *Journal of Contingencies and Crisis Management* 8(4): 185–191, December 2000.

Boin A., McConnell A., "Preparing for Critical Infrastructure Breakdowns: The Limits of Crisis Management and the Need for Resilience." *Journal of Contingencies and Crisis Management* 15: 50–59, 2007.

Bolton A., Heikkala S.G., Green M.M., May P.J., *Land Use Planning for Earthquake Hazard Mitigation: A Handbook for Planners.* Natural Hazards Research and Applications Information Center, University of Colorado, Boulder, CO.

Boschi E., Guidoboni E., *Catania terremoti e lave dal mondo antico alla fine del Novecento.* Istituto Nazionale di Geofisica e Vulcanologia – Storia Geofisica Ambiente, Editrice Compositori: Bologna, 2001.

Bouwer L.M., Huitema D., Aerts J.C.J.H., *Adaptive flood management: the role of insurance and compensation in Europe.* 2007 Amsterdam Conference – Conference on the Human Dimensions of Global Environmental Change, 24–26 May 2007 Amsterdam, The Netherlands, 2007.

Breda N., Huc R., Granier A., Dreyer E., "Temperate forest trees and stands under severe drought: a review of ecophysiological responses, adaptation processes and long term consequences." *Annals of Forest Science* 63(6): 625–644, 2006.

Britten N., *Floods: Spirits dampened in Tewkesbury.* Daily Telegraph, 24/07/2007

Brooks H.E., Lee J.W., Craven J.P., "The spatial distribution of severe thunderstorm and tornado environments from global reanalysis data." *Atmos. Res.* 67–68, 73–94, 2003.

Brown J.D., Damery S.L., "Managing Flood Risk in the UK: Towards an Integration of Social and Technical Perspectives." *Transactions of the Institute of British Geographers* 27: 412–416, 2002.

Bruckner, T., G. Petschel-Held, F. Toth, H.M. Fssel, C. Helm, and M. Leimbach, "Climate change decision-support and the tolerable windows approach." *Environmental Modelling and Assessment* 4: 217–234, 1999.

Brundtland G.H., *Our Common Future, The Report of the World Commission on Environment and Development* (A/RES/42/187). United Nations New York, 1987.

Buckle P., "New approaches to assessing vulnerability and resilience." *Australian Journal of Emergency management* vol 2., Winter 2000.

Bunde A., Kropp J.P., Schellnhuber H.J., *The Science of Disasters: Climate Disruptions, Heart Attacks, and Market Crashes.* Springer: Berlin, 2002.

Burby, R., "Flood Insurance and Floodplain Management: The U.S. Experience." *Journal of Environmental Hazards* 3(3): 111–122, 2001.

Burlando P., Mancini M., Rosso R., "Impact of climate change on hydrological modeling and flood risk assessment", in Casale R., Havnø K. and Samuels P. (eds), *RIBAMOD – River basin modelling, management and flood mitigation concerted action*, Proc. of the 1st Expert Meeting, Copenaghen, 10–11 October 1996, pp. 7–25, 1997.

Burton I. *Types of Agricultural Occupance of Flood Plains in the United States.* University of Chicago, Department of Geography, Research Paper No. 75, 1962.

Burton I., Kates R.W., "The Perception of Natural Hazards in Resource Management". *Natural Resources Journal*, Vol. III, No. 3, pp. 412–441, 1964.

Burton I., Kates R.W., White G.F, "The Human Ecology of Extreme Geophysical Events". *Natural Hazard*, Working Paper No. 1, 1968.

Burton I, Kates R.W., White G.F., *The Environment as Hazard.* Oxford University Press: New York, 1978.

Cappellin R., Batey P.W.J., *Regional Networks, Border Regions, European Integration.* Pion Limited: London, 1993.

Cardellini S., Osimani P., *Living with landslide: the Ancona case history and early warning system.* Proceedings of the First Landslide Forum. 18–21 November 2008, United Nation University, Tokyo, Japan, Parellel Session Volume.

Cardona O.D. *Indicators of Disaster Risk and Risk Management.* Inter-American Development Bank, Washington, D.C., 2007.

Carpenter S.R., Walker B., Anderies J.M. and Abel N., "From metaphor to measurement: Resilience of what to what?" *Ecosystems* 4: 765–781, 2001.

Cauvin C., Martin J.-P., Reymond H., "Une accessibilité renouvelée", in Bonnafous A., Plassard F., Vulin B. (eds.), *Circuler demain.* Datar/Editions de l'Aube: Paris, pp. 93–127, 1993.

CEA (Comité Européen des Assurences), CEA Position on the Green Paper on Adapting to climate change – Options for EU actions. CEA: European insurance and reinsurance federation, 2008.

CEA (Comité Européen des Assurences), *Reducing the social and economic impact of climate change and natural catastrophes. Insurance solutions and public-private partnership.* July 2007. Available at: http://www.cea.eu/

Ceylan A., Alan I., Ugurlu A., "Causes and effects of flood hazards in Turkey" in *International congress on river basin management."* General Directorate of State Hydrolic Works: Ankara, Turkey, 2007, pp. 415–423.

Chang S., Shinozuka M., Moore II J., "Probabilistic earthquake scenarios: extending risk analysis methodologies to spatially distributed systems." *Earthquake Spectra* vol. 16: 3, August 2000.

Chapin, T., *Concepts and strategies to address sustainability in a changing world*, presentation available at www.alaska.edu/epscor/living-on-earth/Terry-Chapin.ppt., 2009

Chatelain J.L., Tucker B., Guillier B., Kaneko F., Yepes H., Fernandez J., Valverde J., Hoefer G., Souris M., Dup'erier E., Yamada T., Bustamante G., Villacis C., "Earthquake risk management pilot project in Quito, Ecuador." *Geojournal* 49: 185–196, 2000.

Chen J.L., Wilson W.L., Tapley B.D., "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet." *Science* 313: 1958–1960, 2006.

Chester D.K., Degg M., Duncan A.M. and Guest J.E., "The increasing exposure of cities to the effects of volcanic eruptions: a global survey." *Environmental Hazards* 2: 89–103, 2001.

Chester D.K., Dibben C.J.L., Duncan A.M., "Volcanic hazard assessment in western Europe." *Journal of Volcanology and Geothermal Research* 115: 411–435, 2002.

Christensen O.B., Christensen J.H., "Severe summertime flooding in Europe." *Nature* 421: 805–806, 2003.

Christoplos I., *Links between relief, rehabilitation and development in the tsunami response.* Tsunami Evalaution Coalition, July, 2006.

Christou M., Porter S. (eds.), *Guidance on land use planning as required by council directive 96/82/EC (Seveso II).* JRC, Ispra. EUR 18695 EN, 1999.

Church J.A., Gregory J.M., Huybrechts P., Kuhn M., Lambeck K., Nhuan M.T., Qin D., Woodworth P.L., "Changes in sea level", in Houghton J.T., Ding Y., Griggs D.J., Noguer M., Van der Linden P.J. and Xiaosu D. (eds.) *Climate Change 2001. The Scientific Basis*. Cambridge University Press: Cambridge, 2001, pp. 639–693.

Chuvieco E., Allgöwer B. and Salas F.J. "Integration of physical and human factors in fire danger assessment", in Chuvieco E. (ed.), *Wildland fire danger estimation and mapping. The role of remote sensing data*. World Scientific Publishing: Singapore, Series in remote sensing, 4: 197–218, 2003.

Ciais P., Reichstein M., Viovy N., Granier A., Ogée J., Allard V., Aubinet M., Buchmann N., Bernhofer Chr., Carrara A., Chevallier F., De Noblet N., Friend A.D., Friedlingstein P., Grünwald T., Heinesch B., Keronen P., Knohl A., Krinner G., Loustau D., Manca G., Matteucci G., Miglietta F., Ourcival J.M., Papale D., Pilegaard K., Rambal S., Seufert G., Soussana J.F., Sanz M.J., Schulze E.D., Vesala T., Valentini R., "Europe-wide reduction in primary productivity caused by the heat and drought in 2003." *Nature* 437: 529–533, 2005.

Cinque E., Mazzella A., "The OSP economic and financial approach." *Urbanistica* 134, 2007.

Cioni R., Guidi M., Raco B., Marini L., Gambardella B., "Water chemistry of Lake Albano (Italy)." *J. Volcanol. Geotherm. Res* 120: 179—195, 2003.

Cioni R., Santacroce R., Sbrana A., "Pyroclastic deposits as a guide for reconstructuring the multi-stage evolution of the Somma-Vesuvius Caldera." *Bull Volcanol.* 60: 207–222, 1999.

Cipolla C., *Uomini e tecniche, economie*. Feltrinelli, 1996.

Cochrane H., "Forecasting the economic impact of a mid-west earthquake", in Jones, B. (ed.) *Economic consequences of earthquakes: Preparing for the unexpected.* MCEER: Buffalo, NY, 1997.

COM, *Libro Bianco su una politica europea di comunicazione*, Bruxelles, 1.2.2006.

COM, Legitimacy, institutions and the communication strategy in the European Union, Bruxelles, 3.10.2007.

Comfort L.K., *Shared Risk. Complex Systems in Seismic Response*. Pergamon, Elsevier Science Ltd.: The Netherland, 1999.

Conedera M., Cesti G., Pezzatti G.B., Zumbrunnen T., "Lightening-induced fires in the Alpine region: An increasing problem." *Forest Ecology and Management* 234(1): S68, 2006.

Costa, L. Thonicke, K, Poulter B., Badeck, F., "Sensitivity of Portuguese forest fires to climatic, human and landscape variables – Sub-national differences between fire drivers in extreme fire years and decadal averages." *Regional Environmental Change*, in press. doi: 10.1007/s10113-010-0169-6.

Costanza R., Patten B., "Defining and predicting sustainability." *Ecological Economy* 15: 193–196, 1995.

Covington J., Simpson D.M., *An Overview of Disaster Preparedness Literature: Building Blocks for an Applied Bay Area Template*. Center for Hazards Research and Policy Development, Working Paper 06–02, August 2006.

CRED, Centres for Research on the Epidemology of Disasters, CRED CRUNCH Newsletter, December 2006, Brussels, Belgium, 2006. Available at: http://www.em-dat.net/documents/CRED%20CRUNCH%207%20-%20December% 202006.pdf

Crichton D., *Flood Risk and Insurance in England and Wales: Are there lessons to be learned from Scotland?* Benfield Hazard Research Centre, 2005.

Crozier M., McClure J., Vercoe J., Wilson M., "The effects of hazard zone information on judgements about earthquake damage." *Area* 38: 143–152, 2006.

Crowley T., "Causes of Climate Change Over the Past 1000 Years." *Science* 289(5477): 270–277, July 2000.

Cruz A.M., Steinberg L., Vetere-Arellano A.L., "Emerging Issues for Natech Disaster Risk Management in Europe." *Journal of Risk Research* 9: 483–501, 2006.

Cuny F.C., *Disaster and development*. Oxford university press: New York, 1983

Damm A., "Determinants of Recent Immigrants. Location Choices: Quasi-Experimental Evidence". *Journal of Population Economics* 20, 2007.

Dandoulaki M., *European Centre on Prevention and Forecasting of Earthquakes*, Athens (Mt. Parnitha-Athens earthquake).

Dankers R., Feyen L., "Climate change impact on flood hazard in Europe: An assessment based on high-resolution climate simulations." *J. Geophys. Res.* 113, submitted 2007.

Davis M., Ricci T., Mitchell L., "Perceptions of risk for volcanic hazards at Vesuvio and Etna, Italy." *The Australasian Journal of Disaster and Trauma Studies* vol. 2005:1 (available free in the internet).

De Elera A., "The European research area: on the way towards a European scientific community?". *European Law J.* 12(5): 559–574, 2006.

De Marchi B., "Uncertainty in Environment Emergencies: A Diagnostic Tool". *J. Contingencies and Crisis Management* 3(2) : 103–112, 1995.

De Marchi B., *Review of chemical emergencies management in the EU Member States*. Joint Research Centre, European Commission, Insitute for Systems Engineering and Informatics, n. 5529-93-10 ED ISP I, Luxembourg, 1996.

De Marchi B., Scolobig A., Delli Zotti G., Del Zotto M., *Risk construction and social vulnerability in an Italian Alpine Region*. Report T11-07-12 of FLOODsite Integrated Project, 2007. Available at: http://www.floodsite.net/html/publications2.asp?ALLdocs=on&Submit=View

De Roo A. and 20 others, "Development of a European flood forecasting system". *Int. J. River Basin Management* 1(1): 49–59, 2003.

De Roo A., Barredo J.I., Lavalle C., Bodis K., Bonk R., "Potential flood hazard and risk mapping at pan-European scale", in Peckham R., Jordan G. (eds.), *Digital terrain modelling-development and applications in a policy support environment*. Springer, 2007.

De Roo A., Wesseling C.W., Van Deursen W.P.A., "Physically based river basin modelling within a GIS: the LISFLOOD model." *Hydrological processes* 14: 1981–1992, 2000.

Deutscher Wetterdienst (German Weather Service), *Extreme precipitation amounts in Central Europe from 1–13 August 2002*.

DFID, *Natural disaster and disaster risk reduction measures*. Draft final report, 2005. Available at http://www.crid.or.cr/digitalizacion/pdf/eng/doc16399/doc16399-contenido.pdf

Di Castri F., Nereo Rotelli M., Pandolfi O., *Empowerment Da Rapa Nui, l'ombelico della terra, a ovunque nel mondo*, Editore Fondazioni Mare Nostrum, 2005.

Diffenbaugh N.S., Pal J.S., Filippo G., Gao X., "Heat stress intensification in the Mediterranean climate change hotspot." *Geophysical Res. Lett.* 34: L11706, 2007.

Dilley M., Chen R., Deichmann U., Lerner-Lam A., Arnold M., *Natural Disasters Hotspots. A Global Risk Analysis*. The World Bank, Disaster Risk Management Series: Washington DC, 2005.

DINAS-COAST Consortium, *DIVA 1.0*. Potsdam Institute for Climate Impact Research: Potsdam, Germany, CD-ROM, 2004.

Dipartimento della Protezione Civile, *Il Piano Nazionale di Emergenza*. Available at: http://www.protezionecivile.it [accessed 16th November 2007], 2005.

DINAS COAST, www.pik-potsdam.de/DINAS-COAST, 2004

Dobson A., *Justice and environment. Conceptions on environmental sustainability and theories of distributive justice.* Oxford university press: Oxford, 1998.

Domanski H., "Is the East European 'underclass' feminized?" *Communist and Post-Communist Studies* 35: 383–394, 2002.

Dotzek N., "An updated estimate of tornado occurrence in Europe." *Atmos. Res.* 67–68, 153–161, 2003.

Douville H., Chauvin F., Planton S., Royer J.F., Salas-Melia D., Tyteca S., "Sensitivity of the hydrological cycle to increasing amounts of greenhouse gasses and aerosols." *Climate Dynamics* 20: 45–68, 2002.

Dubreuil G.F.H., "Present challenges to risk governance." *Journal of Hazardous Materials* 86: 245–248, 2001

Dwarkanath S., Daconta M., *Emergency services enterprise framework: A service oriented approach*, in Proc. 3rd Int. ISCRAM Conference, Newark (NJ), 2006, pp. 298–304.

EA, *The report on the current state and future pressures of water resources in England and Wales*, December 2008.

EA, *Flood Map For England and Wales.* Bristol, Environment Agency, 2005.

EA and HSE, *Report for the deputy prime minister the right hon John Prescott MP into the major fire on 30 october 2000 at Cleansing Service Froup Ltd, Sandhurst.* 2001, available at: http://www.hse.gov.uk/chemicals/sandhurst.pdf

EA and HSE (undated) Report for the Deputy Prime Minister the Right Hon. John Prescott into the major fire on 30 October 2000 at Cleansing Service Group Ltd. Sandhurst. Available at: http://www.hse.gov.uk/chemicals/sandhurst.pdf

EC, *Civilian instruments for EU crisis management.* European Commission Conflict Prevention and Crisis Management Unit: Brussels, 2003a.

EC, Directive concerning measures to safeguard security of electricity supply and infrastructure investment. European Commission: Brussels, 2003b.

EC, European energy and transport trends to 2030. European Commission: Brussels, 2003c.

EC, Trans-European energy networks : TEN-E priority projects. European Commission: Brussels, 2004.

EC, Communication from the Commission on the Social Agenda. European Commission: Brussels, 2005a.

EC, *Bridging the broadband gap.* European Commission: Brussels. 2006a.EC, Green paper: Confronting demographic change: a new solidarity between the generations. European Commission: Brussels, 2005b.

EC, Green paper: On a European programme for critical infrastructure protection (EPCIP). European Commission: Brussels, 2005c.

EC, *TEN-T priority axes and projects 2005.* European Commission: Brussels, 2005d.

EC, *Water scarcity and drought first interim report.* Presented for discussion at the water directors meeting, 30.11.06, 2006.

EC, The demographic future of Europe – from challenge to opportunity. European Commission, 2006b.

EC, Memo on the European programme for critical infrastructure protection (EPCIP). European Commission, 2006c.

EC, Communication on i2010 – Annual Information Society Report 2007. European Commission, 2007a.

EC, *Employment in Europe 2007*. European Commission: Brussels, 2007b.

EC, Energy policy and maritime policy: Ensuring a better fit. European Commission: Brussels, 2007c.

EC, Green paper from the commission to the council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: Adapting to climate change in Europe – options for EU action. European Commission, 2007d.

EC, Green paper: Adapting to climate change in Europe – options for EU action. European Commission, 2007e.

EC, Joint report on social protection and social inclusion: Social inclusion, pensions, healthcare and long term care. European Commission, Belgium, 2007f.

ECLAC/IDNDR, *Manual for Estimating the Socio-Economic Effects of Natural Disasters*. Geneva and Mexico: Economic Commission for Latin America and the Caribbean, United Nations and International Decade for Natural Disaster Reduction, 1999.

ECLAC, *A Methodological Framework for a Social Vulnerability Index in the Caribbean Subregion*. Document presented at the Ad Hoc Expert Group Meeting on a Methodological approach for a Social Vulnerability Index for Small Island Developing States, July 2003.

ECTA, European Competitive Telecommunications Association. Broadband penetration in EU: the haves and the haves not, 2006.

ECTA, Competition reignites broadband growth in Europe: EU draws level with the US and Japan. European Competitive Telecommunications Association, 2007.

EEA, Scenarios as tools for international environmental assessments, Experts' corner report prospects and scenarios, No 5, 2001.

EEA, Urban sprawl in Europe. The ignored challenge, Report 10, Copenhagen, 2006.

EEA, The pan-European environment: glimpses into an uncertain future, Copenhagen, Report 4, 2007.

EEA, Land use scenarios for Europe: qualitative and quantitative analysis on a European scale, Copenhagen, Report 9, 2007.

EEA, glossary (available at http://glossary.eea.europa.eu/EEAGlossary/D/disaster), 2008

EEA, *Mapping the impact of recent natural and technological disasters in Europe. An overview of the last decade*, Copenhagen, 2010.

Egan M.J., "Anticipating Future Vulnerability: Defining Characteristics of Increasingly Critical Infrastructure-like Systems." *Journal of Contingencies and Crisis Management* 15: 4–17, 2007.

Eisenack, K., J. Scheffran, and J.P. Kropp, "Viability analysis of management frameworks for fisheries." *Environmental Modelling and Assessment* 11(1), 69–79, 2006.

EMCC, *Background paper on gender balance*. European Monitoring Centre for Change, 2004.

Engeström Y., Brown K., Engeström R., Koistinen K., "Organisational forgetting: an activity-theroetical perspective", in Middleton D., Edwards D. (eds.) *Collective Remembering*. Sage Publisher, 1990, pp. 139–168.

ENTEC, Strategic Flood Risk Assessment of East London, with JBA Consulting. Thames Gateway London Partnership, June 2005

Erkut G., Ozgen C., *The economic and spatial peripherality of border regions in Southeastern Europe*. The 43rd European Congress of the Regional Science Association, Jyväskylä, Finland, 27th-30th August 2003.

ESPON, *ESPON project 1.2.1. Transport services and networks: territorial trends and basic supply of infrastructure for territorial cohesion.* Available at: http://www.ESPON.eu

ESPON, *ESPON project 1.3.2. Territorial trends of the management of the natural heritage.* Available at: http://www.ESPON.eu

ESPON, *ESPON project 1.3.3. The role and spatial effects of cultural heritage and identity (2004–2006).* Available at: http://www.ESPON.eu

ESPON, *ESPON project 2.4.1. Territorial trends of energy services and networks and territorial impact of energy policy. Final report (2005) Available* at: http://www.ESPON.eu

ESPON, web site: http://www.ESPON.eu

ESPON, ESPON project 3.2: Spatial Scenarios and Orientations in relation to the ESDP and Cohesion Policy. European Community through the Interreg III ESPON Programme, 2006.

EU ARMONIA Project, WP2: Collection and evaluation of current methodologies for risk map production. Del. 2.1 – Report on current availability and methodology for natural risk map production. Seismic risk, 2005

EU ARMONIA Project, del. 4.1 Report: Technical Glossary of a Multi Hazard Related Vulnerability and Risk Assessment Language. EU ARMONIA Project publication, 2006.

EU, Development Sustainable Development Strategy (SDS). The European Council of June 2006, 2006a.

EUROFOUND, European Foundation for the Improvement of Living and Working Conditions, *Annual report* 2007. Dublin, Ireland, 2007. Available at: http://www.eurofound.europa.eu/pubdocs/2008/22/en/1/ef0822en.pdf

European Commission DG Joint Research Centre, *NEDIES PROJECT - Lessons Learnt from Earthquake Disasters That Occurred in Greece*, Chara Theofili and Ana Lisa Vetere Arellano Editors, 2001, available at: http://nedies.jrc.it/index.asp?ID=89

European Commission, Humanitarian Aid Office, *Disaster Preparedness and Prevention (DPP):State of play and strategic orientations for EC policy.* Working Paper. Available at: http://europa.eu.int/comm/echo/pdf_files/dipecho/dpp_paper.pdf

European Commission, *Taking European knowledge society seriously. Report of the expert group on science and governance to the science, economy and society directorate, Directorate-General for Research, European Commission.* EUR 22700, 2007.

Eurosion project, *Living with coastal erosion in Europe: Sediment and Space for Sustainability, final report, 2010*, available at http://www.eurosion.org/reports-online/reports.html

EUROSTAT, Population projections 2004–2050, 2005. http://ec.europa.eu/eurostat

Fabbri K., Weets G., "ICT for Environmental Risk Management in the EU Research Context", in Osterom P., Zlatanova S., Fendel E. (eds.), *Geo-information systems for Disaster Management.* Springer, 2005, pp. 51–56.

Faella C., Nigro E. "Effetti delle colate rapide sulle costruzioni", in Commissariato di Governo per l'Emergenza Idrogeologica in Campania, *Fenomeni di colata rapida di fango nel maggio '98,* Napoli, 2001

Faludi A., "From European spatial development to territorial cohesion policy." *Regional Studies* vol. 40(6): 667–678, 2006.

FAO, *Wildland fire management terminology.* FAO Forestry Paper 70, FAO, Rome, 257, 1986.

Fay H., "Land-Use Planning Approaches to Natural Hazards in the UK", in Fleischhauer, M., Greiving, S., Wanczura, S. (eds.) *Natural Hazards and Spatial Planning in Europe.* EU – ARMONIA. (2006)

Ferber U., Grimski D., Millar K. and Nathanail P., *Sustainable Brownfield Regeneration: CABERNET Network Report.* University of Nottingham, 2006.

Fiedrich F., Burghardt P., "Agent-based systems for disaster management." *Communications of the ACM* 50(3): 41–42, 2007.

Fiordham M., Ketteridge A.M., *Flood Disasters – Dividing the Community.* Paper presented at the Emergency Planning '95 Conference. Lancaster, UK, 1995.

Fiore M., Panneri C., Pardo A., Sacco P., "Awards to urbanism and prospective interventions. The two operative sides of the Plan." *Urbanistica* 134, 2007.

Flannigan M.D., Amiro B.D., Logan K.A., Stocks B.J., Wotton B.M., "Forest Fires and Climate Change in the 21st Century." *Mitigation and Adaptation Strategies for Global Change* 11(4): 847–859, 2005.

Fleischauer M., Greiving S., Wanczura S., *Natural hazards and spatial planning in Europe.* Dortmunder Vertrieb für Bau- und Planungsliteratur, 2006.

Flyvbjerg B., Bruzelius N., Rothengatter W., *Megaprojects and risk. An anatomy of ambition.* Cambridge University Press: Cambridge, 2003.

Flyvbjerg B., "Rationality and power", in Scott C. and Fainstein S.F. (eds.), *Readings in planning theory.* Blackwell Publishing: Oxford, 2003.

Folke C., Carpenter S., Elmqvist T., Gunderson L., Holling C.S., Walker B., Bengtsson J., Berkes F., Colding J., Danell K., Falkenmark M., Gordon L., Kasperson R., Kautsky N., Kinzig A., Levin S., Mäler K.-G., Moberg F., Ohlsson L., Olsson P., Ostrom E., Reid W., Rockström J., Savenije H., Svedin U., *Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformation.* Scientific Background Paper on Resilience for the process of the World Summit on Sustainable Development on behalf of the Environmental Advisory Council to the Swedish Government, 2002. Available at: http://www.sou.gov.se/mvb/pdf/resiliens.pdf

FORESIGHT (European Commission FP6 Project) Frequent Observation-driven Realistic Evaluation and Simulation of Interaction of Geophysical Hazard Triggers. Available at: http://www.acri-st.fr/foresight/project.htm

Fortune J., Peters G., *Learning from failure.* John Wiley & Sons: UK, 1995.

Freeman P.K., Martin L.A. et al. *Catastrophe and Developtment Integrating Natural Catastrophe into Development Planning.* Paper Series No 4. Washington, World Bank, 2002.

Fritz C.E. "Disaster", in Merton R.K. and Nisbet R.A. (eds.), *Contemporary social problems.* Harcourt, Brace, and World: New York, 1961.

Firitzon Ã., Ljungkvist K., "A nascent sector: European critical infrastructure protection", in Boin A., Ekengren M., Rhinard M. (eds.) *Protecting The European Union Policies, Sectors And Institutional Solutions.* Stockholm University and Leiden University, 2006.

Funtowicz S., Shepherd I., Wilkinson D., Ravetz J., "Science and governance in the European Union: a contribution to the debate." *Science and Public Policy* 27(5): 327–336, 2000.

Funtowicz S., Strand R., "Models of science and policy", in Traavik T., Lim L.C. (eds.), *Biosafety first: holistic approaches to risk and uncertainty in genetic engineering and genetically modified organisms.* Tapir Academic press: Trondheim, 2007.

GAC, Concentrating Solar Power for the Mediterranean Region. German Aerospace Center (DLR), 2005.

GALAHAD, (European Commission FP6 Project) *Advanced Remote Monitoring Techniques for Glaciers, Avalanches and Landslides Hazard Mitigation.*

Gallopin G., Raskin P*., Global sustainability. Bending the curve.* Routledge, 2002.

Gasparini P., *Bayesian approach and early warning methods for real time reduction of risks from earthquakes and volcanic eruptions: Application to the Campania region, Southern Italy.* Presentation at "Shift in Thinking", first scenario workshop, Potsdam, 2007.

Ganopolski A., Petoukhov V., Rahmstorf S., Brovkin V., Claussen M., Eliseev A., Kubatzki C., "CLIMBER–2: a climate system model of intermediate complexity. Part II: model sensitivity." *Climate Dynamics* 17: 735–751, 2001.

Gentleman A., *France faces nuclear power crisis.* The Guardian: London, August 13, 2003.

Giardini D., Grunthal G., Shedlock K.M., Zhang P., "The GSHAP Global Seismic Hazard Map." *Ann. Geofis.* 42(6): 1225–1230, 1999.

Giardini D., Jiménez M.J., Grünthal G., *European-Mediterranean Seismic Hazard Map.* European Seismological Commission. UNESCO-IUGS International Geological Correlation Program Project no. 382 SESAME, 2003.

Godard O. (ed.), *Le principe de precaution dans la conduite des affaires humaines.* Editions de la Maison des Sciences de l'Homme: Paris, 1997.

Gordon C., Cooper C., Senior C.A. et al. "The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments." *Climate Dynamics* 16: 147–168, 2000.

Greiving S., Fleischhauer M., Wanczura S. (eds.), *Natural Hazards and Spatial Planning in Europe.* Armonia Project, 2006.

Grinsted A., Moore J.C., Jevrejeva S., "Reconstructing sea level from paleo and projected temperatures 200 to 2100AD". *Clim. Dyn.*, doi:10.1007/s00382-008-0507-2, 2009.

Grothmann T., Reusswig F., "People at risk of flooding: why some residents take precautionary action while others do not." *Natural Hazards* 38: 101–120, 2006.

Grunthal G., Thieken A.H, Schwarz J., Radtke K., Smolka A., Merz B. "Comparative risk assessment for the city of Cologne, Germany – storms, floods, earthquakes." *Nat. Hazards* 38(1–2): 21–44, 2006. Available at: http://www.springer link.com/content/w575m410m0187682/

Guilhou X, Lagadec P., *La fin du risque zéro.* Les Èchos, Eyrolles Editeur: Paris, 2002.

Gunderson L.H., Holling C.S., (eds.), *Panarchy: Understanding transformations in human and natural systems*. Island Press: Washington, DC, 2002.

Jasanoff S., *The Fifth Branch: Science Advisers as Policymaker*. Harvard University Press: Cambridge, Mass., 1990.

Haeberli W., Kääb A., Muhll D.V., Teysseire P., "Prevention of outburst floods from periglacial lakes at Grubengletscher, Valais, Swiss Alps." *Journal of Glaciology* 47: 111–122, 2001.

Handmer J., "Natural and anthropogenic hazards in the Sidney sprawl: is the city sustainable?", in Mitchell J. (ed.), *Crucibles of hazard: megacities and disasters in transition*. United Nations University Press, 1999.

Handmer J., "Improving flood warnings in Europe: a research and policy agenda." *Environmental Hazards* 3: 19–28, 2001.

Handmer J., "Improving flood warnings in Europe: a research and policy agenda." *Environmental Hazards* 3: 19–28, 2002.

Handmer J., "We are all vulnerable." *The Australian Journal of Emergency Management* Vol. 18 No 3. August 2003

Hansen J.E. "Scientific reticence and sea level rise". *Environ. Res. Lett.* 2, 024002 doi:10.1088/1748-9326/2/2/024002, 2007.

Hansen J., Sato M., Ruedy R., Kharecha P., Lacis A., Miller R., Nazarenko L., Lo K., Schmidt G.A., Russell G., Aleinov I., Bauer S., Baum E., Cairns B., Canuto V., Chandler M., Cheng Y., Cohen A., Del Genio A., Faluvegi G., Fleming E., Friend A., Hall T., Jackman C., Jonas J., Kelley M., Kiang N.Y., Koch D., Labow G., Lerner J., Menon S., Novakov T., Oinas V., Perlwitz J., Rind D., Romanau A., Schmunk R., Shindell D., Stone P., Sun S., Streets D., Tausnev N., Thresher D., Unger N., Yao M., Zhang S., "Dangerous human-made interference with climate: a GISS modelE study." *Atmospheric Chemistry and Physics* 7: 2287–2312, 2007.

Hardill I., Spradbery J., Arnold-Boakes J., Marrugat M.L., "Severe health and social care issues among British migrants who retire to Spain." *Ageing and Society* 25: 769–783, 2005.

Harremoes P., *Scientific incertitude in environmental analysis and decision making.* The Heineken lecture. In The Heineken award for environmental sciences. The Royal Netherlands Academy of Arts and ciences; October 2nd, 2000. KNAW, Heineken Lectures 2000, pub. 2002

Hasselmann K., "Is climate predictable?" in Bunde A., Kropp J., Schellnhuber H.J., (eds.), *The science of disasters: Climate disruptions, market crashes and heart attacks.* Springer: Berlin, 2002.

Healy J.D., "Excess winter mortality in Europe: a cross country analysis identifying key risk factors." *J. Epidemiol Community Health* 57(10): 784–789, 2003.

Heidenreich M., "Regional Inequalities in the Enlarged Europe." *Journal of European Social Policy* 13: 313–333, 2003.

Heiling G.K., European Rural Development (ERD) Project, IIASA, Laxenburg, 2002.

Henry E., Smit M., "350,000 to lose drinking water in 'unprecedented' flooding." *Daily Telegraph* 23/07/07. Digest ed. London, 2007.

Hewitt K., *Regions of risk. A geographical introduction to disasters.* Longman: Singapore, 1997.

Hewitt K., "Geomorphic hazards in mountain environments", in Owens P.N., Slaymaker O. (eds.), *Mountain Geomorphology.* Hodder and Stoughton: London, 2004, pp. 187–218.

Hewitt K., Burton I., *The hazardousness of a place: A regional ecology of damaging events.* University of Toronto Press: Canada, 1971.

Hewitt K., *Interpretations of calamity.* Allen and Unwin inc.: Boston, 1983.

HMG, *Planning for a Sustainable Future White Paper.* Her Majesty's Government London, 2007.

HMG, *Securing the future: delivering UK sustainable development strategy.* Her Majesty's Government London, 2005. Available at: http://www.sustainable-development.gov.uk/publications/pdf/strategy/SecFut_complete.pdf 05/07/07

Hofherr, T., and M. Kunz, "Assessment of extreme wind climatology for Germany." *Clim. Res.* 41, 105–123, 2010, DOI: 10.3354/cr00844

Holland A., "Sustainability", in Jamieson D. (ed.) *Oxford Companion to Applied Ethics.* Blackwell: Oxford, 2000, pp. 390–401.

Holling C.S., "Resilience and stability of ecological systems". *Ann. Rev. of Ecol. and Syst.* 4, 1973.

Hoozemans F.M.J., Marchand M., Pennekamp H.A., *Sea level rise: A global vulnerability assessment—vulnerability assessments for population, coastal wetlands and rice production on a global scale.* Second revised edition, Delft Hydraulics and Rijkswaterstaat, Delft and The Hague, The Netherlands, 1993, 184 pp.

Horan T.A., Schooley B.L., "Time-critical information services." *Communications of the ACM* 50 (3): 73–78, 2007.

Horvat V., "Brain Drain. Threat to Successful Transition in South East Europe?" *Southeast European Politics* V: 76–93, 2004.

Howe C., Cochrane H., *Guidelines for the Uniform Definition, Identification and Measurement of Economic Damages from Natural Hazard Events.* Institute of Behavioral Science, University of Colorado, Boulder, CO, Program on Environment and Behavior Special Publication No. 28, 1993.

Huynen M., Menne B., *Phenology and Human Health: Allergic Disorders.* Report of a WHO Meeting, Rome, Italy, 16–17 January 2003. Health and Global Environmental Change, Series No. 1 (EUR/03/5036791 and EUR/02/5036813). Geneva: World Health Organization; 2003.

IFRC International Federation of the Red Cross and Red Crescent Societies, *World disasters report: Focus on information* IMAGE Team, *The IMAGE 2.2 implementation of the SRES scenarios*, RIVM CD-ROM Publication 481508018, RIVM, Bilthoven, 2002.

IOM, *World Migration, Costs and Benefits of International Migration.* Geneva, International Organisation for Migration, 2005.

Ioannides K., Dikeoulakos V., *Earthquake Planning and Protection Organisation (EPPO), Athens* (Kalamata earthquake).

IPCC, *Climate change 2001: The scientific basis.* WG I of the Intergovernmental Panel on Climate Change (IPCC). Houghton J.L., Ding Y., Griggs D.J. et al. (eds.). Cambridge University Press: Cambridge, 2001.

IPCC, *Climate change 2007: The Physical Science Basis.* WG I of the Intergovernmental Panel on Climate Change (IPCC). Cambridge: Cambridge University Press, 2007.

IPCC, *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability.* Working Group II Contribution to the Intergovernmental Panel on Climate

Change Fourth Assessment Report formally approved at the 8th Session of Working Group II of the IPCC, Brussels, April 2007, 2007a

IPCC (ed.), *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, in Solomon. S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (eds.). Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA, 2007b.

IPCC, Intergovernmental Panel on Climate Change, 2009, http://www.ipcc.ch/

IPCC, Nakicenovic N. et al., *Special Report on emissions scenarios: A special report of working group III of the intergovernmental panel on climate change.* Cambridge University Press: Cambridge, UK, 2000.

IPCC, SRES, Special Report on Emissions Scenarios, 2001

ISDR/LA RED, "Comparative analyses of disaster databases – Final report 2002.

Istanbul Earthquake Master Plan, Istanbul Greater Municipality, 2003, Istanbul.

Istanbul Metropolitan Municipality, www.ibb.gov.tr (April, 2009)

Jasanoff S., *The Fifth Branch: Science Advisers as Policymaker.* Harvard University Press: Cambridge, Mass., 1990.

Jasanoff S. "Bridging the two cultures of risk analysis." *Risk Analysis,* 13(2): 123, 1993.

JRC/ISDR, "State of the Art in Na-Tech Risk Management" EUR21292 EN, 2004.

Kallache M., Rust H., Kropp J.P., "Trend Assessment: Applications for Hydrology and Climate, Nonlin." *Processes Geophys.* 2: 201–210, 2005. http://www.nonlin-processes-geophys.net/2/201/2005/.

Kasperson J.X., Kasperson R.E. and Turner B.L., *Regions at Risk: Comparisons of Threatened Environment.* United Nations University Press: New York, 1995.

Kates, R. W., Natural Hazard in Human Ecological Perspective: Hypotheses and Models *Economic Geography* 47(3): 438–451, 1971.

Kates, R.W., Risk Assessment of Environmental Hazard, ICSU/SCOPE Report No. 8, Wiley International, 1978.

Kay A.L., Jones R.G., Reynard N.S., "RCM rainfall for UK flood frequency estimation. II. Climate change results." *Journal of Hydrology* 318: 163–172, 2006.

Keiler M., Sailer R., Jorg P., Weber C., Fuchs S., Zischg A., Sauermoser S., "Avalanche risk assessment – A multi-temporal approach, results from Galtür, Austria." *Natural Hazards and Earth System Sciences* 6: 637–651, 2006

King R., "Generalisations from the history of return migration", in Ghosh B. (ed.), *Return Migration: Journey of Hope or Despair?* IOM/UN: Geneva; 7–55, 2000.

King R., Warnes A.M., Williams A.M., "International retirement migration in Europe." *International Journal of Population Geography* 4: 91–112, 1998.

Klein R., Nicholls R., Thomalla F., "Resilience to natural hazards: how useful is this concept?" *Environemntal Hazards* 5: 35–45, 2003.

Klein A.M., Vaissière B.E., Cane J.H., Steffan-Dewenter I., Cunningham S.A., Kremen C., Tscharntke T., *Importance of pollinators in changing landscapes for world crops.* Proceedings of the Royal Society B 274: 303–313, 2007.

Klein Tank A.M.G., Peterson T.C., Quadir D.A. et al. "Changes in daily temperature and precipitation extremes in central and south Asia." *Journal of Geophysical Research* 111: D16105, 2006. Available at: http://www.knmi.nl/publications/fulltexts/2005jd006316.pdf

Klinenberg E., *Heat Wave: A Social Autopsy of Disaster in Chicago.* University of Chicago Press: Chicago, 2002.

Korup O., Tweed F.S., "Ice, moraine and landslide dams in mountainous terrain." *Quaternary Science Reviews* 26: 3406–3422, 2007.

Kovats R.S., Jendritzky G., *Heat-waves and human health. Climate Change and Adaptation Strategies for Human Health*, in Menne B., Ebi K.L. (eds.) Springer: Darmstadt, Germany, 2006, pp. 63–90.

Kropp J.P., Eisenack K., Scheffran J., "Marine Overexploitation: a Syndrome of Global Change." In *Multiple Dimensions of Global Environmental Change*, 2006, pp. 257–284, S. Sonak (ed.), TERI Press, New Delhi.

Kropp J.P., Schellnhuber H.J., *In Extremis: Extremes, Trends and Correlations in Hydrology and Climate.* Springer: Berlin, 2011.

Kundzewicz Z.W., Radziejewski M. and Piskwar I., "Precipitation extremes in the changing climate of Europe." *Climate Research* 31: 51–58, 2006.

Kundzewicz Z.W., "Editorial—Searching for change in hydrological data." *Hydrological Sciences Journal* 49(1): 3–6, 2004.

Kunreuther H., "Neglecting Disaster: Why Don't People Insure Against Large Losses?" *The Journal of Risk and Uncertainty* 28(1), 2004.

Kunreuther H., Roth R.J. (cur.), *Paying the price: the status and role of insurance against natural disasters in the United States.* Joseph Henry Press: USA, 1998.

Lagadec P., *Crisis management in the 21st century 'unthinkable' events in 'inconceivable' contexts.* Tech. Rep. 2005.

Lavalle C., Barredo J.I., De Roo A., Feyen L., Niemeye S., Camia A., Hiederer R., Barbosa P., *Pan European assessment of weather driven natural risks,* 2006. Available at: http://ec.europa.eu

Leckebusch G.C., Ulbrich U., "In the relationship between cyclones and extreme windstorm events over Europe under climate change." *Global and Planetary Change* 44(1–4): 181–193, 2004.

Leggett J., Pepper W.J., Swart R.J., "Emissions Scenarios for IPCC: An Update." In Houghton, J.T., B.A. Callander and S.K. Varney (eds.), Climate Change 1992. The Supplementary Report to the IPCC Scientific Assessment, Cambridge University Press, Cambridge, UK, 1992, pp. 69–95.

Lehner B., Döll P., Alcamo J., Henrichs T., Kaspar F., "Estimating the impact of global change on flood and drought risks in Europe: a continental integrated analysis." *Climatic Change* 75: 273–299, 2006.

Lele S.M., "Sustainable development: a critical review." *World Development* 19(6): 607–621, 1991.

Lessloss, Deliverable Report 10, *Vulnerability assessment for landslides*, February, 2006

Levermann A., Griesel A., Hoffman M., Montoya M., Rahmstorf S., "Dynamic sea level changes following changes in the thermohaline Circulation." *Climate Dynamics* 24: 347–354, 2005.

Lewis J., *Development in disaster-prone places, studies of vulnerability.* Intermediate Technology Publications: UK, 1999.

Li X., "Diversification and localization of energy systems for sustainable development and energy security." *Energy Policy* 33: 2237-2243, 2005.

Lindell M. (guest editor), "Adoption and implementation of hazard adjustments." *International Journal of Mass Emergencies and Disasters*, special issue, November 1997.

Linnerooth-Bayer J., Amendola A., "Global change, natural disasters and loss sharing: issues of efficiency and equity." *The Geneva papers on risk and insurance*, Blackwell Pub., UK, 25(2), April, 2000.

Linnerooth-Bayer J., Mace M., Verheyen R., *Insurance related actions and risk assessment in the context of the United Nations Framework Convention on Climate Change (UNFCCC)*. Background paper, May 2003.

Lissner T., Holsten A., Walther C., Kropp J.P. (in printing). Toward sectoral and standardised vulnerability assessment: the example of heatwaves impacts on human health. Submitted to Climate Change.

Lofstedt R., Boholm A., "Off track in Sweden." *Environment* 41:4, May 1999.

Low B., Ostrom E., Simon C., Wilson J., "Redundancy and diversity in governing and managing natural resources", in Berkes F., Colding J., Folke C. (eds.), *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge University Press: Cambridge, UK, 2003.

Lumbroso D., Report on current availability and methodology for natural risk map production – Floods –. In S. Bukalova (ed.), Collection and evaluation of current methodologies for risk map production. Report 2.1, Armonia – EC project Applied multi Risk Mapping of Natural Hazards for Impact Assessment, 2005.

Luterbacher J., Dietrich D., Xoplaki E., Grosjean M. and Wanner H., "European seasonal and annual temperature variability, trends and extremes since 1500." *Science* 303: 1499–1503, 2004.

Madden S., Franklin M., Hellerstein J., Hong W., "TinyDB: an acquisitional query processing system for sensor networks," *ACM Transactions on Database Systems (TODS)* 30(1): 122–173, 2005.

Manoi B., Baker A.H. "Communication challenges in emergency response," Communications of the ACM, 50(3): 51–53, 2007.

Martin, E., Giraud G., Lejeune Y., Boudart G., "Impact of climate change on avalanche hazard." *Ann. Glaciol.* 32: 163–167, 2001.

Marzocchi W., Sandri L., Gasparini P., Newhall C., Boschi E., "Quantifying probabilities of volcanic events: The example of volcanic hazard at Mount Vesuvius." *Journal of Geophysical Research* 108 (B11201), 2004.

Marzocchi, W., Sandri L., Selva J., "BET EF: a probabilistic tool for long- and short-term eruption forecasting." *Bull. Volcanol.* 2007, DOI: 10.1007/s00445-007-0157-y.

Massard-Guilbaud G., Platt, H., Scott D., *Cities and catastrophes. Coping with emergency in European history*. Peter Lang, 2002.

Materna J., Daniel M., Danielova V., "Altitudinal distribution limit of the tick Ixodes ricinus shifted considerably towards higher altitudes in central Europe: results of three years monitoring in the Krkonose Mts. (Czech Republic)." *Cent. Eur. J. Public Health* 13: 24–28, 2005.

Matkovic T., Šucur Z., Zrinscak S., "Inequality, Poverty, and Material Deprivation in New and Old Members of European Union." *Croatian Medical Journal* 48: 636–652, 2007.

Maskey S., Guinot, V., Price R., "Treatment of precipitation uncertainty in rainfall-runoff modelling: a fuzzy set approach." *Advances in Water Resources* 27: 889–898, 2004.

May P., Burby R., Ericksen N., Handmer J., *Environmental management and governance: Intergovernmental approaches to hazards and sustainability*. Routledge: London, 1996.

McCormick J., *Environmental policy in the European Union.* Palgrave, 2001.
McEntire, D.A., "Triggering Agents, Vulnerabilities and Disaster Reduction: Towards a Holistic Paradigm", *Disaster Prevention and Management* 10 (3): 189–196, 2001.
McGranahan G., Balk D., Anderson B., "The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones." *Environment and Urbanization* 19(1): 17–37, 2007.
McNamara K., "Conceptualizing discourses on environmental refugees at the United Nations." *Population and Environment* 29: 12–24, 2007.
McNeill D. "The concept of sustainable development", in Lee K., Holland A. and McNeill D. (eds.), *Global sustainable development in the 21st century.* Edinburgh University Press: Edinburgh, 2000.
McPherson G.R., Wade D.D., Phillips C.B., *Glossary of Wildland Fire Management Terms Used in the United States.* Society of American Forester: Washington DC, 1990, 138 pp.
Mechler R., "Natural disaster risk and cost benefit analysis", in Kreimer A., Arnold M., Carlin A., (eds.), *Building safer cities. The future of disaster risk.* The World Bank Management Facility: Washington DC, 2003.
Michel-Kerjan E., *Insurance against natural disasters: do the French have the answer? Strengths and limitations.* Cahier n. 2001–007, Laboratoire d'Econometrie, Ecole Polytechnique: Paris, August 2001.
Middelkoop H., Daamen K., Gellens D., Grabs W., Kwadijk J.C.J., Lang H., Parmet B.W.A.H., Schaedler B., Schulla J., Wilke K., "Impact of climate change on hydrological regimes and water resources management in the Rhine basin." *Climatic Change 4*9: 105–128, 2001.
Middleton D., Edwards D. (eds.), *Collective remembering.* Sage Publisher, 1990.
Milankovic M., *Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem.* Académie royale serbe, Éditions specials: Belgrad, 1941.
Mileti D., Nathe S., Gori P., Greene M., Lemersal E., *Public hazards communication and education: The state of the art.* Informer Issue 2. Natural Hazards Center, University of Colorado, 1–13, May 20, 2004. Available at: http://www.colorado.edu/hazards/informer/.
Mileti D.S., *Disasters by design: A reassessment of natural hazards in the United States.* Joesph Henry Press: Washington DC, 1999.
Mileti D.S., Gailus J.L., "Sustainable development and hazards mitigation in the United States: disasters by design revisited." *Mitigation and Adaptation Strategies for Global Change* 10: 491–504, 2005.
Mitcham C., "The concept of sustainable development: it's origins and ambivalence." *Technology in Society* 17(3): 311–326, 1995.
Mitchell J. (ed.), *Crucibles of hazard: megacities and disasters in transition.* United Nations University Press, 1999.
Mitchell R.B., Clark W.C., Cash D.W., Dickson N.M. (eds.), Global Environmental Assessments: Information and Influence. MIT Press: Cambridge, 2006.
Mitchison N., Porter S. (eds.) Guidelines on a major accident prevention policy and safety management system, as required by Council Directive 96/82/EC (SEVESO II). EUR 18123 EN.Ispra: European Commission, DG JRC, 1998
Morrow B.H. "Identifying and Mapping Community Vulnerability." *Disasters* 23: 1–18, 1999.
Munich Re Foundation, *A world of natural hazards.* CD ROM Atlas, 2000.

Munich Re Foundation, *Topics geo – Annual Review: Natural Catastrophes 2003.* 2004.

Munich Re Foundation, *From Knowledge to Action*. Munich Re. 2006.

Munich Re Foundation, NatCatSERVICE®A guide to the Munich Re database for natural catastrophes, 2003. Available at: http://www.munichre.com/publications/302-03901_en.pdf

Munich Re Foundation, *Topics Geo Annual review: Natural catastrophes 2004*. 2005. Available at: http://www.munichre.com/publications/302-04321_en.pdf

Munich Re Foundation, *Natural Hazard and Climate Change in Europe*. Munich Re Media Breakfast Baden, 2007.

Murphy J.M., "Predictions of climate change over Europe using statistical and. dynamical downscaling techniques." *Int. J. Climatol.* 20: 489–501, 2000.

Myers N., "Environmental Refugees: A Growing Phenomenon of the 21st Century." *Philosophical Transactions: Biological Sciences* 357: 609–613, 2002.

Myers F.M., Showalter P, *Natural disasters as the cause of technological emergencies: a review of the decade 1980–1989*, Natural Hazard Research and Applications Center, University of Colorado, Boulder, Colorado, 1992.

NAO, *The Thames Gateway: Laying the foundations*. National Audit Office, 2007.

Neal D., "Reconsidering the phases of disaster." *International Journal of Mass Emergencies and Disasters* 15(2): 239–264, 1997.

New M., Hulme M., "Representing uncertainty in climate change scenarios: a Monte-Carlo approach." *Integrated Assessment* 1: 203–213, 2000.

Nicholls R., Cavenaze A. "Sea-Level Rise and Its Impact on Coastal Zones". *Science* 328(5985): 1517–1520, 2010.

Nicholls R.J., "Rising sea levels: potential impacts and responses", in Hester R., Harrison R.M. (eds.), *Global Environmental Change*. Issues in Environmental Science and Technology, Number 17, Royal Society of Chemistry, Cambridge, 2002a, pp. 83–107.

Nicholls R.A., Lowe J.A., "Benefits of mitigation of climate change for coastal areas Global." *Environmental Change* 14: 229–244, 2004.

Nordas R., Gleditsch N.P., "Climate change and conflict." *Political Geography* 26: 627–638, 2007.

NRC, *The Impact of Natural Disaster: a framework for loss estimation*. National Academy Press.: Washington D.C., January 1999, available at http://www.nap.edu/openbook.php?isbn=0309063949

O'Brien G., O'Keefe P., Rose J., Wisner B., "Climate change and disaster management." *Disasters* 30: 64–80, 2006.

ODPM, Coastal Towns: Housing, Planning, Local Government and the Regions Committee report; written evidence. Office of the Deputy Prime Minister, 2006.

ODPM, *Assessing the Impacts of Spatial Interventions: Regeneration, Renewal and Regional Development: Main Guidance*. Interdepartmental group on the EGRUP review, final draft, Office of the Deputy Prime Minister, September 2003.

OECD, Jobs Study: Evidence and Explanations. OECD: Paris, 1994.

Okuyama Y., Hewings G.J.D., Sonis M., "Economic impact s of an unscheduled, disruptive event: A miyazava multiplier analysis", in Hewings GJD et al. (eds.), *Understanding and interpreting economic structure.* Springer-Verlag: Berlin, Germany, 1999.

Oreskes N., "Why predict? Historical perspectives on prediction in earth sciences", in Sarewitz D., Pielke R.A. Jr., Byerly R. Jr., (eds.) *Prediction. Science, decision making and the future of nature.* Island Press: Washington D.C., 2000

Oreskes N., Shrader-Frechette K., Belitz K., "Verification, validation, and confirmation of numerical models in the earth sciences." *Science* Feb. 4, 263, 1994.

O'Riordan T., Jordan A., "The Precautionary Principle in Contemporary Environmental Politics." *Environmental values* 4(3): 191–212, 1995

Orsi G., *La pericolosità vulcanica.* In Provincia di Napoli, Primo Rapporto sullo Stato dell'Ambiente, 2001.

OST, *Indicateurs de sciences et de technologies*, Rapport de l'Observatoire des Sciences et des Techniques, Paris: Economica, 2004.

Otero R.C., Marti R.Z., *The impact of natural disasters in developing economies. Implications for the International Development of Disaster Community*, 1995. Available at: http://sup.kathimerini.gr/xtra/media/files/fin/nat_doc6538.pdf

Overpeck J.T., Otto-Bliesner B.L., Miller G.H., Muhs D.R., Alley R.B., Kiehl J.T. "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise." *Science* 311: 1747–1750, 2006.

Palmer T., Räisänen J., "Quantifying the risk of extreme seasonal precipitation events in a changing climate." *Nature* 415: 512–514, 2002.

Papadakis G.A., Amendola A. (eds.), Guidance on the preparation of a safety report to meet the requirements of Council Directive 96/82/EC. EUR 17690 EN, JRC,Ispra, 1997.

Papanek V., *Design for the real world. Human ecology and social change.* Second edition, Thames and Hudson, 1997.

Pappalardo S., *Un terremoto per amico. Potere, trasgressioni e dispute dopo una calamità naturale.* Franco Angeli: Milan, 1994.

Parker D.J., Green C.H., Thompson P.M. *Urban flood protection benefits, a project appraisal guide.* Aldershot, Gower, 1987.

Parker D.J., "Disaster response in London", in Mitchell J. (ed.), *Crucibles of hazard: megacities and disasters in transition.* United Nations University Press, 1999.

Parker D.J., Fordham M., "An evaluation of flood forecasting, warning and response systems in the European Union." *Water Resources Management* 10: 279–302,1996.

Parker D.J., Handmer J., "The role of unofficial flood warning systems." *The Journal of Contingencies and Crisis Management* 6(1): 45–60, 1998.

Paton, D. , "Community Resilience: Integrating Individual, Community and Societal Perspective", in Gow K., Paton D. (eds), *The Phoenix of Natural Disasters: Community Resilience.* Nova Science Publishers Inc., 2008.

Pearce L., "Disaster Management and Community Planning and Public Participation: How to Achieve Sustainable Hazard Mitigation." *Natural Hazards* 28: 211–228, 2003.

Pelling M., *The vulnerability of cities: Natural disasters and social resilience.* Earthscan: London, UK, 2003.

Pelling M., Schipper L., "Disaster risk, climate change and international development: scope for, and challenges to, integration." *Disasters* 30(1): 19–38, 2006. Available at: http://www.blackwell-synergy.com/doi/pdf/10.1111/j.1467-9523.2006.00304.x

Peltonen L., "Recommendations for a risk mitigation oriented European Spatial Policy", in Schmidt-Thomé P. (ed.), *Natural and technological hazards and risks* *affecting spatial development of European Regions*. Geological Survey of Finland, Special Paper 42: 153–167, 2006, pp.

Perrow Ch., *Normal accidents. Living with high risk technologies.* Basic Books: New York, 1999.

Petersen M.S., Hansen H.K., Hansen C.O., Rich J., Ulied A., Larrea E., Pearman A., Shires J., Enei R., Korchenevych A., Bröcker J., Leder P., Gohkale R., Merten T., Granberg T., Jovanovic R., *Traffic flow: Scenario, Traffic Forecast and Analysis of Traffic on the TEN-T, Taking into Consideration the External Dimension of the Union*, Final report, December 2009.

Petit J.R., Jouzel J., Raynaud D., Barkov N.I., Barnola J.M., Basile I., Bender M., Chappellaz J., Davis J., Delaygue G., Delmotte M., Kotlyakov V.M., Legrand M., Lipenkov V., Lorius C., Pépin L., Ritz C., Saltzman E., Stievenard M., "Climate and Atmospheric History of the Past 420,000 years from the Vostok Ice Core, Antarctica." *Nature* 399: 429–436, 1999.

Petschel-Held, G., H.J. Schellnhuber, T. Bruckner, F. Toth, and K. Hasselmann, "The tolerable windows approach: Theoretical and methodological foundations." *Climatic Change* 41 303–331, 1999.

Pielke R. Jr, "The role of models in prediction for decision", in Canham C., Cole J. and Lauenroth W.K. (eds), *Models in ecosystem science.* Princeton Univ. Press, 2003, pp. 111–135.

Plapp T., *Perception and Evaluation of Natural Risks – Interim report on first results of a survey in six districts in Germany.* Risk Research and Insurance Management, Working Paper No. 1, Institute for Insurance, University of Karlsruhe (TH), Germany, November 2001.

Plapp T., Werner U., "Understanding risk perception from natural hazards: examples from Germany", in Amman W.J., Dannemann S., Vulliet L. (eds.), *Risk 21 – Coping with risks due to natural hazards in the 21th century.* Taylor&Francis: London, UK, 2006.

Platt R., *Disasters and democracy. The politics of extreme natural events.* Island Press: Washington DC, Covelo CA, 1999.

Porritt J. "Translating ecological science into practical policy", in Edwards P.J., May R.M., Webb N.R. (eds.), *Large-scale ecology and conservation biology.* Blackwell Science, 1993, pp. 345–353.

Price C., "Evidence for a link between global lightning activity and upper tropospheric water vapor." *Nature* 406: 290–293, 2000.

Priest S.J., Clark M.J., Treby E.J. "Flood Insurance: the challenge of the uninsured." *Area* 37(3): 295–302, 2005.

Priyantha Ranjan S., Kazama S., Sawamoto M., "Effects of climate change on coastal fresh groundwater resources." *Global Environmental Change* 16(4): 388–399, 2006a.

Priyantha Ranjan S., Kazama S., Sawamoto M., "Effects of climate and land use changes on groundwater resources in coastal aquifers." *Journal of Environmental Management* 80(1): 25–35, 2006b.

Provention Consortium, Urban Disasters and Globalization. *The Future of Disaster Risk: Building Safer Cities.* Conference organized by the ProVention Consortium, DMF, and the World Bank, 2002.

Pulver S., VanDeveer S.D. "Thinking About Tomorrows:Scenarios, Global Environmental Politics, and Social Science Scholarship". *Global Environmental Politics* 9(2): 1–13, May 2009.

Quarantelli E., "Problematical aspects of the information/ communication revolution for disaster planning and research: ten non-technical issues and questions." *Disaster Prevention and Management: an International Journal* 6(2): 94–106, 1997.

Quarantelli E., "Social aspects of disasters and their relevance to pre-disaster planning." *Disasters* 1(1): 98–107, 1977.

Quarantelli E., *The computer based information/communication revolution: a dozen problematical issues and questions they raise for disaster planning and managing.* Preliminary Paper, DRC, 1998a.

Quarantelli E. (ed.), *What is a disaster?* Routledge: UK, 1998b.

Quarantelli E., *Emergencies, Disasters and Catastrophe are different phenomena.* Preliminary papers Disaster Research Center, 2000. Available at: http://www.udel.edu/DRC/preliminary/pp304.pdf

Rahmstorf S., "A semi-empirical approach to projecting future sea-level rise." *Science* 315: 368–370, 2007.

Rahmstorf S., Cazenave A., Church J.A., Hansen J.E., Keeling R.F., Parker D.E., Somerville R.C.J., "Recent Climate Observations Compared to Projections." *Science* 316: 709, 2007.

Raleigh C., Urdal H., "Climate change, environmental degradation and armed conflict." *Political Geography* 26: 674–694, 2007.

Rapporto della Commissione di Indagine., *Black out del sistema elettrico italiano del 28 settembre 2003*, Rome, 28 November 2003

Rebetez M., *Helvetien im Treibhaus: Der weltweite Klimawandel und seines Auswirkungen auf die Schweiz.* Haupt Verlag: Bern, 2006.

Rebetez M., Meyer H., Dupont O., Schindler D., Gartner K., Kropp J.P., Menzel A., "Heat and drought 2003 in Europe: a climate synthesis." *Annals for Forest Science* 63: 569—577, 2006.

Redclift M., *Wasted: counting the cost of global consumption.* Earthscan: London, 1996.

Reeve N., Toumi R., "Lightning activity as an indicator of climate change." *Quart. J. Roy. Met. Soc.* 125: 893–903, 1999.

Regan K., "European E-Commerce Growing Fast, But Risks Remain". *E-Commerce Times*, 2002.

Reddy S., "Examining hazard mitigation within the context of public goods". *Environmental Management* 25(2): 129–141, 2000.

Renn O., Webler T., Wiedemann P. (eds.), *Fairness and Competence in Citizen Participation.* Kluwer: Dordrecht, 1995.

Rescher N., *Baffling phenomena and other studies in the philosophy of knowledge and valuation.* Rowmann and Littlefield Pub., 1991.

RETINA (European Commission FP5 Project), *Realistic Evaluation of Temporal Interaction of Natural Hazards.* Available at: http://www.cvarg.azores.gov.pt/Cvarg/CentroVulcanologia/projectoinvestigacaos/RETINA.htm

Reuveny R., "Climate change-induced migration and violent conflict." *Political Geography* 26: 656–673, 2007.

Richard D., Gay M., *GLACIORISK Final Report: Survey and Prevention of Extreme Glaciological Hazards in European Mountainous Regions.* European Commission, 2004.

Richardson S.D., Reynolds J.M., "An overview of glacial hazards in the Himalayas." *Quaternary International* 65/66: 31–47, 2000.

RIMAX (2007): Risk Management of Extreme Flood Events, funded by the Federal Ministry for Education and Research Germany between 2005–2008 by 20 Mio , Online: http: //www.rimax-hochwasser.de

RINAMED (Risques Naturels en. Méditerranée), *Etude sur la perception des risques naturels en mediterranee*, 2004. Available at: www.rinamed.net See: http://www.cvarg.azores.gov.pt/Cvarg/CentroVulcanologia/projectoinvestigacaos/RETINA.htm

Ringland G., *Scenario planning. Managing for the future.* John Wiley & Sons Ltd., 1999.

Robine J.M., Cheung S.L., Le Roy S., Van Oyen H., Herrmann F., *Report on excess mortality in Europe during summer 2003.* EU Community Action Programme for Public Health, Grant Agreement 2005114, 2003.

Roeckner E., Buml G., Bonaventura L., Brokopf R., Esch M., Giorgetta M., Hagemann S., Kirchner I., Kornblueh L., Manzini E., Rhodin A., Schlese U., Schulzweida U., Tompkins A., The atmospheric general circulation model ECHAM 5. Part I: Model description. Max Planck Institute for Meteorology, Report 349, Hamburg, Germany, 2003.

Rolandi G., Barrella A., Borrelli A., "The 1631 eruption of Vesuvius." *J. Volcanol. Geoterm. Res.* 58: 183–201, 1993.

Rose A. "Economic principles, issues, and research priorities of natural hazard loss estimation", in Okuyama Y., Chang S. (eds), *Modeling of Spatial Economic Impacts of Natural Hazards.* Springer: Heidelberg, 2004.

Rose A., Dongsoon L., "Business interruption losses from natural hazards: conceptual and mthodological issues in the case of the Northridge earthquate". *Global Environmental Change Part B: Environmental Hazards* 4(1): 1–14, 2002

Rosi M., Principe C., Vecci R., "The 1631 eruption of Vesuvius reconstructed from the review of chronicles and study of deposits." *J. Volcanol. Geoterm. Res.* 58: 151–182, 1993.

Rotmans J., Van Asselt M., Anastasi C., Greeuw S., Mellors J., Peters S., Rothman D., Rijkens N., "Visions for a sustainable Europe," *Futures* 32: 809–831, 2000.

Roux-Dufort C., "Is crisis management (only) a management of exceptions?" *Journal of Contingencies and Crisis Management* 15:2, June, 2007.

Roy A., "La perception sociale des risques naturels." *Les données de l'environnement* 99, January 2005.

Russell H., Whelan C. *Low income and deprivation in an enlarged Europe.* Dublin, European Foundation for the Improvement of Living and Working Conditions, 2004.

Rycroft M.J., Israelsson S., Price C., "The global atmospheric electric circuit, solar activity and climate change." *Journal of Atmospheric and Solar-Terrestrial Physics* 62(17–18): 1563–1576, 2000.

Sala O.E., Chapin III F.S., Armesto J.J., Berlow E., Bloomfield J., Dirzo R., Huber-Sanwald E., Huenneke L.F., Jackson R.B., Kinzig A., Leemans R., Lodge D.M., Mooney H.A., Oesterheld M., LeRoy Poff N., Sykes M.T., Walker B.H., Walker M., Wall D.H., "Global Biodiversity Scenarios for the Year 2100." *Science* 287: 1770–1774, 2000.

Salagnac J.-L., "Lessons from the 2003 heat wave: a French perspective." *Building Research & Information* 35: 450–457, 2007.

Salter L. et al. *Mandated science. Science and scientists in the making of standards.* Kluwer Academic Publishers: Dordrecht-Boston-London, 1988.

Samuels P., Language of Risk: Project Definitions. Report T32-04-01, EC FLOODSite – project on Integrated Flood Risk Analysis and Management Methodologies, Version 5.0, 2009. http://www.floodsite.net/html/partner_area/project_docs/

Sanson G., *Evalutation des dispositifs de secours et d'intervention mis en œuvre à l'occasion des tempêtes des 26 et 28 décembre 1999.* Rapport complémentaire de la commission interministerielle, 2001.

Sarewitz D., Pielke R. Jr., Byerly R. (eds.), *Prediction. Science, decision making and the future of nature.* Island Press: Washington D.C., 2000

Scanlon J., "Increasingly intolerable boundaries: future control of environmental pollution." *Journal of Hazardous Materials* 86: 121–133, 2001.

Schmidt-Seiwert V., Porsche L., Schon P. (edited by) *ESPON Atlas. Mapping the structure of the European territory.* October 2006. Available at: http://www.ESPON.eu

Schmidt-Thomé P. (ed.), Natural and Technological Hazards and Risks Affecting the Spatial Development of European Regions. Geological Survey of Finland, 2006a.

Schmidt-Thomé P., *The Spatial Effects and Management of Natural and Technological Hazards in Europe – ESPON 1.3.1*, Executive Summary, 2006b

Schneider R.O., "Hazard mitigation and sustainable community development." *Disaster Prevention and Management* 11: 141–147, 2002.

Schneider S., *Flirting with disaster Public Management in crisis situations.* M.E. Sharpe, New York, London, 1995.

Scholtz R.W., Tietje O., *Embedded case study methods: Integrating quantitative and qualitative knowledge.* Sage, Thousand Oaks: CA, 2002.

Schröter D., Cramer W., Leemans R., Prentice C., Araújo M.B., Arnell N.W., Bondeau A., Bugmann H., Carter T.R., Gracia C.A., de la Vega-Leinert A.C., Erhard M., Ewert F., Glendining M., House J.I., Kankaanpää S., Klein R.J.T., Lavorel S., Lindner M., Metzger M.J., Meyer J., Mitchell T.D., Reginster I., Rounsevell M., Sabaté S., Sitch S., Smith B., Smith J., Smith P., Sykes M.T., Thonicke K., Thuiller W., Tuck G., Zaehle S., Zierl B. "Ecosystem Service Supply and Vulnerability to Global Change in Europe." *Science* 310(5752): 1333–1337, 2005.

Schubert R., Schellnhuber H.J., Buchmann N., Epiney A., Griesshammer R., Kulessa M., Messner D., Rahmstorf S., Schmid J., *Climate Change as a Security Risk.* German Advisory Council on Global Change (WBGU): Berlin, 2007.

Schwartz P., *The art of the long view. Planning for the future in an uncertain world.* Doubleday Publisher: New York, 1991.

Schwarze R., Wagner G.G., "In the Aftermath of Dresden: New Directions in German Flood Insurance." *The Geneva Papers* 29: 154–168, 2004.

Scottish Executive, *Scottish neighbourhood statistics data zones, 2004.* Available at: http://www.scotland.gov.uk/library5/society/sndata-02.aspS.

Sepe M., "The Operative Strategic Plan. Decongestioning and revitalisation: the OSP as opportunity for sustainable development." *Urbanistica* 134, 2007.

Sethi D., Racioppi F., Baumgarten I., Bertollini R. "Reducing inequalities from injuries in Europe." *The Lancet* 368: 2243–2250, 2007.

Sharpley G., *CSG in Sandhurst,* 2003. Available at: http://www.tewkesburybc.com/media/pdf/9/k/CSG_Summary_Report_(2006).pdf

Shindell D., Schmidt G., Miller R., Mann M., "Volcanic and Solar Forcing of Climate Change during the Preindustrial Era." *Journal of. Climate* 16: 4094–4107, 2003.

Shinozouka M., Rose A., Eguchi R., *Engineering and socio-economic impacts of earthquakes*. MCEER, Suny Buffalo: New York State, 1998.

Siddall M., Stocker T.M., Clark P.U. "Constraints on future sea-level rise from past sea-level change". *Nature Geoscience* 2: 571–575, 2009.

Siegenthaler U., Stocker T.F., Monnin E., Lüthi D. et al., "Stable Carbon Cycle? Climate relationship during the late pleistocene." *Science* 310(5752): 1313–1317, 2005.

Smith F., "A synthetic framework and a heuristic for integrating multiple perspectives on sustainability", in Smith F. (ed.), *Environmental sustainability. Practical global implications.* St. Lucie Press: Roca Raton, 1997.

Smith F., "Biological diversity, ecosystem stability and economic development." *Ecological Economics* 16: 191–203, 1996.

Smith K., *Environmental Hazards; assessing risk & reducing disaster*. 3rd edn, Routledge: London, 2001.

Snow J.T. (ed.), "Special Issue: European Conference on Severe Storms." *Atmos. Res.* 67–68, 2003, 703 pp.

Spoor M. *Inequality, Rural Poverty and Conflict in Transition Economies.* Paper presented at the International Conference of the Faculty of Economics Sarajevo (ICES), "From Transition to Development: Globalisation and the Political Economy of Development of Transition Economies", 10–11 October 2003. Sarajevo, Bosnia and Herzegovina, 2003.

Stern N. (ed.) *The Economics of Climate Change: The Stern Review*. Cambridge University Press: Cambridge, 2006.

Stiglitz J., "Regulation and Failure", in Moss D. and Cisternino J. (eds.), *New Perspectives on Regulation*. The Tobin Project: Cambridge MA, 2009

Stirling A., "Risk, precaution and science: towards a more constructive policy debate. Talking point on the precautionary principle." *EMBO Reports* 8(4): 309–315 2007.

Storch H., "Climate change in the North Sea storm surge extremes: an ensemble study of storm surges extremes expected in a changed climate projected by four different regional climatic models." *Ocean Dynamics* 56: 3–15, 2006.

Stott P.A., Stone D.A., Allen M.R., "Human contribution to the European heat wave of 2003." *Nature* 432: 610–614, 2004.

Strauss P., "Power cuts plunge Europe into darkness." *Financial Times*, 05/11/06, London, 2006.

Swiss Re, Natural Catastrophes and Man-Made Disaster in 2006, Sigma No.2. Zurich, 2007.

Taylor C., Mittler E., Lund Le V., Overcoming barriers: lifeline seismic improvement programs. Technical Council on Lifeline Earthquake Engineering Monograph No: 13, September 1998. The American Society of Civil Engineers : Virginia, 1998.

Ten Brinke W.B., Bannink B.A. *Dutch dikes and risk hikes: a thematic policy evaluation of risks of flooding in the Netherlands.* Report 5007990002. Netherlands Environmental Assessment Agency, 2004.

Thieken A.H., Petrow T., Kreibich H., Merz B., "Insurability and mitigation of flood losses in private households in Germany." *Risk Analysis* 26: 383–395, 2006.

Thieken A.H., Müller M., Kreibich H., Merz B., "Flood damage and influencing factors: New insights from the August 2002 flood in Germany." *Water Resources Research* 41(12): 1–16, W12430, 2005

Thiruppugazh V., *Urban vulnerability reduction: regulations and beyond*, ASARC Working Paper, 2007/2008.

Thomson K., Deisler P. Jr., Schwing R., "Interdisciplinary vision: the first 25 years of the Society for Risk Analysis (SRA), 1980–2005." *Risk Analysis* 25(6): 1333–1386, 2005.

Thrush D., Burningham K., Fielding J., *Flood Warning for Vulnerable Groups; A Qualitative Study.* Environment Agency: Bristol UK, 2005.

Thuiller W., "Climate change and the ecologist." *Nature* 448: 550–552, 2007.

Tikkanen M., Oksanen J., "Late Weichsilian and Holocene shore displacement history of the Baltic Sea in Finland." *Int. J. of Geography* 180(1–2), 2002

Thywissen K., *Components of Risk: A Comparative Glossary.* United Nations University Institute for Environment and Human Security: Bonn, 2006.

Turmes C., *Why Europe will face more US-style blackouts.* Background paper by Claude Turmes, Member of the European Parliament and rapporteur on the electricity liberalisation directive (on-line), 2003.

Tobin G.A., "Sustainability and community resilience: the holy grail of hazards planning?" *Global Environmental Change Part B: Environmental Hazards* 1: 13–25, 1999.

Tobriner S., "The Mexico Earthquake of September 19, 1985 – Past decisions, present danger: an historical perspective on ecology and earthquakes in Mexico City." *Earthquake Spectra* 4(3), 1988.

Tol R.S.J., "The Damage Costs of Climate Change Toward More Comprehensive Calculations." *Environmental and Resource Economics* 5: 353–374, 1995.

Tropeano D., *Historical (An) analysis of flood and landslide events, as a tool for risk assessment in Bormida Valley.* Proccedings of the Conference "Suolosottosuolo", Associazione Mineraria Subalpina, Torino, 27–30 September 1989 1: 145–151. 1989.

Turner B.A., Pidgeon N.F., *Man-Made Disasters.* Butterworth-Heinemann: Boston, 1997.

Turner B.L., Kasperson R.E., Matson P.A., McCarthy J.J., Corell R.W., Christensen L., Eckley N., Kasperson J.X., Luers A., Martello M.L., Polsky C., Pulsipher A., Schiller A., "A framework for vulnerability analysis in sustainability science," in *PNAS*, 100 (14): 8074–8079, 2003, see www.pnas.org.

Twigg J., *Lessons from disaster preparedness.* Notes for presentation to the International Conference on Climate Change and Disaster Preparedness, 26–28 June 2002, The Hague, Netherlands.

Tyndall J., 1861, "On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, Conduction. – The Bakerian Lecture.", *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, Series 4, Vol. 22, pp. 169–194, 273–285.

UNCHS, United nations for human settlements (Habitat), An Urbanizing World, *Global report on Human Settlements 1996.* Oxford University Press: Oxford, 1996.

UNCHS, United nations for human settlements (Habitat), *Cities in a Globalizing World, Global report on Human Settlements 2001.* Earthscan: London and Sterling, VA, 2001.

UNDRO, Evaluation of the United Nations Disaster Relief Co-ordinator, Doc.JIU/REP780/11, Oct. 1980.

UNESCO, *Convention concerning the protection of the world cultural and natural heritage.* Paris, 1972.

UN/ISDR, *Global assessment report on disaster risk reduction: risk and poverty in a changing climate,* United Nations International Strategy for Disaster Reduction Secretariat, 2009

UN/ISDR, *Hyogo Framework for Action 2005–2015: ISDR International Strategy for Disaster Reduction International Strategy for Disaster Reduction; Building the Resilience of Nations and Communities to Disasters* United Nations Development Programme Geneva, 2005.

UN/ISDR, *Terminology: Basic terms of disaster risk reduction.* 2004.

Vale L.J., Campanella T.J., *The Resilient City. How modern city recover from disaster.* Oxford University Press: NY, 2005.

Van der Sluijs J.P., Janssen P., Petersen A., Kloprogge P., Risbey J., Tuinstra W., Ravetz J., *RIVM/MNP Guidance for uncertainty assessment and communication: tool catalogue for uncertainty assessment*, Report n. NWS-E-2004-37. Copernicus Institute & RIVM: Utrecht/Bilthoven, 2004.

Van der Veen A., *Economic hotspots: Visualizing Vulnerability to Flooding*, 2004. Available at: http://www.iemss.org/iemss2004/pdf/keynotes/Keynote_Vanderveen.pdf

Van der Veen A., Vetere Arellano A.L., Nordvik J.-P., *In Search of a Common Methodology for Damage Estimation*, Office for Official Publications of the European Communities, Brussels, Joint NEDIES and University of Twente Workshop, Report EUR 20997 EN, 2003.

Van Vuuren D.P., O'Neill B., *The consistency of IPCC's SRES scenarios to recent literature and recent projections.* Climatic Change (in press), online DOI:10.1007/s10584-005-9031-0, 2006.

Van Wagner C.E., Development and structure of the Canadian Forest Fire Weather Index System. Canadian Forestry Service, Ottawa, Ontario. *Forestry Technical Report* 35, 1987, 37 p.

Verburg P.H., Schulp C.J.E., Witte N., Veldkamp A., "Downscaling of land use change scenarios to assess the dynamics of European landscapes." *Agricolture, Ecosystems and Environment* 11: 39–56, 2006.

Vermeer M., Rahmstorf S., "Global sea level linked to global temperature". *PNAS* 106(51): 21527–21532, 2009.

Walker G.P., "Siting nuclear new build", in Dorfman P. (ed.) *Nuclear consultation: Public trust in government.* nuclearconsult.com with The Joesph Rowntree Charitable Trust, UK, 2008.

Walker G.P., Burningham K., Fielding J., Smith G., Thrush D., *Addressing Environmental Inequalities: Flood Risk.* Environment Agency: Bristol, UK, 2006.

Watson R.T., The Core Writing Team (eds.), *Climate Change 2001: Synthesis Report.* Cambridge University Press: Cambridge, 2001, 396pp.

WBGU, *The Future Oceans – Warming Up, Rising High, Turning Sour.* German Advisory Council on Global Change to the Federal Government (WBGU): Berlin, 2006, 110 pp., ISBN 3-936191-14-X

WBGU, *World in transition – towards a sustainable energy system.* Earthscan: London, UK, 2004.

Weicheselgartner J., Obersteiner M., "Knowing sufficient and applying more: challenges in hazard management." *Environemtnal Hazards* 4: 73–77, 2002.

Wen Y., Ellingwood B., Veneziano D., Bracci J., *Uncertainty modelling in earthquake engineering*, MAE Centre Project FD-2 report, February 2003.

Wenisch A., Meissner M., *PLEX: Information around plant lifetime extension in the nuclear industry.* Austrian Institute of Ecology: Vienna, 2007.

White G.F., *"Floodplain Adjustment and Regulations, Handbook of Applied Hydrology",* Section 25-V, Ven Ta Chow, Editor. McGraw-Hill: New York, 1964.

White G.F., *Human Adjustment to Floods.* PhD thesis, University of Chicago, 1945.

White G.F., Kates R. and Burton I., "Knowing better and losing even more: the use of knowledge in hazard management." *Environmental Hazards* 3(3): 81–92, 2001.

Wilby R.L., Dawson C.W., Barrow E.M., "SDSM: a decision support tool for the assessment of regional climate change impacts." Environmental Modelling & Software 17: 147–159, 2002.

Williams E.R., "Lightning and climate: A review." *Atmospheric Research* 76(1–4): 272–287, 2005.

Wisner B., Blaikie P., Cannon T., Davis I., *At Risk. Second Edition. Natural hazards, people's vulnerability and disasters.* Routledge: London, 2004.

Xue W., Luo Q., Ni L., "Systems Support for Pervasive Query Processing," Proceedings of the 25th IEEE International Conference on Distributed Computing Systems (ICDCS'05)-Volume 00, pp. 135–144, 2005.

Yan Z., Jones P.D., Davies T.D. et al. "Trends of extreme temperatures in Europe and China based on daily observations." *Climatic Change* 53(1–3): 355–392, 2002.

Yates A., *The nexus between regulation enforcement and catastrophic engineering failures*, Paper presentato alla conferenza: "Current issues in regulation: enforcement and compliance conference", Melbourne, 2–3 Settembre, 2002.

Yohe G.W., Tol R.S.J., "Indicators for social and economic coping capacity - moving towards a working definition of adaptive capacity". *Global Environmental Change* 12 (1): 25–40, 2002.

Zimmerli P., *Hailstorm in Europe. A new look at familiar risk.* Swiss Re publication, 2005. Available at: http://www.swissre.com

Legislations

UK Government- Secretary of State for Environment, Food and Rural Affairs. *Securing the future: delivering UK sustainable development strategy* (March 2005) Available at: http://www.sustainable-development.gov.uk/publications/uk-strategy/index.htm (last link on 31 January 2008)

UK Government- Secretary of State for Environment, Food and Rural Affairs. Climate Change: The UK Program 2006 (March 2006). Available at: http://www.defra.gov.uk/ENVIRONMENT/climatechange/uk/ukccp/index.htm

UK Government – Communities and local government. *Planning Policy Statement 25 (PPS 25): "Development and flood risk"* (December 2006). Available at: http://www.communities.gov.uk/publications/planningandbuilding/pps25flood risk (last link on 31 January 2008)

UK Government – Communities and local government. *Planning Policy Statement: "Planning and Climate Change"* (December 2007). Available at: http://

www.communities.gov.uk/publications/planningandbuilding/ppsclimatechange (last link on 31 January 2008)

UK Civil Contingencies Secretariat. *Civil Contingencies Act 2004: a short guide (revised).* Available at: http://www.ukresilience.info/preparedness/ccact.aspx (last link on 31 January 2008)

Hellenic Republic- Ministry For The Environment, Physical Planning And Public Works. *National strategy for sustainable development – executive summary.* (May 2002) Available at: http://www.minenv.gr/4/41/e4100.html (last link on 31 January 2008)

Hellenic Republic- Ministry For The Environment, Physical Planning And Public Works. *National reporting to the twelfth session of the commission on sustainable development of the united nations.* (March 2004). Available at: www.minenv.gr/4/41/000/csd12_final%20edition.pdf (last link on 31 January 2008)

Spanish Legilsation: Law 62/2003 – Art. 129. Available at: http://www.mma.es/portal/secciones/acm/aguas_continent_zonas_asoc/planificacion_hidrologica/MarcoNormativo.htm (last link on 6 February 2008)

Spanish Forest Law No. 43 of 2003 Available at: http://noticias.juridicas.com/base_datos/Admin/l43-2003.html (last link on 8 February 2008)

Spanish Legilsation: *Ley de Suelo* (May, 2007). Available at: http://www.vivienda.es (last link on 11 February 2008)

Spanish Legilsation: Plan Nacional de Adaptación al Cambio Climático. Available at: www.mma.es (last link on 11 February 2008)

German National Forest Program. Available at: http://www.bmelv.de (last link on 11 February 2008)

Lütkes S., Holzfuß H. (Editors), *ICZM, Integrated Coastal Zone Management in Germany, Assessment and steps towards a national ICZM strategy* (March, 2006). Available at: http://ec.europa.eu/environment/iczm/evaluation/iczm_national_reporting_germany.htm (last link on 11 February 2008)

Seventh Amendment of the German Federal Water Act (2002) Available at: http://www.bmu.de/english/water_management/downloads/doc/20201.php (last link on 11 February 2008)

The German *National Climate Protection Program 2005.* Available at: http://www.bmu.de/english/climate/downloads/doc/35833.php (last link on 11 February 2008)

Italian law 183/89: *Norme per il riassetto organizzativo e funzionale della difesa del suolo.* Available at: http://www.protezionecivile.it/legislazione (last link on 11 February 2008)

Italian Law 225/92. Available at: http://www.protezionecivile.it/legislazione (last link on 11 February 2008)

Italian Legislation. *Legislative decree 112/98.* Available at: http://www.protezione civile.it/legislazione (last link on 11 February 2008)

Italian Law 353/2000: *Legge quadro in materia di incendi boschivi.* Available at: http://www.protezionecivile.it/legislazione (last link on 11 February 2008)

Italian Legislation. *Prime Minister decree, 20 December 2001.* Available at: http://www.protezionecivile.it/legislazione (last link on 11 February 2008)

World Wide Web

UK Office of Public Sector Information website
http://www.opsi.gov.uk

UK Department for Environment, Food and Rural Affairst website:
http://www.defra.gov.uk/

UK Environment Agency website:
http://www.environment-agency.gov.uk/

UK Resilience Website:
http://www.ukresilience.info/

UK Government sustainable development website:
http://www.sustainable-development.gov.uk/

Hellenic Ministry for the Environment website:
http://www.minenv.gr/

Civil protection website (Greece)
http://www.civilprotection.gr/

France legislation website:
http://www.legifrance.gouv.fr/

European Space Agency (earth observation section) website:
http://earth.esa.int/

European Union-Environment Commission website:
http://ec.europa.eu/environment/index_en.htm

Bavarian State Ministry of the Environment, Public Health and Consumer Protection website:
http://www.stmugv.bayern.de

German Federal Ministry of Food, Agriculture and Forestry website:
http://www.bmelv.de

The Spanish General Directorate for Civil Protection website:
http://www.proteccioncivil.org/

Spanish *Ministerio de Medio Ambiente* website:
http://www.mma.es

NOFDP "nature-oriented flood damage prevention" project website:
http://nofdp.bafg.de

Italian Civil Protection website:
http://www.protezionecivile.it

Italian Environment Ministry website
http://www.minambiente.it

Avalanche risk assessment – a multi-temporal approach, results from Galtür, Austria
http://www.nat-hazards-earth-syst-sci.net/6/637/2006/nhess-6-637-2006.pdf

Istanbul Metropolitan Municipality
http://www.ibb.gov.tr

The Italian Agency for Environmental Protection and Technical Services (APAT) website
http://www.apat.gov.it

The Italian Istituto Nazionale di Geofisica e Vulcanologia website:
http://www.ingv.it

Regione Campania website:
http://www.regione.campania.it

Event reports on the RTE website:
http://www.rte.ie/news

SCALING (2005): Online:
http://www.pik-potsdam.de/skalenanalyse/index.html

List of Abbreviations

A

ABI	Association of British Insurers
ADRC	Asian Disaster Reduction Centre
AKOM	Coordination Center for Disasters
APAT	Agenzia per la protezione dell'ambiante e per I servizi tecnici (Italian Environmental Agency, recently given the new name of ISPRA: Istituto Superiore per la Protezione e la Ricerca Ambientale)
AR4	Fourth Assessment Report
ATSR	Along Track Scanning Radiometer
AVI	Aree Vulnerate Italiane

B

BUI	Build Up Index

C

CARG	Geologic and geothematic cartography
CatNat	Catastrophe Risques naturals
CEA	Comité Européenne des Assurence
CECIS	Common Emergency and Information System
CEDIM	Center for Disaster Management and Risk Reduction Technology
CFSP	Common Foreign and Security Policy
CI	Critical Infrastructure
CIS	Commenwealth of Independant States
CLIMBER	CLIMate and BiosphERe model
CRED	Centre for Research on the Epidemiology of Disasters
Credoc-Ifen	Centre de recherché pour l'étude et l'observation des condition de vie
CORINE	Coordination of Information on the Environment

D

DC	Drought Code
DEWS	Distant Early Warning System
DFID	Department for International Development (UK)
DFO	Dartmouth Flood Observatory
DFV	Design Flood Value
DIPECHO	Disaster Preparedness ECHO
DINAS COAST	Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise
DISNO	Code used within the EM-DAT database to identify events: stands for unique DISaster Number
DIVA	Dynamical Interactive Vulnerability Assessment
DMC	Duff Moisture Code

E

EA	Environment Agency
EAFRD	European Agricultural Fund for Rural Development
EC	European Commission
EC8	Eurocode 8
ECCP	European Climate Change Program
ECHO	European Commission Humanitarian Aid Office
ECLAC	Economic Commission for Latin America and the Caribbean
ECMWF	European Centre for Medium-Range Weather Forecast
ECTA	European Competitive Telecommunications Association
EEA	European Environmental Agency
EFAS	European Flood Alert System
EFFIS	European Forest Fire Information System
EMCC	European Monitoring Centre for Change
EM-DAT	International Disaster Database
EMISs	Emergency Management Information Systems
EOCs	Emergency Operation Centers
EPCIP	European Policy on Critical Infrastructure Protection
EPICA	European Project for Ice Coring in Antarctica
ESPON	European Observation Network, Territorial Development and Cohesion
ESTOFEX	European Storm Forecast Experiment
ERDF	European Regional Development Fund
EU	European Union
EUROSION	Coastal erosion management practices in Europe
EUSF	European Union Solidarity Fund

F

FAO	Food and Agriculture Organization of the United Nations
FFMC	Fine Fuel Moisture Code

FORESIGHT	Frequent Observation-driven Realistic Evaluation and Simulation of Interaction of Geophysical Hazard Triggers, FP6 EU funded project
FP5	Framework Program 5
FP6	Framework Program 6
FWI	Fire Line Intensity

G

GAC	German Aerospace Centre
GALAHAD	Advanced Remote Monitoring Techniques for Glaciers, Avalanches and Landslides Hazard Mitigation, EU funded project
GCM	Atmospheric-Ocean General Circulation Models
GDACS	Global Disaster Alert and Coordination System
GDP	Gross Domestic Product
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse gas emissions
GIS	Geographic Information System
GISCO	Geographic Information System of the European Commission
GITEWS	German Indonesian Tsunami Early Warning System
GLACIORISK	Survey and prevention of extreme glaciological hazards in European mountainous regions
GMES	Global Monitoring for Environment and Security
GRACE	Gravity-measuring satellite
GRIP	Global Risk Identification Program
GSHAP	Global Seismic Hazard Assessment Program

H

HIRHAM	a regional climate model
HMG	Her Majesty's Government
HSE	Health and Safety Executive

I

IA	Integrated assessment
ICT	Information and communication technologies
IDNDR	International Decade for Natural Disaster Reduction
IEMP	Istanbul Earthquake Master Plan
IFFI	Inventario dei Fenomeni Franosi in Italia – Italian Landslide Inventory
IFRC	International Federation of Red Cross and Red Crescent Societies
IIASA	International Institute for Applied Systems Analysis
IGM	Istanbul Greater Municipality
IMAGE	Integrated Model to Assess the Global Environment, developed to explore the long-term dynamics of global change

	as the result of interacting demographic, technological, economic, social, cultural and political factors.
IMD	Aggregated Indices of Multiple Deprivation
INSPIRE	Infrastructure for Spatial Information in Europe
INGV	Italian National Institute of Geophysics and Volcanology
INTERREG	Interregional – A Community initiative which aims to stimulate interregional cooperation in the EU. It is financed under the European Regional Development Fund
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
IPCU	Istanbul Project Coordination Unit
IRI	International Research Institute for Climate Prediction
ISI	Initial Spread Index
ISTAT	L'Istituto nazionale di statistica è un ente di ricerca pubblico

J

JICA	Japan International Cooperation Agency
JRC	Joint Research Centre

L

La Red	Red de estudios sociales Prevención de desastres en America Latina
LISFLOOD	GIS-based hydrological rainfall-runoff-routing model
LNG	Liquid Natural Gas

M

MARS	Major Accident Reporting System
MEDIGRID	Mediterranean Grid of Multi-Risk Data and Models
MHIDAS	Major Hazard Incident Data Service
MIC	Monitoring and Information Centre
Munich	Re Munich Reinsurance Company

N

NAF	North Anatolian Fault
Na-Tech	Natural hazards triggering technological Disasters
NAO	National Audit Office
NEDIES	Lessons Learnt from Natural Disasters
NFIB	National Flood Insurance Program
NRC	National Research Council

O

OASIS	Open advanced systems for disaster & emergency management
OCHA	United Nations Office for the Coordination of Humanitarian Affairs

ODPM	Office of the Deputy Prime Minister
OECD	Organization for Economic Cooperation and Development
OFDA/EU	Office of Foreign Disaster Assistance/European Union
ORCHESTRA	Open Architecture and Spatial Data Infrastructure for Risk Management
OSP	Operative Strategic Plan
OST	L'Observatoire des Sciences et des Techniques
OTE	Hellenic Organization of Telecommunications

P

PAI	Piano per l'Assetto Idrogeologico: River Basin Plans (in Italian)
PELCOM	Pan European Land Cover Monitoring
PGA	Peak Ground Acceleration
PIAC	Principal International Alert Centre
PPS25	Planning Policy Statement 25
PRA	Probabilistic risk assessment
PRUDENCE	Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects

R

RETINA	Relevant Transformation of the Inputs Network Approach
RINAMED	Risques naturels en Méditerranée
RMS	Risk Management Solution
RTD	Research and Technological Development

S

SAFER	Seismic Early Warning for Europe
SCAI	Study of inhabited Centers
SFRA	Strategic flood risk assessment
SICI	Sistema Informativo sulle Catastrofi Idrogeologiche
SLR	Sea Level Rise
SOA	Super Output Areas
SRES	Special Report on Emissions Scenarios
Swiss Re	Swiss Reinsurance Company
SWOT	Strengths, Weaknesses, Opportunity and Threats

T

TEMRAP	
TCIP	Insurance against Natural Hazards
TEN-T	Trans-European Network Transport
TPG	Transnational project groups
TSR	Tropical Storm Risk

U

UNCHS	United Nations Centre for Human Settlement
UNDP	United Nations Development Program
UNDRO	United Nations Disaster Relief Coordinator
UNEP	United Nations Environment program
UNESCAP	United Nations Economic and Social Commission for Asia
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN/ISDR	United Nations International strategy for disaster reduction

V

VEI	Volcanic Explosivity Index

W

WARMER	Water Risk Management in Europe
WBGU	German Advisory Council on Global Change
WFD	Water Framework Directive
WFP	United Nations World Food Program
WIN	Wide Information Network for Risk Management Integrated Project

Index