Measuring vulnerability to natural hazards

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Measuring vulnerability to natural hazards: Towards disaster resilient societies (second edition)

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Endorsements

"*Measuring Vulnerability to Natural Hazards* quickly established itself as essential reading for all who study or manage disaster risk. Birkmann and his colleagues have made sense of a complex and subtle problem, and one that is central to the promotion of resilience."

David Alexander, Professor of Risk and Disaster Reduction, Institute for Risk and Disaster Reduction, University College London, and Editor of *Disasters* and *International Journal of Disaster Risk Reduction*

"Jörn Birkmann is to be congratulated: he has assembled a coherent volume that does much more than report on the state of thinking and implementing vulnerability assessments worldwide – it goes inside assessment tools to critically examine their frames, methods, language and assumptions. This book should be the regular companion for all those whose work demands knowledge of vulnerability."

John Handmer, Geographer, Professor and Director of the Centre for Risk and Community Safety, RMIT University, Melbourne

"This completely revised book on measuring vulnerability to natural hazards, edited by Jörn Birkmann who has brought together more than 30 authors working in this field, is an excellent and very positive addition to the scientific literature on disaster risk reduction. The strategic connections with climate change adaptation are very timely and comprehensive.

The focus on vulnerability and its assessment makes it highly relevant to scholars and also towards the development of strategic policy."

Gordon McBean, President Elect of the International Council for Science (ICSU) and Professor of Political Science and Geography, Institute for Catastrophic Loss Reduction, University of Western Ontario

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Foreword

David M. Malone

The links between poverty, environmental degradation, disaster risk and socio-economic development pathways have been a subject of discussion since the 1970s. However, scientific as well as political discourse often progressed independently in each of the topics. Understanding disaster risks and disaster impacts due to natural hazards and extreme events has come a long way since the first major initiative, the United Nations International Decade for Natural Disaster Reduction (IDNDR) in the 1990s.

While the first phase of the discourse around disaster risk reduction focused heavily on management of the physical phenomena (floods, droughts, storms, earthquakes), the second and ongoing phase has emphasized the social context of disaster risk in order to understand why similar hazards can lead to very different impacts and human harm, loss and destruction. Particularly after the World Conference for Disaster Risk Reduction in Kobe 2005 more attention is being paid to understanding the complexity of disaster risk – including the phenomena of exposure and vulnerability.

Research shows that disaster risks will have a considerable impact on sustainable development options, particularly for the most vulnerable groups and countries. This nexus is increasingly receiving attention in international politics and by decision-makers at various levels. As a consequence, Disaster Risk Reduction (DRR) is being integrated in other policy discourses, such as sustainable development and climate change.

For example, DRR became one of the emerging issues at the Rio+ 20 Conference on Sustainable Development in 2012.

In the ongoing climate change negotiations – particularly after the Cancun Climate Change Conference of the Parties (COP 16) in 2010 – scientists and policymakers are developing mechanisms and institutional arrangements for addressing loss and damage in the context of climate change. The work programme of UNFCCC – the United Nations Framework Convention on Climate Change – is an indication that current, and particularly future, risks of loss and damage due to climate change have to be addressed more systematically and rigorously.

Furthermore, the Hyogo Framework for Action 2005–2015 underscores the need for countries to improve their response capacity and preparedness for disaster risks. A comparison of international funding in the area of DRR shows that some countries and donors still focus predominantly on improving response capacities and emergency management, giving insufficient attention to reducing the underlying factors of disaster risk and vulnerability in particular. Identifying, measuring and assessing vulnerability in a comprehensive sense is therefore a core challenge for policy relevant research and a prerequisite for effective risk reduction and climate change adaptation strategies.

I am pleased to see that this second edition of *Measuring Vulnerability to Natural Hazards*, includes contributions from more than 30 experts from around the world who discuss a range of approaches, methods and concrete case studies for assessing vulnerability to natural hazards and climate change. The volume presents an important step forward in the advancement and dissemination of knowledge regarding the assessment of vulnerability, risk and resilience related to natural hazards and extreme events.

This edition – with many new chapters and new findings – is very timely and provides important contributions to the scientific discourse, but is equally valuable for decision-makers and policy processes. As such, the volume can support the discussions around the Post-Hyogo Framework, the Rio+20 process and post-Kyoto Protocol.

The present volume is an output of the ongoing work of the Expert Working Group on Measuring Vulnerability established and organized by UNU-EHS. Several of the approaches discussed in the book, such as the WorldRiskIndex, the Indicator System in the Americas or the Social Vulnerability Index, have achieved a high recognition in the media as well as with policymakers.

I wish to thank the contributing authors, the editor – Jörn Birkmann – and the team at UNU-EHS for putting together and publishing such an important volume. I am confident the book will serve students and scholars, as well as visionary practitioners and policymakers, in addressing not just the symptoms but also the determinants and drivers of risk.

David M. Malone
Rector of the United Nations University (UNU)
Under-Secretary-General of the United Nations

Preface

R. K. Pachauri

Measuring and assessing vulnerability to climate change and extreme events is essential for promoting risk reduction and sustainable adaptation strategies. The 2012 Special Report, *Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) by the Intergovernmental Panel on Climate Change (IPCC) maintains that a changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events and can result in unprecedented extremes of the latter. It also assesses how socio-economic development, natural climate variations and human caused climate changes influence climate- and weather-related disaster risk. Extreme weather and climate events contribute to risk and may even result in disasters possibly similar to the floods in Pakistan in 2010 or the European heat wave in 2003. However, the character and severity of impacts from climate extremes depend not only on the extremes themselves but also on exposure and vulnerability. That means risks and impacts on human, ecological or physical systems can result from the interaction between weather or climate events and different levels of exposure and vulnerability, as the IPCC SREX report correctly points out.

For example, in India drought risk is increasing significantly in certain regions: Maharashtra, for instance, will be experiencing the impacts of a series of recurring droughts. Whether these will cause disasters or will pose major risks to the people can only be determined after the vulnerability of the communities exposed to the droughts has been assessed. Hence, there is no one-size-fits-all relationship between extreme events and disaster risk. A prerequisite for sustainability in the context of climate change is the need to address the underlying causes of vulnerability, including the structural inequalities that create and sustain poverty and constrain access to resources. Where vulnerability is high and adaptive capacity is low, changes in climate extremes can make it difficult for systems to adapt without transformational changes. Actions ranging from incremental steps to transformational changes are essential for reducing risk from climate extremes.

Farmers in India have developed a variety of different strategies for coping with and adapting to droughts. Consequently, assessing vulnerability does not solely imply capturing the people's vulnerability but also assessing their resources and the knowledge they have developed to deal with such phenomena. Hence, integration of local knowledge with additional scientific and technical knowledge, as provided by the IPCC reports and academic books such as this one, can improve disaster risk reduction and climate change adaptation.

Interestingly, non-extreme as well as extreme events can create crisis situations if people are not prepared or have limited means for coping and adapting. In India non-extreme weather events such as recurrent small or medium-scale droughts or floods can lead to severe disruptions or erosion of livelihoods and hence often increased vulnerability. In addition, economic, social, geographic, demographic, cultural, institutional, governance and environmental factors can all be implicated in determining whether extreme or non-extreme climate events will trigger crises or disasters. When assessing the vulnerability, coping and adaptative capacity of societies and communities, a holistic approach is therefore necessary for understanding and managing such risks.

This book provides important insights into ways to measure and assess vulnerability. Examples provided by different authors also suggest that crises may actually trigger learning processes. Indeed, post-disaster recovery and reconstruction provide an opportunity for reducing weather- and climate-related disaster risk and for improving adaptive capacity. While, for example, tropical cyclones caused major damage in Bangladesh in the past, the development of early warning systems and the construction of special shelters and evacuation sites have significantly increased human security and reduced vulnerability, even though the cyclones have not necessarily become less intensive or severe, and even considering that they are likely to affect more people as a result of growing coastal populations. Understanding vulnerability, therefore, is not merely for academics but is an important element for improving the management of risks due to extreme events in a rapidly changing world.

The United Nations University Institute for Environment and Human Security took the initiative to invite leading scholars and practitioners to discuss the state of measuring vulnerability in order to devise new research into capturing vulnerability at different aggregate levels of society. This volume is an essential summary of this work. It presents various methodologies – from global indexing projects to local participatory self-assessment approaches. Through a review of existing approaches, the book demonstrates that "measuring the unmeasurable" (vulnerability) is needed, leaving no doubt that there is still a long way to go from concepts, criteria and indicators to a full practical implimentation of anticipative vulnerability assessment and its application in policy processes. However, the book also reveals the progress and the various approaches to measuring vulnerability that have been developed in the last few years. Providing important insights into different concepts and methods, it is timely and essential reading for students and academics, and for practitioners as well as decision-makers who aim to reduce the vulnerability of people and societies exposed to extreme and non-extreme events.

R. K. Pachauri
Chairman of the Intergovernmental Panel on Climate Change (IPCC)
and Director-General of the Energy and Resources Institute (TERI)

Preface

Sálvano Briceño

The disaster in Haiti in 2010 triggered by an earthquake causing more than 230,000 deaths, the floods in Pakistan that devastated a whole country the same year, the complex crises in Somalia also linked to droughts and the impacts of Hurricane Katrina in 2005 and Hurricane Sandy in 2012 in the United States are shattering reminders of how people's lives and property can be swept away in a matter of minutes. The colossal loss of livelihoods and infrastructure are not, however, primarily the result of the physical event (for example, flood, earthquake, storm) but are determined by the various vulnerabilities of people, communities or countries exposed to such phenomena. The different vulnerabilities revealed through such crises and disasters are also an expression of the long-term failure of development processes and specific modernization pathways in countries that make it more likely that extreme events and other natural hazards can turn into disasters. The combined impact of the earthquake and tsunami in Japan in March 2011 that triggered a cascade of additional threats, particularly due to the failure within a nuclear power plant, underscored again the linkages between specific modernization pathways and development processes and disaster risk – even in so-called highly developed countries.

Overall, the human losses due to vulnerability to natural hazards are still much higher in developing and, particularly, in least-developed countries than in developed countries. While in January 2010 an earthquake in Haiti with a moment magnitude of 7 caused approximately

230,000 fatalities, a nearly similar event – in February 2011 an earthquake in New Zealand with a moment magnitude of 6,3 – caused approximately 187 fatalities. Even in Chile, also a developing country but with greater risk awareness, only 525 people died after a magnitude 8.8 earthquake. These differences cannot be explained sufficiently by the physical event (earthquake); rather, the different levels of vulnerability are key factors that account for the different levels of impact. Consequently, assessing vulnerability and adaptive capacities of people and countries at risk before and after disasters remains a key task and a prerequisite for effective risk reduction and adaptation.

The *IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) points in a similar direction. Although it recognizes that climate-related extreme events contribute to a disaster, it also clearly shows that the magnitude and impact of the disaster depends mainly on specific human, social, economic, institutional and environmental factors and conditions that make exposed communities vulnerable to natural hazards and therefore at risk (see IPCC 2012).

The current widespread disregard for disaster risks, in particular the vulnerabilities to natural hazards and climate change, presents an extraordinary challenge to communities and nations in their efforts to move closer to Millennium Development Goals and to further sustainable development. Now is the time to realize that we are far from powerless: communities and nations can build their resilience to disasters by investing in proactive measures to reduce risk and vulnerability. Disaster risk reduction is essential to meet global challenges, in particular to eradicate poverty and achieve sustainable development. Disaster risk concerns every person, every community and every nation. Indeed, disaster impacts are slowing development, and in an increasingly globalized world, disasters in one region have an impact on risks in another, as may be seen in the case of the long-distance repercussions of the floods in Bangkok or the Fukushima disaster. Without addressing the urgent need to reduce disaster risk and particularly vulnerability in an appropriate manner, the world simply cannot hope to move forward in its quest for eliminating poverty and achieving sustainable development.

The Hyogo Framework for Action (2005–2015): Building the Resilience of Nations and Communities to Disasters carries a strong commitment for governments and regional, international and non-governmental organizations. The Hyogo Framework will soon expire and discussions are underway for a successor agreement which will need to go beyond the original. It will need to provide more specific guidance to ensure greater effectiveness in translating the hopeful expectations of the Hyogo Framework into practical measures at international, regional, national and community levels – and into tangible activities to reduce risk and vulnerability to natural hazards. The new agreement should also provide specific benchmarks or targets and indicators by which progress in disaster reduction can be measured and their effectiveness assessed.

In particular, collaboration and team work within and between different scientific communities needs to be strengthened in order to ensure that both people at risk and decision-makers can base their actions on sound information. Most crises and disasters in the context of natural hazards and climate change manifest themselves at the local level. However, many aspects of vulnerability and the respective drivers of disaster risk go far beyond the local level and therefore also require international approaches. In this regard, a more systematic approach towards the identification of vulnerability and the root causes of disaster risk, as well as the evaluation of appropriate strategies to reduce risk, is needed. This development has to be facilitated by academic networks such as the network on "Integrated Research on Disaster Risk" (IRDR). Linking different experts and developing methodologies, such as FORIN, for investigating disaster risks and examining the various root causes and factors that contributed to past disasters are core goals of IRDR.

In this context, I am very pleased to support the work of the UNU-EHS through its Expert Working Group on Measuring Vulnerability. This second edition of *Measuring Vulnerability to Natural Hazards – Towards Disaster Resilient Societies* is an indicator of the need to provide a systematic overview of different concepts and assessment approaches that allow for translating abstract terms such as "vulnerability" and "resilience" into practical policy and technical applications. Understanding disaster risks induced by vulnerability to natural hazards is a precondition for the implementation of effective disaster reduction strategies and programmes at all levels. The scientific exchange of different concepts and methods on how to assess the dynamic and multifaceted nature of vulnerability is a pressing challenge. Hence, the UNU-EHS Expert Working Group with its annual meetings that bring together experts on this topic from around the globe is a valuable contribution to the implementation of the Hyogo Framework, itself an essential requirement for sustainable development. A closer collaboration between the UNU-EHS Expert Working Group on Measuring Vulnerability and the Integrated Research on Disaster Risk programme would greatly facilitate more effective support and advice to governments and other actors pursuing risk reduction objectives.

I look forward to increased collaboration between UNU-EHS and the IRDR.

Sálvano Briceño

Former Chair and current Vice-Chair, Science Committee, Integrated Research on Disaster Risk (IRDR) programme of ICSU/ISSC/UNISDR and former Director, Secretariat of the UN International Strategy for Disaster Reduction (UNISDR)

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Of course, putting this book together would not have been possible without the immense amount of behind-the-scenes and often unnoticed work done by the production team. Therefore, I am extremely grateful to the Rector of the United Nations University (UNU), David M. Malone, and the Vice Rector in Europe of UNU and Director of the Institute for Environment and Human Security (UNU-EHS), Jakob Rhyner, for their continued support for the production of this second edition of *Measuring Vulnerability to Natural Hazards*.

Moreover, I would like to express my deep gratitude to all the contributing authors from Africa, Asia, Latin America, North America, South East Asia and Europe who often had to respond to many remarks and requests under the constraints of tight deadlines.

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My sincere words of thanks also go to Prof. Jakob Rhyner for his compelling introduction and to Prof. Rajendra K. Pachauri, Chairman of the Intergovernmental Panel on Climate Change (IPCC) and Director-General of the Energy and Resources Institute (TERI), and last but not least especially Sálvano Briceño, former Director of the Secretariat of the UN International Strategy for Disaster Reduction (UNISDR) for their remarkably fitting prefaces.

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I am also very grateful for the positive and critical feedback received by readers of the first edition – particularly scholars and practitioners around the world – which provided important incentives to produce a second edition. In this regard I wish to also thank again those who helped me to develop the first edition of *Measuring Vulnerability*, particularly Prof. Janos Bogardi, who continuously supported the book project and the UNU-EHS Expert Working Group on Measuring Vulnerability.

Finally, I would like to thank my wife and my two daughters for their continuous support.

Jörn Birkmann
Bonn/Aachen, Germany
3 April 2013

Abbreviations

BBC	approach to vulnerability analysis that goes beyond assessment of deficiencies and impacts, and views vulnerability in the context of a dynamic process. See discussion by Birkmann, Chapter 1, section on "the BBC conceptual framework".
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe [German Federal Institute for Geosciences and Natural Resources]
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung [German Federal Ministry for Economic Cooperation and Development]
CATSIM	IIASA catastrophe simulator
CBDM	community-based disaster management
CBDRM	community-based disaster risk management
CCA	climate change adaptation
CFMS	community-based flood management strategy
CRA	community risk assessment
CRED	Centre for Research on Epidemiology of Disasters
DDI	Disaster Deficit Index
DesInventar	Sistema de Inventario de Desastres [Disaster Inventory System]
DFID	Department for International Development
DPSIR	driving forces – pressure – state – impact – response
DRI	Disaster Risk Index
DRM	disaster risk management
DRR	disaster risk reduction
ECLAC	Economic Commission for Latin America and the Caribbean

EEA	European Environmental Agency
EM-DAT	Emergency Events Data Base
ESPON	European Spatial Planning Observation Network
EWS	early warning systems
FEMA	Federal Emergency Management Agency
FEWS NET	Famine Early Warning Systems Network
GAR	Global Assessment Report on Disaster Risk Reduction (of UN/ISDR)
GDP	gross domestic product
GEO	Global Environmental Outlook (of UNEP)
GHG	greenhouse gas
GIS	geographical information system
GN	"Grama Niladari" subdivision of city, etc., smallest statistical unit in Sri Lanka
GNDR	Global Network of Civil Society for Disaster Reduction
GRA	Global Risk Analysis
GRIP	Global Risk Identification Programme
GSHAP	Global Seismic Hazard Assessment Program
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit [German Technical Cooperation Agency]
GWES	Groundwater for Emergency Situations programme (of UNESCO)
GWP	IPCC Global Warming Potential
HFA	Hyogo Framework for Action
HIPCI	Highly Indebted Poor Countries Initiative
HSI	Human Security Index
HVRI	Hazards and Vulnerability Research Institute
IADB or IDB	Inter-American Development Bank
IDEA	Instituto De Estudios Ambientales [Institute of Environmental Studies]
IDNDR	International Decade for Natural Disaster Reduction (1990–1999)
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
LA RED	Red de Estudios Sociales en Prevención de Desastres en América Latina [Network of Social Studies in the Prevention of Disasters in Latin America]
LDI	Local Disaster Index
MA	Millennium Ecosystem Assessment
MCE	maximum considered event
MEA	Multilateral Environmental Agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MOVE	Methods for the Improvement of Vulnerability Assessment in Europe
NAPA	National Adaptation Program of Action
NatCatSERVICE	Munich Re database for natural catastrophes

NCCK	National Christian Council of Kenya
NGI	Norwegian Geotechnical Institute
NGO	non-governmental organization
NIDIS	US National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration
NUTS	nomenclature of territorial units for statistics in the European Union
NSGRP	National Strategy for Growth and Reduction of Poverty (Tanzania)
OECD	Organisation for Economic Co-operation and Development
PAL	probable annual losses
PGRDP	PREVIEW Global Risk Data Platform
PLA	participatory learning activities
PML	probable maximum losses
PREVIEW	Project for Risk Evaluation, Vulnerability, Information and Early Warning
PVI	Prevalent Vulnerability Index
RMI	Risk Management Index
RRA	rapid rural assessment
SDI	Spatial Data Infrastructure
SoVI	Social Vulnerability Index
SRES	Special Report on Emissions Scenarios
SREX	IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
SRTM	Shuttle Radar Topography Mission
UN/ISDR	United Nations International Strategy for Disaster Reduction
UNDP	United Nations Development Programme
UNDP/BCPR	United Nations Development Programme/Bureau for Crisis Prevention and Recovery
UNDRO	United Nations Disaster Relief Co-ordinator
UNEP	United Nations Environment Programme
UNEP-GRID	United Nations Environment Programme-Global Resource Information Database Resource Information Database
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNU	United Nations University
UNU-EHS	United Nations University-Institute for Environment and Human Security
USAID	US Agency for International Development
WCDR	World Conference on Disaster Reduction
WCED	World Commission on Environment and Development
WFP	World Food Programme
WHO	World Health Organization
WRI	World Risk Index
WWDR	World Water Development Report

Introduction

Jakob Rhyner

The nexus between disaster risk due to natural hazards and development has been discussed since the 1980s, but important debates are still appearing in scattered places. The Rio+20 Conference in Rio de Janeiro in 2012 emphasized that disaster risk and sustainable socio-economic development are clearly closely interlinked. To recognize the link between risks involving natural hazards, particularly climate related, and development requires in-depth knowledge about the concept(s) of vulnerability and the different ways to assess it.

The Hyogo Framework for Action, for example, states that the development of indicator systems for disaster risk and vulnerability is required to enable decision-makers to assess the possible impacts of disasters and to strengthen proactive actions for disaster risk reduction. Also within climate change research and climate change adaptation policies, strategies for reducing potential loss and damage are seen as a core topic. In this regard the identification of priority areas for intervention and adaptation strategies requires an improved knowledge base about those regions and people that are likely to face severe harm, loss and disruption of livelihoods when exposed to such hazards and stressors. For all these reasons understanding vulnerability is essential.

While after a disaster, such as Hurricane Katrina, or the major earthquake in Haiti as well as the Tohoku-Fukushima crises, we can retroactively analyse the factors that led to a disaster, we have to critically review the options for proactively assessing the disaster risk; and we need to know whether this knowledge and the methods of assessing such risks

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and vulnerabilities are sufficient for advising parliaments and governments as well as local stakeholders and non-governmental actors.

Although further research and application of vulnerability assessments has advanced significantly during the past two decades, a systematic overview of different methods is still lacking. In addition, scientific discussion about the concept itself is evolving. Initially vulnerability, in the context of natural hazards, was mainly viewed and assessed in terms of loss of life and economic loss, while today environmental or institutional aspects have become increasingly important. Thus, approaches for assessing and measuring vulnerability also have to address these new challenges and the broader understanding of the concept. It is important to join forces to map the scientific issues and challenges involved, to develop, debate and test methods, without losing sight of the mandate and requirements set by the Hyogo Framework of Action or the recent Rio+20 Conference.

This volume, edited by Jörn Birkmann, aims to move the whole agenda forward. It provides an overview of different methods for assessing vulnerability, documenting the efforts being made by the scientific community to address issues well beyond these terminological concerns about what vulnerability means. This volume summarizes the state of the art of measuring vulnerability. Compared to the first edition, this edition also addresses vulnerability to natural hazards and to climate change, building on the new cooperation which has been established, for example, in the context of the IPCC Special Report "Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation". The IPCC SREX report that was jointly developed by experts on natural hazards, the risk research community and experts from the field of climate change and adaptation research emphasized the need to improve the understanding of place-specific patterns of vulnerability and the dynamic changes occurring in vulnerability and risk. This second edition provides various examples of how actual quantitative or qualitative assessments can help to capture the complex phenomena of vulnerability. The methods and selected examples provided by various experts in the different chapters highlight the policy relevance of such methods and findings.

Understanding and communicating

Although vulnerability is already being used in various contexts, broadly understood as a predisposition to be harmed should an extreme event or hazard occur, it is still not sufficiently assessed in a holistic way by various countries or communities. Many policymakers and governments still seem to prioritize the assessment of physical changes and hazards when disasters are likely to occur. However, in the last two decades the international community and various researchers have demonstrated that the concept of vulnerability provides important insights for understanding differential impacts and consequences of societies exposed to natural hazards and climate change.

Hence, vulnerability, once it is properly assessed and preferably quantified, is the crucial feature which could serve to estimate the potential consequences of both rapid onset and/or creeping (natural) hazard events upon the affected entities. Moreover, the assessment of vulnerability and the visualization of certain indicators that represent characteristics of the complex phenomena in maps and figures are also crucial tools for communication. As experience for example, from early warning shows, it is important not only to identify vulnerability and risk but also to develop methods that allow the visualization and communication of such complex phenomena in a way that can be understood by policymakers, non-experts and the general public. The so-called World Risk Index (WRI) serves this purpose, describing the complex interplay between exposition and physical as well as social vulnerability in a simplified indicator-based way. The considerable media attention generated by the WRI and other global indices described in the present volume shows the need for formats suitable for reaching out to policymakers and the general public.

In this context I am confident that vulnerability assessments will become the crucial component of disaster preparedness and adaptation strategies. Assessing and monitoring vulnerability may also be used to identify specific targets for vulnerability and risk reduction. It is not sufficient to declare after a disaster that preventive measures are needed; rather, it will be important to also engage at various governance levels in an in-depth discussion on how to use assessments in a proactive manner. These assessments should become a core element of a "political early-warning" system. Indicators and criteria that can help to translate the abstract concept of vulnerability into information that can be visualized and communicated are an important step towards improving policy and decision-making processes.

Challenges ahead and remaining questions

It seems to be evident that vulnerability assessments are needed. However, can we really capture the multifaceted and dynamic nature of vulnerability? Compared to fatalities and material losses that are clearly visible after a disaster, vulnerability, as the potential to be adversely affected, is a more abstract concept. Capturing it is especially difficult in social contexts, because vulnerabilities of people and their coping or adaptive capacities are to some extent a moving target that is shaped and influenced by various driving forces.

In a broader context, approaches of assessing vulnerability might need to answer the following questions, partly posed in the earlier edition:

- Can vulnerability be measured, and if yes, how?
- Can vulnerability be aggregated to characterize societies' overall susceptibility towards several distinct hazards?
- Can vulnerability and coping capacity be conceived and assessed separately?
- At what aggregation level can vulnerability be defined and measured?
- What are the data sources that allow capturing and assessing vulnerability in different regions of the world?
- How can vulnerability be assessed before actual disasters or crises occur?
- What options do exist to also assess rather qualitative dimensions of vulnerability, such as environmental or institutional vulnerability?
- To what extent can one capture changes in vulnerability due to specific interventions or risk reduction strategies?
- What lessons can be learned from the assessment of vulnerability for policy-making?
- Is vulnerability the flip side of resilience and adaptive capacity or are resilience and adaptive capacities parts of vulnerability and respective response capacities?

Although incomplete, the set of questions above offers a first flavour of the different aspects that need to be considered when dealing with the development of quantitative, semi-quantitative and qualitative assessment methods presented in this second edition, which brings together more than 40 authors from all over the world to discuss a multitude of approaches to answer some of these questions formulated above.

The book includes 5 core sections, with 23 chapters that address various aspects of, and approaches to, measuring vulnerability and resilience. The first chapter deals with the concept of vulnerability and how it differs and overlaps with the concepts of resilience and adaptation. Birkmann introduces different definitions and conceptual frameworks to systematize vulnerability development and provides an overview of the historic development of the discourse from the early hazard research to the newest integrated IPCC Special Report SREX. His second chapter deals with the requirements of vulnerability indicators and also examines the scope and limits of current global disaster databases. Both chapters include links to various approaches presented in the book, thus providing an important framework for the chapters that follow.

The third chapter by Renaud gives insight into the relationship between vulnerability and environmental change as well as environmental degradation. Renaud shows that the environment is not only the cause of various natural hazards but can in turn also be vulnerable to such phenomena. Chapter 4 is by Pulwarty and Verdin, who both work in the USA on issues of drought warning. They stress the importance of accounting for social vulnerability in the context of drought early warning and risk management. Then in Chapter 5, Kok and Jäger examine the linkages between human vulnerability and environmental change by presenting "archetypical patterns of vulnerability to environmental change" that are also used in the flagship publication of UNEP's *Global Environmental Outlook.* Chapters 6 to 14 present concrete approaches to measuring vulnerability at global, national and sub-national levels. Pelling starts in Chapter 6 with a review of global risk index projects that are also presented in-depth in following chapters. Chapter 7 shows a global risk analysis developed by Peduzzi and his team within the context of the "Global Assessment Report on Disaster Risk Reduction", followed by the presentation of the Disaster Risk Hotpots project in Chapter 8 by Maxx Dilley. The last global indexing approach encompasses the WorldRiskIndex that has been developed at UNU-EHS. In Chapter 9 Welle et al. outline its structure and results as well as opportunities and constraints.

Regional and national approaches for assessing risk and vulnerability are contributed by Cardona and Carreño in Chapter 10, which deals with the indicators for the Americas; an approach developed for Europe's regions by Greiving is found in Chapter 11. In addition, this edition of *Measuring Vulnerability* also presents and discusses the Social Vulnerability Index developed by Susan Cutter et al., whose methods and results are documented in Chapter 12. These broader concepts for assessing risk and vulnerability, often from a multihazards perspective, are followed by two approaches that have a more specific focus. Kiunsi and Minoris examine disaster vulnerability, particularly to the droughts in Tanzania in Chapter 13, while Schneiderbauer et al. present an approach for assessing vulnerability to natural hazards and climate change in mountain environments with case studies from the Alps in Chapter 14.

The fourth section introduces local vulnerability assessment methods that enhance the discussion of quantitative global and national approaches towards semi-quantitative and qualitative approaches. In Chapter 15 Bollin and Hidajat describe the community-based risk index, developed in Indonesia, followed in Chapter 16 by a participatory GIS-based assessment of vulnerability at local and district levels in Mozambique by Kienberger. Then, another approach to frame and assess vulnerability is outlined in Chapter 17 by Villagrán de León, who focuses on different sectors that can be vulnerable to natural hazards. Based on the presentation of these rather semi-quantitative assessment approaches, Wisner, in Chapter 18 shows the advantages of a qualitative and participatory self-assessment approach to coping capacities of communities at risk, closing the discussion of local approaches.

The final section deals with institutional capacities, public-sector vulnerability and the dynamics of vulnerability. A method for assessing institutionalized capacities and drawing from intensive field research and practices for dealing with flood risk by Lebel et al. opens this section. Next, in Chapter 20, Hochrainer-Stigler, Mechler and Pflug outline what is meant by public-sector fiscal vulnerability to disasters. They describe the scope and application of the IIASA CATSIMmodel for assessing vulnerability. In Chapter 21 Birkmann et al. present an assessment of changes in vulnerability in the context of resettlement. The contribution highlights the dynamic nature of vulnerability and ways to capture it. These individual approaches demonstrate that vulnerability assessment today encompasses a variety of different methods that can also account for specific challenges, such as institutional vulnerability, or the public-sector fiscal vulnerabilities as part of economic vulnerability.

Finally, against the background of the rich compilation of different approaches for assessing vulnerability presented earlier, Birkmann formulates conclusions on where vulnerability assessment methods and concepts stand and which challenges need further investigations in the future. Thereafter, a glossary of key terms compiled by Marre lists the various definitions of the same terms by different institutions and experts.

It is my pleasure to thank the many contributors to this book, and fellow scientists and practitioners who joined UNU-EHS in its quest to find answers to the question of how to measure the unmeasurable. My particular thanks are also due to Dr Jörn Birkmann, whose enthusiasm and leadership as editor were instrumental in motivating the authors and in bringing their contributions together.

We are at the beginning of a long road. We know, both as scientists and concerned human beings, that we have an obligation to proceed towards better risk preparedness. Recognizing our vulnerabilities is perhaps the first important step. In this context the book provides important insights and is essential reading for all of those who have an interest in translating and assessing the complex concept of vulnerability. Like the first edition, it should become essential reading for researchers, practitioners and students dealing with vulnerability in the context of disaster risk reduction, climate change adaptation and sustainable development.

Part I

Basic principles and theoretical basis

1

Measuring vulnerability to promote disaster-resilient societies and to enhance adaptation: Discussion of conceptual frameworks and definitions

Jörn Birkmann

Introduction

Assessing and measuring vulnerability in the context of natural hazards and climate change requires first and foremost a clear understanding of the concept(s) of vulnerability. This chapter deals with the systematization of different definitions and frameworks used to describe and define vulnerability. In addition, concepts such as resilience, coping and adaptation are revisited.

The concept of vulnerability has emerged as a key topic in development geography, hazard and disaster risk research as well as, in recent years, in the field of climate change science (see Watts and Bohle, 1993; Blaikie et al., 1994; Cutter, 1994; Wisner et al., 2004, Birkmann, 2006a; Füssel and Klein, 2006; Füssel, 2007; Intergovernmental Panel on Climate Change [IPCC], 2012a). It has been discussed and continuously developed over the past four decades; however, the meaning, framing and assessment of vulnerability remains contested terrain. Various scientific communities and stakeholders define vulnerability differently. Despite differences in the interpretation of the concept of vulnerability, it has, however, become an essential element to underscore the importance of social factors and societal structures in the construction of risk and of adaptation options. Furthermore, it also has created important links between different research communities, particularly disaster risk management (DRM), climate change adaptation (CCA), development and resilience research. The IPCC special report "Managing the Risk of

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Extreme Events and Disasters to Advance Climate Change Adaptation" (IPCC, 2012a) is a joint product of the disaster risk research and climate change adaptation communities. It is a good example of how the concept of vulnerability has served as a guiding element to address disaster risk in the context of climate change and climate variability (see IPCC, 2012a, p. 32). The concept of vulnerability stresses the fundamental importance of examining the preconditions and context of societies and communities (for example, different social groups) and elements at risk (for example, buildings, critical infrastructures) to effectively promote risk reduction and climate change adaptation. Hence, it shows that the consequences of natural hazards and extreme events to communities or societies are not merely defined by the magnitude of the event but rather that the conditions within societies and socio-ecological systems strongly determine whether these physical events (for example, floods, droughts, storms etc.) are likely to cause major harm, loss or damage. Despite the fact that the term "vulnerability" is being used differently by various communities and disciplines, it has, however, allowed a strong social science perspective on disaster, natural hazard and climate change adaptation research to be established. Today, identifying, assessing and reducing vulnerability is seen as a key step towards disaster risk reduction, climate change adaptation and resilience building (Hyogo Framework for Action [HFA] in United Nations, 2005; IPCC, 2012a).

This chapter provides a profound analysis of different definitions and concepts of vulnerability, focusing also on the historic development of the vulnerability concept in selected research fields. Particular attention is paid to concepts that have been developed and used in disaster risk management, in climate change science and in development research. Important typologies that help to better differentiate key factors and dimensions of vulnerability are discussed. In this regard, the author argues that vulnerability is differential and dynamic, meaning that vulnerability changes over time and in terms of spatial patterns. This chapter examines linkages and differences between the concepts of vulnerability, risk, resilience, coping and adaptation. In the final part it deals with different frameworks to systematize vulnerability, risk and resilience.

Vulnerability, risk and disasters

Recent disasters reveal that it is not solely the hazard and its magnitude or frequency that determines harm, loss and damage. For example, the tsunami disaster in Japan, in March 2011, was caused by an earthquake with a magnitude of 9.0 Mw (moment magnitude scale) (see US Geologi-

Box 1.1 Differences between the disaster contexts in Haiti and Japan

Overall, the scale of harm and loss in Haiti compared with Japan is better explained by considering the wider social and economic factors and conditions. Haiti is the poorest country in the Western hemisphere with 76 per cent of its population living below the poverty line of $2 per day (Gauthier and Moita, 2011, p. 28). A large proportion of the population in Haiti is highly dependent on revenues in order to be able to afford a minimum of the social safety net. At the same time the country is classified as a fragile and failed state (see Failed State Index, 2011; Fund for Peace, 2012). Hence, the state is unable to fulfil its responsibilities to its citizens. At the same time, individuals are often unwilling to accept the state and a common set of rules (see Gauthier and Moita, 2011). These examples illustrate that people had, due to poverty, limited financial capacities to afford, for example, earthquake robust buildings or capital that would help them to rapidly bounce back to normal conditions after a disaster. In addition, state institutions are weak and are incapable of providing effective disaster response and recovery support. Hence, differential consequences of such hazard events in Haiti and Japan are particularly connected with the development status and development pathway of the country and the preparedness level of societies and communities.

While poverty and state failure are key drivers of vulnerability to natural hazards in Haiti, developed countries such as Japan might also be subject to increased vulnerability as a result of their dependency on exposed technological structures, such as critical infrastructures. This was particularly evident in the cascading disaster in Japan in which an earthquake triggered a tsunami that led, among other things, to a server accident at the Fukushima Daiichi nuclear power plant. This event revealed the vulnerability of so-called developed societies due to their dependency on critical infrastructures that pose additional systemic risks when combined with natural hazards. Similarly, the levee break in New Orleans, in the context of Hurricane Katrina, can be seen as another example. These cascading and systemic risks may increasingly reveal what Beck terms the "risk society" (Beck, 1992), suggesting that societies in developed countries challenge their own security through their modernization processes.

cal Survey, 2012[1]). This event resulted in approximately 20,000 fatalities, widespread destruction and losses and a major failure in an atomic power plant (Simons et al., 2011; Khazai et al., 2011). Comparing this event to the earthquake disaster in Haiti in 2010, which had a magnitude of

7.0 Mw (approximately 100 times weaker than the Tohoku Earthquake in Japan) but resulting in more than 220,000 deaths (see Office for the Coordination of Humanitarian Affairs [OCHA], 2011). These differences raise important questions:

- Why did the earthquake in Haiti, with a significantly lower magnitude, cause many more fatalities compared to the event in Japan?
- Which factors have significantly increased the harm and loss of life in Haiti?
- Can we measure differences in vulnerability and response capacity before such disasters strike societies?

Overall, these examples and questions underscore the notion that disaster risk cannot be sufficiently understood by focusing on the hazard event or climate stressor alone. Instead of defining disasters primarily as physical occurrences, requiring largely technological solutions, disasters and risks are better viewed as a result of the complex interaction between a potentially damaging physical event (for example, floods, droughts, fire, earthquakes) or creeping environmental changes (for example, sea-level rise, salinization) and the vulnerability of a society, its infrastructure, economy, environment and governance system(s), which are determined by human behaviour (Maskrey, 1993; Lavell, 1996; Oliver-Smith, 2004; Kasperson et al., 2005b; Birkmann, 2006a and b, UN/ISDR, 2011; IPCC, 2012a). In this regard, it is also essential to acknowledge that (disaster) risk and disasters are different concepts. While disasters are specific points in time when risk is revealed and harm and loss manifests itself in specific locations, disaster risk represents a continuum and a latent condition that can lead to severe harm and loss (ICSU-LAC, 2010a and b; IPCC, 2012a, p. 69).

The promotion of disaster-resilient societies and of adaptation to climate change requires a paradigm shift, where the primary focus on natural hazards or physical-biogeochemical climate projections and their quantification shifts towards the inclusion and assessment of vulnerability. To achieve this, various vulnerabilities and capacities of societies need to be identified, assessed and ranked.

The emergence of vulnerability concepts in different schools of thought

The concept of vulnerability has emerged from different schools of thought. Most prominent were: (i) geographic development and poverty research; (ii) hazard and disaster risk reduction research; and, more recently in the last two decades, (iii) climate change science and, in particular, the research on adaptation.

Development and poverty research

In the 1970s, research about crises and disasters in the context of droughts in Africa – particularly the Sahel – resulted in a discussion about the root causes of famine and hunger in terms of the "food availability decline" thesis on the one hand and the "food entitlement decline" on the other (see Bohle, 2009, p. 101). The extension of the focus from the availability of food towards the understanding of entitlement rights was particularly supported by the work of Sen (1981), who emphasized that the disruption of entitlement rights and exchange conditions of entitlements are major drivers of food insecurity (see Sen, 1981). This research has been influential in the development of social-science-related concepts of vulnerability in geographic development and poverty research. In 1989, Chambers, who was one of the pioneers in this field, formulated that

> vulnerability (here) refers to exposure to contingencies and stress, and difficulty in coping with them. Vulnerability has thus two sides: an external side of risks, shocks and stress to which an individual or household is subject; and an internal side which is defencelessness meaning a lack of means to cope without damaging loss. (Chambers, 1989, p. 1)

A further enhancement of the concept of vulnerability was later undertaken by Watts and Bohle (1993, p. 46) and Bohle (2001, 2002a and b). Their work stressed that local and historical configurations of poverty, hunger and famine define the space of vulnerability, which is seen as a multilayered and multidimensional social space determined by political, economic and institutional factors. The concepts by Chambers (1989) and by Watts and Bohle (1993) developed from research on destabilization processes in developing countries, linked mainly to drought-induced crises and disasters and thus focusing primarily on slow-onset hazards.

The disaster risk reduction community

The formation of a new school of research on disaster risk reduction goes back to the 1980s. Particularly, the report of the United Nations Disaster Relief Co-ordinator (UNDRO) commission (1980), the research work of Burton et al. (1978) as well as Hewitt (1983), Susman et al. (1983) and the paper in *Nature* by O'Keefe, et al. (1976) were important impulses for the emerging field of social-science-related disaster risk research. The book by Burton et al. (1978), *The Environment as a Hazard,* is also seen as the starting point of so-called hazard research. However, the term "hazard research" might be misleading from the perspective of the newer discourse since it focuses on risks and vulnerabilities and the capacities of societies and communities to deal with different natural phenomena and natural hazards. Hence, most of the research Burton et al. (1978 and 1993) conducted falls into the field of disaster risk research rather than research on physical phenomena and natural hazards per se. Also, Hewitt's work, specifically the book *Interpretations of Calamity* (1983), already emphasized in the 1980s that disaster situations and actual losses, crises and relief as well as rehabilitation processes, cannot be sufficiently explained by focusing solely on the natural hazard (Hewitt, 1983, p. viii). He argued that disaster cannot be understood primarily as extraordinary circumstances that have mainly been brought about by external and unexpected hazards. Rather, disasters and ineffective social responses to risk have to be understood in the context of the "normal" socio-economic order (see in detail Hewitt, 1983). On similar lines, the paper of O'Keefe et al. (1976) in *Nature* called, "Taking the Naturalness out of Natural Disasters" was an important starting point for rethinking the dominant philosophy and interpretation of disasters. The formula used today, that risk has to be seen as a function of hazard and vulnerability:

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

was already embedded in this early work discussed above, although the equation was not used. Today, this equation is a powerful tool which also helps to communicate the necessity to examine and understand vulnerability in more natural science-oriented research groups.

The contributions of Hewitt and O'Keefe et al. were important triggers for a stronger political ecology perspective compared to a rather hazard-oriented human-environmental perspective in risk and disaster research. Although often overlooked, in other regions, for example in Latin America, Europe and Asia, a discourse on the social construction of risk emerged at the same time. For example, an important advancement of vulnerability and disaster risk research emerged from work in Latin America: particularly, the research network "La Red" which dealt with risk and vulnerability to natural hazards since the early 1990s (see for example, Wilches-Chaux, 1989; Lavell, 1992; Cardona, 1993, 2011; Lavell, 1994; Maskrey, 1993, 1998). "La Red" examined different factors and dimensions of vulnerability, such as physical, economic, social and cultural aspects (Wilches-Chaux, 1989; see also overview in Cardona, 2004b).

In the early 1990s the work of Blaikie et al. (1994) – particularly the first edition of the book *At Risk* – became a major reference point for researchers dealing with risk and natural hazards. The first and second editions of *At Risk* underscore the need to assess the progression of vulnerability and to examine dynamic pressures and root causes of vulnerability, such as power relations and ideologies. The work of Blaikie et al. (1994)

and Wisner et al. (2004) was particularly informed by their own research in developing countries and research in the domain of political economy.

A further enhancement of the discourse can be seen in the improved understanding of feedback processes between risk reduction strategies and natural hazards, as well as the multiple dimensions of vulnerability. This work in disaster risk reduction is linked to research on holistic and integrative perspectives on vulnerability (see Cardona, 1999a, 2011; Birkmann, 2006b; Birkmann and Fernando, 2008) as well as on the social-ecological systems perspective, with connections to resilience research (see for example, Turner et al., 2003). A main pillar of the social-ecology school of thought is the critique of the dichotomy of social systems on the one hand and nature or environmental systems on the other. Instead of treating social and natural systems as separate entities, social ecology examines various phenomena within the conceptual frameworks of so-called coupled human-environmental or social-ecological systems (see for example, Bundesministerium für Bildung und Forschung [BMBF] 2004). In this regard the assessment of vulnerability deals particularly with the sensitivity of "human-environmental systems" (see for example, Turner et al., 2003).

Compared to social ecology, political ecology pays more attention to the political and institutional settings on how environmental resources or conflicts over scarce resources are managed. In this sense, political ecology often views the environment as another arena in which conflicts over resources are dealt with, while less emphasis is given to the actual understanding of so-called coupling processes within social-ecological systems.

Today, the field of disaster risk reduction research spans a wide range of contributions and different perspectives that have particularly enriched the research on vulnerability with regard to the identification of different core components of vulnerability and the various dimensions in which vulnerability might be manifested: for example, social, economic, environmental and institutional (see for example, Birkmann et al., 2012; IPCC, 2012a).

In addition, research on vulnerability in the context of natural hazards has also significantly improved the systematic differentiation of key concepts such as hazards, vulnerability, risks and disasters (see for example, ICSU-LAC, 2010a and b). It has enhanced the knowledge of how disasters and disaster response strategies modify the vulnerability patterns of different social groups. Hence, vulnerability is not just a precondition of a society before an event but might also be modified and even increased through different policies or the coping strategies of individuals after a disaster (see for example, Birkmann and Fernando, 2008; Birkmann et al., 2010a). Consequently, social-science-based approaches to vulnerability often combine the analysis of the susceptibility of exposed people and communities with their social, economic and cultural capacities to cope and adapt to physical changes and natural hazards (Hilhorst and Bankoff, 2004, p. 2; Birkmann, 2011a and b). The differentiation of coping and adaptation is, however, rather new and emerged within the cooperation between climate change adaptation science and disaster risk reduction research.

Climate change and climate change adaptation

A third community that gained attention in the last two decades deals with vulnerability to climate change. This research particularly evolved in the frame of the IPCC Working Group II that deals with impacts, adaptation and vulnerability to climatic change (see IPCC, 2012a; Füssel and Klein, 2006). Interestingly, the first reports of the IPCC have primarily focused on the need for reducing greenhouse gas emissions, while the question of adapting to climate change played only a minor role (IPCC, 1990). Adaptation at that time had been seen as a threat for more rigorous reduction strategies of greenhouse gases; consequently, it was neither discussed in detail nor examined in depth. In contrast, the fourth and upcoming fifth IPCC assessment reports demonstrate the importance of adaptation and vulnerability reduction as core pillars of the climate change discourse. For example, the fifth Assessment Report of the IPCC (AR5) encompasses four chapters that deal with different aspects of adaptation (IPCC, 2012b). This is a clear indicator that consensus is building on the need to shift from a pure focus on greenhouse gas mitigation to fostering and addressing adaptation needs in parallel, particularly in countries and for people who are highly vulnerable to climate change and climate variability.

However, the understanding of vulnerability in the climate change adaptation community differs from the definition of the term in DRM or development and poverty research (see for example, Adger, 2006). For example, the fourth IPCC assessment report (AR4) defines vulnerability as the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change – including the character, magnitude and rate of climate change (IPCC, 2007, p. 883). The description and framing of vulnerability in the AR4 is strongly determined by an impact-oriented perspective of vulnerability – i.e., focusing on the direct consequences of climate change on social systems, global biological systems and geophysical systems due to different temperature increases and even includes the magnitude and rate of climate change (see IPCC, 2007, pp. 787–789). A first shift and modification of the vulnerability concept used within the IPCC can be found in the IPCC special report SREX that underscores that vulnerability is considered to be more or less independent of the physical events, meaning that vulnerability should not include the magnitude and rate of climate change but should focus on the social context that makes people and societies prone to facing harm and loss (IPCC, 2012a, p. 33). The IPCC SREX report established an important bridge between the DRM or DRR and the CCA communities, since these communities had previously developed their concepts and work mainly in parallel (see in depth, Birkmann and von Teichman, 2010). Although the report has made a significant contribution to an improved understanding and exchange between the two communities, one still needs to acknowledge the differences between both research communities in terms of spatial, temporal and functional scales in addition to recognizing differences regarding the meaning of similar terms, such as mitigation (see Schipper, 2009; Birkmann and von Teichman, 2010).

Preliminary conclusions regarding different schools of thought

Based on the different schools of thought outlined earlier, it can be concluded that the development of the concept of vulnerability in different research fields (disaster risk management/reduction, development research, resilience research and climate change adaptation research) and schools of thought (political economy, social-ecology, political ecology etc.) has been a process with various perspectives, resulting in different approaches on how to define and assess vulnerability. Despite the fact that various communities still define vulnerability differently, it is important to acknowledge that the concept has been successfully introduced as a response to the purely hazard-oriented perception of disaster risk in the 1970s and in disaster risk management and the natural-science-oriented adaptation discourse in climate change research in the 1990s. Today, a consensus emerges that strategies for risk reduction and adaptation to climate change cannot be solely based on the characterization of physical or environmental changes. Rather, the alternative paradigm of vulnerability can serve as a starting point for identifying priorities. In this regard, the concept of vulnerability constitutes an important pillar in all three research communities, aiding a better understanding of destabilization processes and societal response capacities in the light of climate change, natural hazards and socio-economic changes. The increasing recognition of the importance of vulnerability in risk and climate change adaptation is also revealed in the science-policy discourse and, hence, in important international documents.

The science-policy interface: key international documents that highlight the importance of vulnerability

At the international level the concept of vulnerability has achieved a wide recognition in international key documents of both disaster risk reduction and climate change adaptation. One of the first United Nations reports that highlighted the importance of addressing vulnerability in the context of natural hazards was the report of UNDRO in 1980. The report contains a first guideline for a vulnerability analysis; however, the method is focused on hazard impacts, as opposed to a forward-looking understanding of vulnerability. The report specifically finds that "Information on vulnerability is less plentiful, less reliable and less clearly defined than the information usually available on natural hazards themselves" (UNDRO, 1980, p. 8).

In addition, the Hyogo Framework for Action 2005–2015 (HFA), a key document within disaster risk reduction, and the work programme on loss and damage of the United Nations Framework Convention on Climate Change (UNFCCC) as a key document in the field of climate change and adaptation science, emphasize the importance of addressing vulnerability.

The Hyogo Framework for Action

The disaster risk reduction community underscores in its final document of the World Conference on Disaster Reduction, the "Hyogo Framework for Action 2005–2015", that:

> The starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge. (United Nations, 2005)

The Hyogo Framework for Action emphasizes the need to examine physical, social and economic as well as environmental factors that influence vulnerability and determine disaster risk. However, the HFA provides little information on the key factors of vulnerability, nor does it fully answer the question of how a culture of disaster resilience can be achieved. Those countries that have submitted HFA progress reports demonstrate that mechanisms are in place to systematically report disaster losses and impacts. However, disaster loss and impact reports do not equal vulnerability assessments (see also Chapter 2 of this volume). While impact assessments are by definition ex-post oriented (thus conducted after a disaster), vulnerability assessments mainly aim to have a prognostic function within the broader context of risk assessment. In addition, an impact assessment does not generally deal with the question of why these losses and impacts have occurred and which factors determined the scale of harm, damage and loss. Overall, there is little information on whether those countries that signed the HFA also undertake systematic and holistic assessments of vulnerability.

Disaster loss data might provide information about revealed vulnerability and past disasters (see also Chapter 2), but they often fail to give a more comprehensive picture about existing or future vulnerabilities. The Global Assessment Report of UN/ISDR concludes that the monitoring mechanisms still do not generate the type of comprehensive data required for disaster risk reduction (UN/ISDR 2011, p. 11). Similarly, various country reports on the progress of the implementation of HFA show that risk and vulnerability assessments are still in need of improvement in order to capture the multifaceted nature of vulnerability more comprehensively, and make this information accessible to stakeholders and the public.

Climate change adaptation and the programme on loss and damage

At the international level, the CCA community stresses the need to further improve data and assessment methods to capture loss and damage associated with the adverse effects of climate change, including extreme events and slow-onset hazards (see UNFCCC, 2012). The Conference of the Parties (COP) in Cancun in 2010 established an own work programme on loss and damage in order to address losses and damages due to climate change in developing countries that are particularly vulnerable to these effects (UNFCCC, 2012). Although the discussion on how to frame loss and damage (for example, direct and indirect economic losses, and/or loss of trust etc.) is still ongoing (see Surminski et al., 2012), the request for such assessments reveals the need to better understand different dimensions and factors that increase or reduce loss and damage. Hence, the programme has catalysed the discussion on how to assess vulnerability and risk in the framework of actual and future climate change. In addition, UNFCCC, Article 2, calls for avoiding "dangerous anthropogenic interferences" with the climate system. In this regard, the IPCC reports assess dangerous anthropogenic interferences with the climate system through the use of a vulnerability lens. While the past IPCC assessment reports have in general examined the impacts of gradual increases in temperature due to climate change on social and biophysical systems, recent reports – such as the IPCC special report SREX (IPCC, 2012a) – enhance this focus by extending it to sudden-onset hazards (extreme events) that might cause extreme impacts. The IPCC SREX report emphasizes the need to improve vulnerability assessment, particularly in terms of capturing the dynamics and changes in vulnerability, rather than assuming that vulnerability is a static phenomenon.

Discussion and review of key terms

The current literature encompasses more than 30 different definitions, concepts and methods to systematize vulnerability (for example, UNDRO, 1980; Cardona, 1986, 1990; Chambers, 1989; Bohle, 2001; Wisner et al., 2004; Downing et al., 2006; United Nations/ISDR, 2004, p. 16; Pelling, 2003, p. 5; Luers, 2005, p. 215; Green, 2004, p. 323; United Nations-Habitat, 2003, p. 151; Schneiderbauer and Ehrlich, 2004; van Dillen, 2004, p. 9; Turner et al., 2003, p. 8074; Cardona, 2004b, p. 37; Füssel and Klein, 2006; O'Brien et al., 2004, Weichselgartner, 2001; UNISDR, 2004, 2009b; Thywissen, 2006; Manyena, 2006; IPCC, 2007; IPCC, 2012a).

Although vulnerability has to be viewed in its multifaceted nature (Bohle, 2002a and b), the different definitions and approaches show that we are still dealing with a paradox: we aim to measure vulnerability yet we cannot define or assess it precisely (Birkmann, 2006a, 2006b). Compared to disaster outcomes such as fatalities and different forms of harm and damage that can directly be measured, vulnerability is rather fuzzy and often linked to complex and dynamic inherent characteristics of societies or communities or social-ecological systems that can only be measured indirectly, such as the degree of defencelessness of a person to a specific hazard or the strength of social networks. In addition, various disciplines have developed their own definitions and pre-analytic visions of what vulnerability means. An overview of different definitions is given by Marre in this volume (see glossary).

The following section examines different definitions and, in particular, the differentiation of key terms such as vulnerability, resilience, hazard, risk, coping and adaptation, in order to provide a basis for the systematic discussion of different frameworks used to conceptualize vulnerability and to structure respective assessment processes. In addition, it describes different thematic dimensions and core factors of vulnerability that might function as an important background for an assessment.

Vulnerability

One of the best-known definitions of vulnerability was formulated by the International Strategy for Disaster Reduction (UN/ISDR). The UN/ISDR defines vulnerability as:

> The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. (United Nations/ISDR, 2004)

In addition, the United Nations Development Programme (UNDP) defines vulnerability as:

> a human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard. (UNDP, 2004, p. 11)

Furthermore, IPCC characterizes vulnerability within its fourth IPCC assessment report as: "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2007, Appendix I, Glossary).

While the definition of vulnerability used by UN/ISDR encompasses various conditions that have an impact on the susceptibility of a community, the UNDP definition understands vulnerability primarily as a human condition or process. In contrast, the IPCC fourth assessment defines vulnerability as relating to the susceptibility and limited coping capacity of a system, in addition to the character, magnitude and rate of climate change and variation (see IPCC, 2007, Appendix I, Glossary). While the first part of the definition used in the IPCC fourth assessment report is nearly similar to the understanding of vulnerability in the DRM community (see for example, UN/ISDR definition), major differences exist in terms of the second part of the definition. If the definition of vulnerability also accounts for characteristics of the hazard phenomena, such as the magnitude and rate of climate change, vulnerability moves towards a risk definition in the perspective of the DRM community. The integration of characteristics of the physical phenomena (magnitude and rate of climate change as physical phenomena) into the vulnerability concept is rather problematic, since these assessments of vulnerability tend predominantly to focus on impacts. In this context the analytic power of vulnerability in terms of showing the social construction of disaster risk will be undermined.

Overall, one can conclude that specific definitions imply different views and thus may lead to different priorities in assessments.

Coping capacity

According to UN/ISDR, coping capacity can be defined as:

> a combination of all strengths and resources available within a community or organization that can reduce the level of risk or to reduce the effects of a disaster. (UN/ISDR, 2002)

Coping capacity and adaptive capacity

McCarthy et al., 2001 define adaptive capacity as a function of wealth, technology, education, information, skills, infrastructure etc. that describes the ability of a system to adjust to actual or expected climatic hazards (McCarthy et al., 2001; Smit and Wandel, 2006; Engle, 2011). While coping is often used to characterize the availability of resources and the ability to utilize these resources to deal with hazards and shocks, adaptive capacity might also include the capacity of communities and societies to adapt to expected future hazards and climate change. Hence these resources may be developed in the future based on the existing capacities to develop them. However, in many scientific papers and policy documents coping and adaptation are merged. In contrast to this practice, the author argues that the differentiation of the two terms and concepts is important and of great help for guiding decision-making and analytical approaches.

On the other hand, it is also evident that in some real-world cases a clear-cut differentiation between coping and adaptation is rather difficult to achieve (see also Birkmann, 2012a and b). Interestingly, the words "adaptation" and "adaptive capacity" have recently attained a prominent role in disaster risk reduction, although the early work of Gilbert White, Robert Kates and Ian Burton had previously dealt with types of adaptations and adjustments (see Burton et al., 1978; Burton et al., 1993). For example, observing drought crises in Africa, Burton et al. highlighted changes in location, adjustments in land use and cropping processes or preventive strategies that mitigate harm or losses (see in detail Burton et al., 1993, p. 53).

Compared to the discourse of adjustment and adaptation, the more recent discussions deal particularly with the question of whether coping and adaptation are actually the same or significantly different concepts. The IPCC SREX (IPCC, 2012a) finds that adaptive and coping capacity are different concepts. While adaptive capacity is viewed as the combination of the strength, attributes and resources available to an individual, a community or a society to reduce impacts and harm, coping capacity in contrast is seen as the ability to actually use available skills and resources to manage and overcome adverse effects (see IPCC, 2012a, pp. 556–558). In addition, the term "adaptation" is often used to emphasize that adjustments of existing structures and changes are needed in order to be able to live with changing environmental and socio-economic conditions in the medium and long term (see Schipper and Burton, 2008; Birkmann, 2011a; Birkmann, 2011b, p. 1117). While adaptation implies a constantly unfolding process of learning, experimentation and change (see Birkmann et al., 2012; Kelly and Adger, 2000; Yohe and Tol, 2002; Pelling, 2010), coping deals with the protection and conservation of the current system and institutional settings (see Birkmann 2011b). This view is also supported by the earlier work of Vogel and O'Brien (2004), who argue that coping is in tendency rather short term and deals with capacities and survival in the light of extreme events or hazards, while adaptive capacities require planned and strategic actions and involve changes in the norms and structures that lead to such crises and disasters. Although the discourse has significantly enhanced the understanding of different societal response capacities, a coherent and systematic differentiation of coping and adaptive capacities and its application into real-world cases remains a challenge (see Birkmann et al., 2012).

Natural hazard

A hazard is often characterized as a potential occurrence of a natural or human-induced socio-natural physical event that may cause harm and loss (see for example, IPCC, 2012a and the glossary of Marre in this volume). Consequently, the definition of a hazard encompasses a broad range of threats, ranging from rather pure natural phenomena, such as earthquakes, to socio-natural hazards, like floods, to technological and so-called man-made hazards, such as an accident in a chemical plant (for example, Bophal 1984). Of particular interest in this volume are those hazards which originate from natural sources and that are modified by humans, and that have been known to cause considerable damage in the past, such as floods, storms or droughts. In addition, some chapters in this volume also consider future hazards, such as sea level rise (see for example, Welle et al., Chapter 9).

In the climate change discourse, the wording surrounding such phenomena, as described above, may differ. For example, hazards due to climate change, such as heat waves, droughts or floods, are often described as climate stimuli or extreme events (see IPCC, 2012, p. 116), even though they may also be considered under the umbrella of natural hazards in the DRM community.

Risk

Compared to the terms "hazard" and "vulnerability", the term "risk" can be described as the product of an interaction between hazard and vulnerability including the probability and magnitude of such consequences (if measurable).

> In risk sciences, the term risk encompasses the probability and the magnitude of harmful consequences or expected losses that may result from interactions between natural or human induced hazards and vulnerable conditions. (UN/ISDR, 2002)

However, it might be difficult to apply probability functions for rare events and new risks that might manifest themselves through new phenomena, such as sea level rise or cascading events. For these phenomena the general definition of risk, as the result of the interaction of a hazard or hazards with vulnerable communities, societies or social-ecological systems, is still valid or more appropriate to apply.

Having now discussed core definitions and respective differences between vulnerability, coping, adaptation, hazard and risk, the following section will outline core factors and key dimensions of vulnerability. This framing is essential in order to establish an understanding of the multi-faceted nature of vulnerability.

Core factors and key dimensions of vulnerability

Vulnerability concepts and assessment approaches in disaster risk management as well as climate change adaptation can be differentiated into components that deal with: (a) core factors of vulnerability; and (b) different thematic dimensions, such as social, environmental or economic and institutional vulnerability.

Core factors of vulnerability

Core factors of vulnerability encompass, for example, susceptibility, sensitivity or fragility (which are often used synonymously) and coping or adaptive capacities as categories to systematize societal response capacities to deal with adverse environmental conditions. Although most of the criteria used under the heading of sensitivity or susceptibility are nearly capturing similar aspects (Costa and Kropp, 2013), the author argues that the term "susceptibility" is a more appropriate term for vulnerability assessments in the context of natural hazards and climate change, since it points to deficiencies that determine the likelihood to experience severe harm and loss due to adverse events. In contrast, the term "sensitivity" is more neutral and could mean movements in positive and negative directions. In addition, the term "sensitivity" is used in ecology to describe the reaction time of a system, which is not a meaningful definition for vulnerability research. Moreover, the term "susceptibility" is used by the author and other scholars to highlight that vulnerability encompasses factors that describe the deficiencies of a system, while vulnerability also has to account for the capacities people and communities have, even though they are exposed and susceptible.

Exposure is an additional factor that in some approaches is defined as a part of vulnerability (see for example, Turner et al., 2003; Birkmann, 2006a, p. 38), while in other concepts it is seen as an own factor next to vulnerability (see IPCC, 2012a) or as a hybrid between vulnerability and the natural hazard or physical event (see for example, Cardona and Barbat, 2000). Exposure generally refers to the extent to which a unit or system of the assessment (for example, community, city, building) falls within the geographical range of a hazard event. Hence, exposure describes the presence of people, livelihoods, environmental services, resources or infrastructures or other valuable items in places that could be adversely affected (IPCC, 2012a, p. 559). If people or assets or social-ecological systems are actually or potentially not exposed to natural hazards or consequences of climate change, it is also less important to assess their susceptibility or sensitivity to such physical phenomena. Assessments can qualify exposure in terms of spatial and temporal patterns (Setiadi et al., 2010; Setiadi, 2011; Cutter and Finch, 2008, Birkmann et al., 2012 and 2013).

Compared to exposure, susceptibility (sometimes also called sensitivity or fragility) characterizes the predisposition and likelihood to suffer harm when a hazard strikes a community or a system is exposed. Susceptibility is revealed within physical, social, environmental, cultural and institutional dimensions. Even if a community or system (for example, a city or a social-ecological system) is exposed to a hazard or climatic stressor, this does not necessarily mean that it is highly susceptible, since susceptibility refers primarily to the conditions of the community or the system exposed. Susceptibility or sensitivity generally describe deficits and problematic conditions that might manifest themselves through people's defencelessness due to poverty or the lack of awareness about risks. At the same time, vulnerability research over the past few decades, for example, underscored that so-called vulnerable groups – that are highly susceptible – have also developed mechanisms to cope and in some cases to adapt to these adverse consequences. Hence, many assessments of vulnerability do not solely account for susceptibility or sensitivity but also consider the various capacities (for example, coping, adaptation) of people exposed to natural hazards and climate change to deal with the adverse consequences (see for example, Turner et al., 2003, Smit and Wandel, 2006; Birkmann et al., 2013; IPCC, 2012a).

Overall, it is important to note that newer vulnerability assessments do not solely focus on one specific aspect (for example, susceptibility) or configuration but also try to capture processes and dynamics of vulnerability: for example, by addressing different factors of vulnerability and their interplay, such as linkages between exposure, susceptibility, coping and adaptation.

Dimensions of vulnerability

In addition to the key factors of vulnerability, assessments deal with different thematic dimensions. Key dimensions of vulnerability encompass, for example, social, environmental, economic and institutional vulnerability. These dimensions can be further specified and enlarged by, for example, cultural or gender dimensions.

Social dimension of vulnerability

The social dimension of vulnerability deals with aspects of justice, social differentiation and societal organization as well as individual strength (Adger and Kelly, 1999; Adger, 2006; Birkmann, 2006a, 2006b, 2006c; Birkmann, 2011b; O'Brien et al., 2008; Few, 2007). In various studies the social dimension of vulnerability includes issues such as poverty, social marginalization and powerlessness, demography (vulnerable age groups), social networks, education, health and well-being (for example, Cutter et al., 2003; Cardona and Carreño, in this volume, Chapter 10); migration and displacement, and risk perception are also increasingly considered but still difficult to capture (see Dwyer et al., 2004). Furthermore, social vulnerability might also deal with the influence of institutions and rule systems that might make people more susceptible to suffer harm and loss due to natural hazards and climate change impacts (see for example, Wisner et al., 2004; Birkmann et al., 2011b). While past disasters such as the Indian Ocean tsunami, which hit Indonesia and Sri Lanka hardest, revealed that young and elderly, as well as female persons, were among the most vulnerable demographic groups, the heat wave in 2003 in Europe showed that elderly people particularly were more vulnerable compared to other age groups due to a variety of factors, such as health conditions, social isolation, family composition and mobility, all of which are social determinants of vulnerability (see IPCC, 2012a). Consequently, vulnerability patterns are not universal but often depend on specific context conditions and development processes in the respective country or region and on the respective hazard focus.

In addition, the criteria used to measure social vulnerability (for example, the percentage of elderly people in a community) might also serve as proxies for hinting towards more complex problems, such as the phenomenon of social isolation of the elderly in some developed countries, such as Germany. The research on these differential vulnerabilities shows that, for example, gender is not just an intrinsic feature of people who are vulnerable due to birth but who are made vulnerable by societal structures and processes, such as specific societal conditions that made women more susceptible to coastal hazards due to social norms such as factors that discourage female persons from engaging in, for example, survival training for girls (see also IPCC, 2012a). Also, characteristics, such as socio-economic class and caste (O'Keefe et al., 1976; Peacock et al., 1997; Ray-Bennet, 2009), gender (Sen, 1981; Neal and Phillips, 1990; Enarson and Morrow, 1998; Fordham 1998), age (both the elderly and children), race and ethnicity (Bartlett, 2008; Wisner, 2006) and housing tenure (whether renter or owner), as well as the differential access to financial resources in post-disaster processes, have been identified as the most common social vulnerability characteristics that influence susceptibility as well as exposure to hazards (Cutter and Finch, 2008; Birkmann and Fernando, 2008; Setiadi, 2011; Elliot and Pais, 2006; Fothergill et al., 1999). However, a universal checklist of vulnerable groups often falls short in addressing the diversity and dynamics of people's changing conditions and the local vulnerabilities. Therefore, characteristics and criteria identified in the literature have to be tested and extended through national or local research. In this regard, it is also important to assess the context in which societies or communities are embedded, such as aspects of governance in the specific region. For example, in terms of the drought disaster in Somalia or the earthquake disaster in Haiti, governance failure plays a major role in making people vulnerable (see for example Fund for Peace, 2011).

Additionally, Cannon et al. (2003, p. 5) argue that social vulnerability is linked to a set of characteristics that includes a person's:

- Initial well-being (nutritional status, physical and mental health);
- Livelihood and resilience (assets and capitals, income and qualifications);
- Self-protection (capability and willingness to build a safe home, use a safe site);
- Social protection (preparedness and mitigation measures);
- Social and political networks and institutions (social capital, institutional environment and the like).

In summary, vulnerability is not only determined by the type of hazard but is driven by precarious livelihoods, the degree of self-protection or social protection, qualifications and institutional settings and governance structures that define the overall context in which a person or a community experiences and responds to the adverse consequences of such phenomena (Cannon et al., 2003, p. 5). Hence, the concept of social vulnerability is not limited to social fragilities, such as people with physical disabilities but also includes topics such as social inequalities regarding income or gender as well as characteristics of communities and the built environment (Fordham, 1997, 1998, 2007; Cutter et al., 2003, p. 243; Enarson et al., 2007).

Economic dimension of vulnerability

Economic vulnerability can on the one hand refer to specific occupational and livelihood patterns and economic assets of households at risk; on the other hand a second group of approaches examines within economic vulnerability the susceptibility of an economic system or the inability of a system, for example, an individual household or a state, to absorb and deal with a specific magnitude of damage and economic loss (see for example, Hochrainer-Stigler et al., in this volume, Chapter 20; Rose, 2004; Mechler et al., 2010; Cardona et al., 2010).

While the latter deals with the capacity of a state, private company or household to deal with loss and damage as well as business interruption costs, another approach examines the susceptibility of different occupations and livelihoods to, for example, climatic changes and specific hazards. In this context the diversity of occupations a household is engaged in might be used as a measure of economic vulnerability at a microscale. The underlying hypothesis is that households or communities that heavily depend on one occupation only (for example, fishing or agriculture) might face higher losses and larger difficulties to recover due to a hazard event or disaster than those communities that are able to shift to alternative livelihoods and income-generating activities in the face of adverse events and environmental change.

Compared to this focus on livelihoods and different occupations, the second school assesses economic vulnerability by focusing on, for example, macroeconomic issues, such as the economic effects of a potential disaster on the gross domestic product (GDP), consumption and the fiscal position (Mechler et al., 2010). Assessments that analyse these economic vulnerabilities at the macroeconomic level include, for example, the CATSIM model (see Hochrainer-Stigler et al., in this volume, Chapter 20) and the Disaster Deficit Index (DDI) presented by Cardona and Carreño in Chapter 10. The Disaster Deficit Index, for example, measures the economic loss that a particular country could suffer when a catastrophic event takes place, and the implications in terms of resources needed to address the situation, such as the financial resources needed to compensate and reconstruct damaged infrastructures and other goods (see in detail Cardona and Carreño, Chapter 10 in this volume). Drivers of macroeconomic vulnerability include, among other issues, low levels of income, low level of GDP, constrained tax revenue, low domestic savings and a high indebtedness with little access to external finance (see for example, Mechler, 2004; Seth and Ragab, 2012; Barrito, 2008; Briguglio et al., 2009).

The environmental dimension of vulnerability

In recent years increasing attention has been given to environmental vulnerability. Although the environment is the sphere in which natural hazards and climate variability originated, it is at the same time an important resource for many people who are highly exposed to these hazards. The GAR of UN/ISDR (2009, 2011), as well as the publications of the Partnership for Environment and Disaster Risk Reduction (PEDRR, 2012 website[2]), stress the importance of ecosystem services and function as a modifier of human vulnerability or of the vulnerability of social-ecological systems; however, precise guidelines on how to assess the environmental dimension of vulnerability are still lacking. While some reports, such as the fourth assessment report of the IPCC, refer to the "Greenland ice sheet" and the "West Antarctic ice" as key vulnerabilities, due to their risk of melting, these phenomena are rather processes of the physical impacts of climate change and can indirectly refer solely to environmental vulnerability. In contrast to these physical processes, vulnerability in the environmental dimension connotes the likelihood of harm and disruption of livelihoods or other societal processes due to the degradation of environmental services and functions. Land degradation and coastal environmental degradation can have severe effects on the exposure of people to natural hazards as well as their susceptibility and coping or adaptive capacities (see for example Beck and Shepard, 2012). Scoones (1998), Renaud in this volume (Chapter 3) and the GEO reports 2007 and 2012 (see UNEP 2007, 2012) underscore the importance of environmental and natural resources for many (rural) livelihoods, human health and the need to integrate environmental aspects and resource dependencies into vulnerability and risk assessment. However, the actual integration of the environmental dimension of vulnerability in respective risk and vulnerability assessments is still in its preliminary phase. Evidence does exist that particularly in coastal environments, ecosystems, such as mangrove swamps and marshes (wetlands), as well as coral and oyster reefs, provide significant resources and services to coastal communities. At the same time these environmental conditions might serve as measures to reduce exposure to coastal hazards (coastal erosion, wave break). Assessing environmental vulnerability can thus refer to the identification of the susceptibility and fragility of ecosystem services that people depend on, such as benefits of coastal wetlands in terms of water filtration, fisheries, cultural benefits and shoreline stabilization, to name just a few (see in detail Beck and Sheppard, 2012; WorldRiskReport, 2012). These services (see for example, Barbier et al., 2011) might be particularly relevant for vulnerable communities that are highly exposed to coastal hazards. Assessments can examine the dependency of communities and different social groups on these environmental services and functions as well as the susceptibility of these ecosystem services and functions to specific hazards.

Moreover, the degree and process of the environmental degradation of, for example, coastal reefs, might also provide important insights about an increasing potential exposure of these communities to coastal hazards, such as the accelerated wave energy people might face due to coral destruction (see Sheppard et al., 2005) or mangrove deforestation (Osti et al., 2008). Reports, such as the Reef at Risk report, provide first indications about the destruction of coral reefs, for example, due to fishing, coastal development and pollution (see World Resource Institute, 1998, 2011). Overall, the environmental dimension of vulnerability deals with the role of regulating ecosystem services and ecosystem functions for people exposed to natural hazards and climate change which directly impact human well-being (see MEA, 2005) and in most cases also livelihoods and coping, as well as adaptive capacities.

The institutional dimension of vulnerability

The institutional dimension of vulnerability often refers to modes and constraints in governance, underlying rules and norm systems that govern society and also to the capacity or incapacity of (formal) organizations to deal with risks and adaptation challenges (see for example, Adger, 1999, 2000; Lebel et al. in this volume (Chapter 19); Fund for Peace, 2011). In addition, some approaches of institutional vulnerability also emphasize the importance of the political economy, and hence refer to modes of production or economic regulation (see for example, Wisner, 1978). Also, limits and constraints of interactions between formal (governmental) and informal (non-governmental) institutions involved in, for example, disaster risk reduction, climate change adaptation and development can hamper effective and integrative policy responses and thus refer to institutional vulnerability (see, for example, Schipper and Pelling, 2006; Mitchell and van Aalst, 2008; Mitchell et al., 2010; Birkmann et al., 2010).

An example, such as a mismatch between governmental and non-governmental adaptation strategies can be observed in the development of structural flood protection measures in some delta regions (for example, Mekong Delta). While local people might apply specific strategies – for example, to deal with increasing flood events (such as adapting their livelihoods to changing flood regimes) – governmental adaptation strategies might prioritize structural measures, such as dyke systems or relocation strategies, that have severe consequences for the households dependent on local ecosystem services (for example, fishing and farming systems) (see in detail Birkmann, 2011a and b). These mismatches can also be observed in the context of resettlement (see Chapter 20 in this volume), when governments aim to reduce people's spatial exposure to hazards but at the same time do not sufficiently consider their dependency on specific locations and environmental services.

At a macroscale of national states, institutional vulnerability can also be linked to the lack of provision of basic human security by states. So-called failed and fragile states often do not provide basic needs and social security to their members. Past disasters, such as the drought disaster in Somalia, and the recovery problems in the aftermath of the earthquake in Haiti (in 2010), underscore the importance of governance on local people's vulnerability and capacity to recover. The assessment of institutional vulnerability at the national level is, for example, illustrated within the WorldRiskIndex approach presented by Welle et al. in this volume (Chapter 9).

Finally, one can also argue whether or not the institutional dimension of vulnerability should be framed as an own dimension or whether the aspects described above are mainly institutional conditions and rules that regulate the other three dimensions discussed earlier. Although most of the issues addressed within institutional vulnerability might also influence and regulate, for example social vulnerability or economic vulnerability, the argument for treating it as an own dimension is rather practical. Most assessments do not sufficiently capture issues of governance as core aspects in their assessment. Hence, treating institutional issues as an own vulnerability dimension might help to improve assessment methods for actually assessing different qualities of governance and their impact on the vulnerability of people or social-ecological systems.

Preliminary conclusions: vulnerability

Understanding and assessing the multifaceted nature of vulnerability to natural hazards and climate change is still a challenge, since not only are hazard and exposure patterns changing but also the social, economic and institutional conditions people are living in are dynamic. The lens proposed within the structure of this chapter differentiates core factors of vulnerability, such as susceptibility and coping etc., and thematic dimensions (social, economic, environmental, institutional) in which exposure, susceptibility, coping and adaptation patterns become manifest.

Today, vulnerability is viewed as a particularly multidimensional, differential and dynamic phenomenon that often manifests itself at different scales simultaneously. However, the real challenge lies in the respective scientific assessment of these issues (for example, dynamics and scale interactions), without trying to assess all processes, dynamics and interlinkages at all scales simultaneously.

In addition, the differentiation made regarding the dimensions of vulnerability does not mean that all these dimensions can be clearly separated. Nevertheless, the various thematic dimensions introduced in this chapter might help scholars to review their approach and to clearly differentiate what is meant by vulnerability compared to physical impacts, hazards or risks.

Particularly in the light of an improved understanding of the dynamic nature of vulnerability and a multidimensional assessment, it is useful to differentiate susceptibilities (or deficiencies, sensitivities etc.) from resources that enhance the capacities of communities or social-ecological systems to deal with shocks and changes, such as coping and adaptive capacities. A clear-cut differentiation of coping or adaptation might in some cases be impossible; however, from a conceptual point of view, it is useful to distinguish the differing nature of response processes.

Another key challenge for defining and assessing vulnerability lies in developing a balanced approach between the assessment of hazard-independent vulnerabilities, such as poverty, and the assessment of vulnerability characteristics that might be hazard and context specific, such as aspects of exposure or specific coping and adaptation processes. For example, local and indigenous knowledge that informs coping and adaptation processes of indigenous people is context specific (see Nakashima et al., 2012). Overall, thinking along two lines – (a) different dimensions and (b) core factors of vulnerability – can help to move from a static to a more process- and holistic-oriented understanding of vulnerability to natural hazards and climate change.

Based on the in-depth discussion of different factors and dimensions of vulnerability, the following section will deal more precisely with resilience, coping and adaptation.

Resilience

Resilience describes the capacities of societies, communities and individuals or a social-ecological system to deal with adverse consequences and the impacts of hazard events (Holling, 2003; Berkes et al., 2003; Folke, 2006; IPCC, 2007; Birkmann, 2011b; Garschagen, 2011). Building resilience is seen as the key strategy to allow societies, communities, individuals or social-ecological systems to transform in order to be able to live with changing environmental and socio-economic conditions. In order to unpack the different meanings of the term, the author examines the development of the concept and different schools of thought.

Resilience as a concept brings together various empirical concepts that have long been the focus of social and human-environmental analysis. The novelty of resilience is, however, linked to the reprioritization and new conceptualization of social and natural systems that are often treated as separate systems, being embedded in different regimes and logics, while resilience research underscores that most systems in reality are coupled social-ecological systems (see for example, Berkes et al., 2003). Hence, a separation of these domains is often arbitrary. In addition, resilience research – particularly in the domain of social-ecological systems – introduced two important theoretical concepts: panarchy and adaptive capacity (see for example, Gunderson, 2000; Walker et al., 2004; Folke, 2006).

In contrast to vulnerability, resilience emphasizes that stressors and crises (phases of weak control) in social-ecological systems also provide windows of opportunity for change and innovation. Hence, crises and destabilization processes are seen as important triggers for renewal and learning. Also, anthropological research on community studies has focused on the apparent contradiction of continuity and change. However, what should be maintained and what has to change in the context of risk reduction to natural hazards and climate change adaptation is still a subject of discussion since, particularly in disaster risk research and climate change adaptation, it is still difficult to define precisely what structures and relationships need to remain and which should change or disappear.

Overall, resilience theory maintains that crises can be an important basis for reorganization and renewal, clearly differentiating this concept from other approaches in crises and disaster management, such as resistance. In the next paragraphs, three different schools of resilience thinking will be introduced.

From ecological to social-ecological resilience

The term "resilience" emerged particularly from research in ecology and social-ecology and goes back to work of C.S. Holling in 1973 regarding the robustness of ecological systems. A core pillar of Holling's resilience concept was linked to his research observation that the survival of a fish population (in the Great Lakes in the United States) is not primarily linked to the *size* of the population but rather to its flexibility and adaptability to changing conditions and the opportunity to sustain major relationships within ecosystems during times of shocks and disturbance (see Holling, 1973, p. 18). He proposed that "resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling, 1973, p. 18). Key terms in this research field were "surprise" (sudden change in a system), "multiple equilibria", "tipping points", "adaptive renewal cycle" and "panarchy". In this context, the notion of resilience is also linked to the concept of self-regulation of systems (see Vester, 2002) and was used as a critique against a static stability thinking.

The operationalization of the concept of resilience for disaster risk management or reduction and climate change adaptation is a challenge (see also Cutter et al., 2008; Klein et al., 2003), since one needs to define which functions of a society are key and need to be maintained. In addition, the transfer of this concept to social-ecological crises and disasters in the context of natural hazards might also be problematic. The idea that in disasters a reduction in human population might not be significant if major functions of the system can be sustained is questionable. Similarly, it would be problematic to translate resilience as robustness or resistance, since, in that case, the notions of reorganization and renewal are neglected.

The innovative potential of the concept of social-ecological resilience is linked to the concept of panarchy, the adaptive cycle and cross-scale interactions. The panarchy approach underscores that social-ecological systems operate in continued and adaptive cycles of growth, accumulation, restructuring and renewal and these phases are closely interlinked. In addition, the concept of resilience emphasizes the importance of the capacity of a system for self-organization, learning and transformation, which are core capacities that improve the system's ability to deal with shocks and surprises (see Holling, 2003, S. 393, 403; Abel et al., 2006; Walker et al., 2004; and Walker et al., 2006). Folke (2006) analysed and systematized different resilience concepts according to their core characteristics, focus and context. His overview also shows the further enhancement of ecological resilience into areas of engineering and social-ecology (see Table 1.1).

While the resilience concept for ecological systems is translated with characteristics of buffer capacities and the maintenance of key functions, the application of resilience in engineering focuses on recovery and continuity (see Folke, 2006). Today, it is used by many scholars in the sense of social-ecological systems, particularly by researchers of the resilience alliance (see website: www.resalliance.org). In this context, particular attention is given to feedback processes and cross-scale dynamics, as well as institutions that govern the management of social-ecological systems,

Table 1.1 Resilience concepts after Folke, 2006

Resilience Concept	Characteristics	Focus On	Context
Engineering resilience	Return time, efficiency	Recovery, constancy	Vicinity of stable equilibrium
Ecological/ ecosystem resilience and social resilience	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibria, stability landscape
Social-ecological resilience	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity, transformability, learning, innovation	Integrated system feedback, cross-scale dynamic interactions

such as framing systems or fishery practices (Folke, 2006; Turner, et al., 2003; Berkes et al., 2003).

Resilience in psychology

Psychological resilience has a longer research history. Compared to social-ecological resilience research that was heavily influenced by ecology, the focus in psychological resilience is on the analysis of individual recovery processes and the ability of individuals to deal with traumatic experiences and avoid negative trajectories associated with risks (Bonanno et al., 2004; Ong et al., 2006). In this regard, analysis of the capacity to choose a vital and authentic life is also part of psychological resilience research. In contrast to the idea of renewal and change, resilience in psychology is rather conservative and guided by the understanding of mitigating change and returning to a pre-impact status of psychological health. One area of this resilience research focused, for example, on the role of positive individual emotions that help to promote flexibility in thinking and problem solving (Fredrickson and Branigan, 2005; Folkman and Moskowitz, 2004), and these individual emotions play an important role in recovery processes after crises or disasters (Fredrickson and Levenson, 1998; Fredrickson and Branigan, 2001). Moreover, recent developments in psychological resilience show a certain shift from the analysis of individual internal capacities and factors of resilience towards a multilevel perspective that also includes protective factors rather than focusing on post-disaster recovery (see for example, Zautra et al., 2010; Bonnano et al., 2006; Meredith et al., 2011). Today, psychological resilience research focuses particularly on two domains with regard to disaster risk research: (a) on the mental health and development processes of individuals after crises (psychology); and (b) on factors at the individual and community levels that are related to disaster preparedness/mitigation.

Infrastructure resilience

Resilience of (critical) infrastructures is rather new and has been intensified, particularly in the light of an increasing dependency of societies on these critical infrastructure services and in terms of recent disasters, such as the Fukushima disaster. In general, critical infrastructures span a broad field of infrastructures that, according to Lauwe and Riegel, can be clustered in, for example, basic infrastructures, (such as electricity and water supply etc.), socio-economic infrastructures (such as crises management institutions, health care etc.) and socio-cultural infrastructures (such as media, research etc.) (see Lauwe and Riegel, 2008, p. 113). Bruneau et al. (2003) suggest that these infrastructures would be resilient if they were characterized by systems that are: (1) robust; (2) redundant; (3) resourceful; and (4) capable of rapid response. In this regard, assessment of the resilience of infrastructure can deal with four interrelated dimensions: (1) technical, (2) organizational, (3) social and (4) economic issues of critical infrastructure (Bruneau et al., 2003) that influence the robustness or capability of rapid responses within these infrastructures and their functioning. Furthermore, Boin and McConnell (2007) stress the need for a paradigm shift from the analysis of the critical infrastructure and contingency planning to the broader understanding of critical infrastructures as part of societal resilience. In addition, the discourses about the "Fukushima crisis" in Japan in 2010 after a major tsunami hit the atomic power plant, and the critical infrastructure failures in Europe during the heat wave in 2003, have stimulated new discussions about the mismatches between private and public sector risk management strategies and the effects of privatization, liberalization and deregulation on such infrastructures and their resilience.

Preliminary conclusions: resilience

The concept(s) of resilience originated from ecology and also psychology. The concepts, however, have been continuously discussed and further enhanced in the last three decades into other application areas with regard to new research fields, as illustrated beforehand from a rather narrow ecological system to complex and coupled social-ecological systems. Consequently, the concept has undergone a substantial shift with respect to its ontology and meaning as well as its area of application and knowledge domain (from basic knowledge to knowledge for decision-making).

While the original resilience concept in ecology focused primarily on the understanding of the survival of populations in times of shocks and perturbations, the newer work on social-ecological resilience also deals with institutions that regulate social-ecological systems and questions of decision-making (see for example, Berkes et al., 2003, Cumming et al., 2006). Furthermore, recent work by Pelling (2010) calls for a critical review of the resilience concept as a guiding vision. He argues that risk reduction and adaptation need to be transformative and hence have to provide the scope for the revision or even replacement of existing structures and social contracts (Pelling 2010). In this regard, a new discourse about transformative change is emerging.

In psychological resilience, that research has undergone an enhancement of the concept from individual capacities to deal with shocks and traumatization towards a multilevel perspective is observable. The interaction between ecological or social-ecological resilience, psychological resilience and infrastructure resilience research is still rather limited. Infrastructure resilience research in particular has been receiving more attention in the last decade due to failures of critical infrastructures and the increasing dependency of various societal processes on the functioning of these critical infrastructures both in so-called developed countries and countries in transition.

Overall, the discussion above indicates that the translation of the concept of resilience and its various characteristics into the context of risk and disaster recovery remains a major challenge. Many scientific contributions still remain abstract in terms of the question of what resilience actually means for disaster risk and adaptation research. For example, the contribution of Allenby and Fink (2005) in *Science*, maintains that resilience is not a global characteristic of a system but that it has to be translated for a specific system and regarding a specific challenge (see Allenby and Fink, 2005, S. 1034). Although one can agree with this observation, it shows that the term and its translation remain vague with respect to an improved understanding and assessment of resilience. Nevertheless, the concept highlights that a shift in thinking is needed in disaster risk reduction, in the sense that disaster and crises cannot always be avoided but have to be seen and used as windows of opportunity for change, reorganization and transformation towards improving learning and adaptive capacities, while at the same time increasing the degree of self-organization and capacities to manage shocks and perturbations. Interestingly, many of the characteristics that are actually used to describe subcomponents of such resilience concepts might call into question current development trends. For example, for critical infrastructures, redundancy is seen as a subcomponent of resilience; at the same time many agencies and private companies who run such critical infrastructures might prefer to avoid redundancies from a microeconomic and private business perspective. Hence, resilience concepts can also function as lenses to critically review current development processes and our understanding of disaster management and the goal of a world free of disasters.

Finally, Cutter et al. (2008) have developed a first framework (drop model) for assessing disaster resilience at community level that particularly stresses that low adaptive resilience in terms of social learning and improvisation after a disaster will also lead to low levels of recovery (see in detail Cutter et al., 2008, p. 602). Although the DROP model and the indicators selected for community resilience (see in detail Cutter et al., 2008, p. 604) provide a first, well-developed entry point, it is still a major research challenge to actually capture cross-scale interactions and interdependencies that in the original ecological and social-ecological resilience framing are discussed under the term "panarchy".

What have we learned so far? Preliminary observations

The overview and discussion of key terms have revealed that although concepts such as vulnerability and resilience have achieved a high degree of recognition in different fields, such as disaster management, climate change adaptation, environmental management and development studies, the concepts are often used with differing connotations. In this context, it might be misleading to try to establish a universal definition of vulnerability. Therefore, the author provides an overview of the different spheres of the concept of vulnerability (Figure 1.1), without intending to be comprehensive.

Nearly all concepts of vulnerability in disaster risk research and climate change adaptation view it as an "internal side of risk", closely linked with the discussion of vulnerability as an intrinsic characteristic of a system or element at risk. That means the conditions of the exposed subject or object (its susceptibility) at risk are seen as core characteristics of vulnerability (UN/ISDR, 2004; Cardona, 2004a, 2004b; Wisner, 2002, pp. 12–17; Marre, in this volume), the inner circle in Figure 1.1. Interestingly, the understanding that vulnerability is seen as an internal side of risk and as an intrinsic characteristic of an element at risk can be applied to very different elements, such as communities and social groups (socioeconomic conditions, institutional framework), physical structures and characteristics of buildings and lifelines (physical structure), as well as ecosystems and their services. The notion of vulnerability as an internal side to risk is a clear contrast with frameworks that assume that disaster risk is mainly an outcome of the natural hazard or environmental phenomenon.

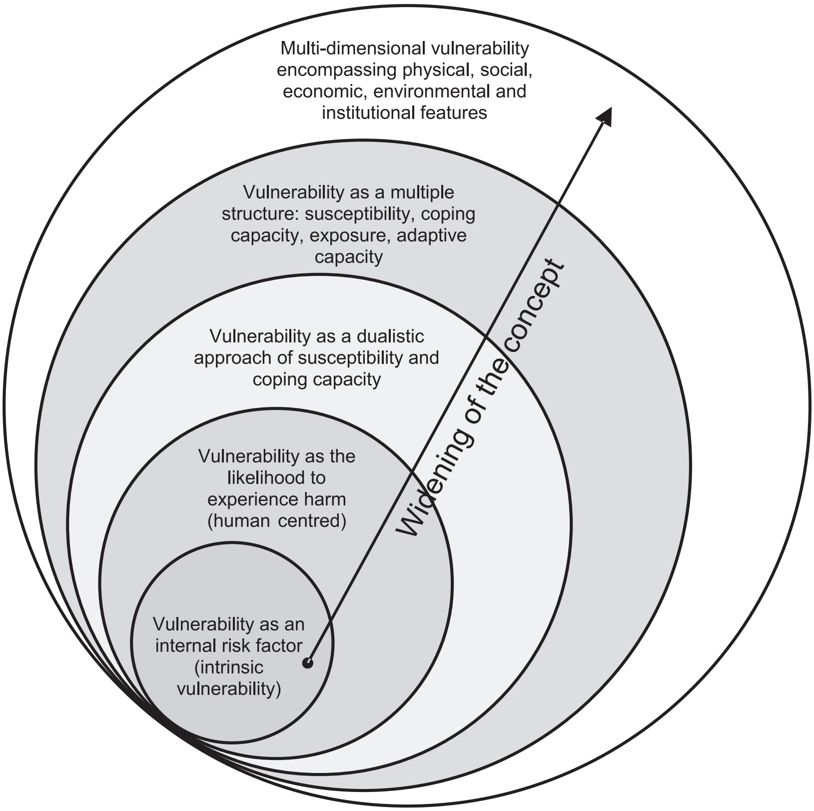

Figure 1.1 Key spheres of the concept of vulnerability
Source: Birkmann 2005.

An extension of this definition can be seen in definitions – such as Wisner's (2002) – that define vulnerability as the likelihood of injury, death, loss and disruption of livelihood in an extreme event and/or unusual difficulties in recovering from the negative impacts of hazardous events – primarily related to people (Wisner, 2002, pp. 12–17). This definition underlines the fact that the main elements of vulnerability are those conditions that increase and determine the likelihood of injury, death, loss and disruption of livelihood of human beings. Hence, the second sphere of vulnerability can be associated with this human-centred definition of the likelihood of death, injury and loss (Figure 1.1).

Furthermore, the "likelihood of injury" is extended by the focus of a dualistic structure of vulnerability, which can be observed in the definitions by Wisner (2002, pp. 12–17) and also partially by Chambers (1989) and Bohle (2001). Wisner clearly identifies the "unusual difficulties in recovering" from such events as part of vulnerability. Hence, coping and recovery capacities are part of a broader understanding of vulnerability. Many conceptualizations of vulnerability, particularly in the area of development geography and geographic risk research, suggest that societies, and poor people especially, are not just susceptible or fragile with respect to natural hazards or climate change impacts but have also developed capacities to cope with and adapt to these treats. Therefore, a third sphere can be associated with the "dualistic structure of vulnerability", focusing on susceptibility or fragility and the coping and response capacities of individuals or communities exposed to adverse consequences.

An additional extension of the concept of vulnerability can be seen in the shift from a double structure to a multistructure. Particularly, the newer frameworks, such as the Turner et al. (2003) framework or the BBC and MOVE frameworks, which will be introduced in the next section, focus on multiple factors and a diverse causal structure of vulnerability, including exposure, susceptibility, coping capacities and adaptive capacities (see for example, Turner et al., 2003; Cardona and Barbat, 2000; Birkmann, 2006a; Birkmann et al., 2013).

A fifth sphere and extension of the discussion can be seen in the analysis of multiple thematic dimensions of vulnerability. While the traditional engineering perspective of vulnerability focused primarily on physical aspects, the current debate regarding vulnerability clearly underlines the necessity to take into account various dimensions that shape and drive vulnerability (UN/ISDR, 2004), such as physical, economic, social, environmental and institutional characteristics. Some approaches also emphasize that additional global drivers that have an impact on vulnerability, such as globalization and climate change, should be integrated in such multidimensional assessment approaches (Vogel and O'Brien, 2004, p. 3; O'Brien and Leichenko, 2000). In summary, the focus of attention has shifted from the analysis of an individual unit or a narrow physical structure (the likelihood that buildings will collapse during an earthquake) to a broad interdisciplinary analysis of the multidimensional concept of vulnerability (for example, Cardona, 2004b, pp. 39–49). The widening of the concept of vulnerability is illustrated in Figure 1.1. It shows that, starting from a basic and in many cases common understanding (first inner sphere), a process of broadening took place that provided the background for the emergence of quite different frameworks and their thematic or causal focus.

Overall, the broadening of the concepts and the different spheres are also an expression of an improved understanding of vulnerability: for example, with regard to different response processes and interlinkages between different thematic dimensions, such as social, economic, environmental and institutional vulnerability. Recent work shows that different spheres of the concept of vulnerability are considered in the various conceptual frameworks to systematize vulnerability. This is a clear advancement compared to the research landscape when the first edition of measuring vulnerability was published in 2006.

Based on the discussion of the different terms and thematic dimensions of vulnerability, the following section presents selected conceptual frameworks of vulnerability used in disaster risk research, development research and climate change adaptation.

Conceptual frameworks of vulnerability

The different views on vulnerability are displayed in various analytical concepts and frameworks on how to systematize it. Since these conceptual frameworks are an essential step towards the development of approaches and methods measuring vulnerability and the systematic identification of relevant indicators, the following paragraphs give an insight into different conceptual frameworks developed in disaster risk research and development geography, climate change science and adaptation research, as well as concepts developed by the United Nations University-Institute for Environment and Human Security (UNU-EHS) and partners.

The approaches and frameworks presented in the following – based on different schools of thought – are not necessarily contradictory but approach vulnerability from a specific viewpoint. This section provides an overview of different approaches to help illustrate the key differences and similarities behind these ways of conceptualizing and measuring vulnerability and its components. Overall, the approaches presented can be classified into at least four different schools of thought: (a) political economy, (b) social-ecology, (c) vulnerability and disaster risk assessment from a holistic view and (d) climate change systems science. While the political economy approach can be illustrated by, for example, the pressure and release (PAR) model published in Blaikie et al. (1994) and Wisner et al. (2004), the social-ecology perspective is represented by the framework developed and published by Turner et al. (2003). Compared to political economy, the perspective of social-ecology puts the coupled human-environmental system at the centre of the vulnerability analysis and stresses the transformative qualities of society with regard to nature. So-called holistic concepts of vulnerability and disaster risk assessment have tried to develop an integrated explanation of risk. These approaches particularly differentiate exposure, susceptibility and societal response capacities (see Cardona, 1999a, 1999b, 2001; IDEA, 2005; Birkmann, 2006a; Carreño, 2006; Carreño et al., 2007; Birkmann and Fernando, 2008; Carreño et al., 2010; Birkmann et al. 2013). A core element of these approaches is a feedback-loop system that claims that vulnerability is dynamic and that vulnerability assessment cannot be limited to the identification of deficiencies. Furthermore, a fourth school of vulnerability concepts emerged within the context of climate change science and adaptation research (see for example, Füssel and Klein, 2006). These approaches define vulnerability as a function of exposure, sensitivity and adaptive capacities while at the same time suggesting that exposure also accounts for aspects of the physical phenomenon of climate change (Füssel, 2007; IPCC, 2007). The IPCC special report SREX (IPCC, 2012a), however, stresses the need to differentiate the physical event from vulnerability in order to maintain the analytic power of the concept of vulnerability as a way to show and examine the social construction of risk.

In the following section, selected frameworks of the different schools of thought will be discussed more in depth.

The double structure of vulnerability

According to Bohle (2001), vulnerability can be seen as having an external and an internal side. The internal side, coping, relates to the capacity to anticipate, cope with, resist and recover from the impact of a hazard; in contrast, the external side involves exposure to risks and shocks. In social sciences, the distinction between the exposure to external threats and the ability to cope with them is often used to underline the double structure of vulnerability (van Dillen, 2004). Based on the perspective of social geography and the intensive famine research carried out by Bohle (2001, p. 119), the pre-analytic vision of the double structure underscores the fact that vulnerability is the result of interaction between exposure to external stressors and the coping capacity of the affected household, group or society. Interestingly, Bohle's conceptual framework describes exposure to hazards and shocks as a component of vulnerability itself.

However, in this way, the term "exposure" goes beyond mere spatial exposure since it also encompasses features related to the entitlement theory and human ecology perspective. Within the debate over the double structure of vulnerability, the term "exposure" also deals with social and institutional features, meaning processes that increase defencelessness and lead to greater danger, such as exclusion from social networks. These alter the exposure of a person or a household to risk (Cannon et al., 2003). Moreover, the conceptual framework of the double structure indicates that vulnerability cannot adequately be characterized without

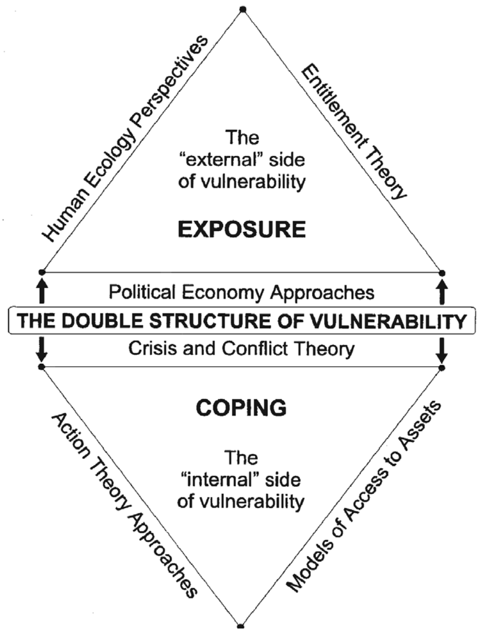

Figure 1.2 Bohle's conceptual framework for vulnerability analysis
Source: Bohle, 2001.

simultaneously considering coping and response capacity, defined here as the internal side of vulnerability.

The sustainable livelihood framework

The "sustainable livelihood framework" can be seen as a framework or vade mecum for vulnerability assessment. Key elements of this approach are the five livelihood assets or capitals (human, natural, financial, social and physical capital), the "vulnerability context" viewed as shocks, trends and seasonality, and the influence of transforming structures for the livelihood strategies and their outcomes (see in detail Department for International Development (DFID, 1999) and Figure 1.3).

The sustainable livelihood framework encompasses two major terms, "sustainability" and "livelihoods". The original concept, developed by Chambers and Conway (1992), viewed livelihoods as the means of gaining a living, encompassing livelihood capabilities and tangible and intangible assets. Within the livelihood framework, the term "sustainability" is often linked to the ability to cope with and recover from stresses and shocks as well as to maintain the natural resource base (DFID, 1999;

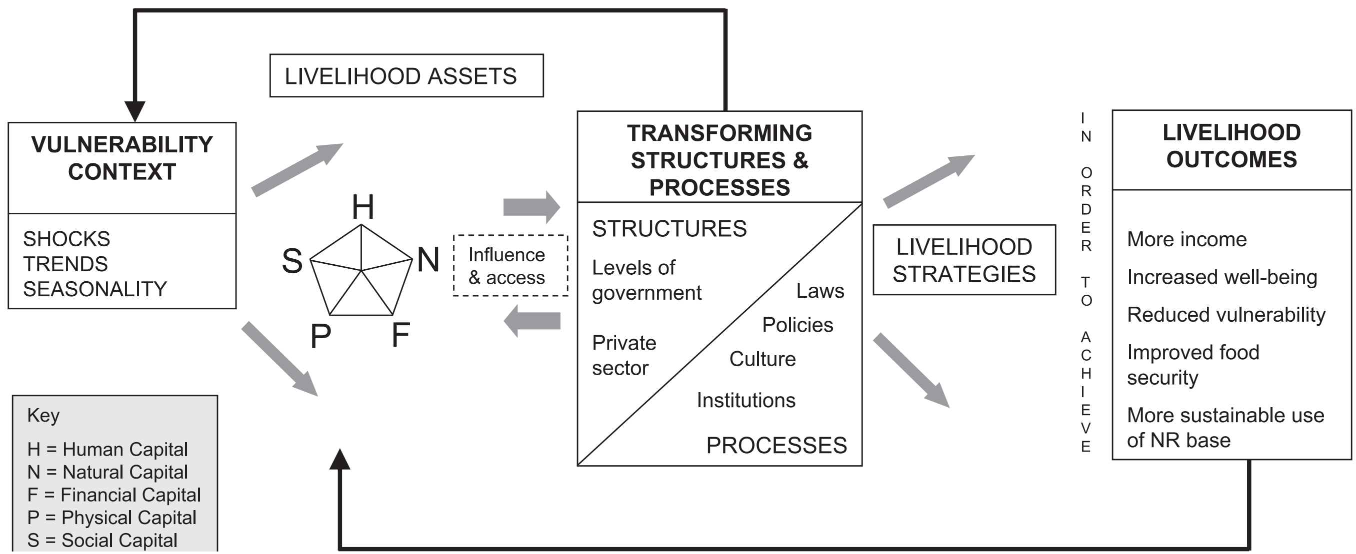

Figure 1.3 The sustainable livelihood framework
Source: DFID, 1999.

Chambers and Conway, 1992). The framework emphasizes that transforming structures in the governmental system or private sector and respective processes (laws, culture) influence the vulnerability context, and determine both the access to and major influences on livelihood assets of people. The approach underlines the necessity of empowering local marginalized groups in order to reduce vulnerability effectively (see in detail DFID, 1999; Schmidt et al., 2005). A central objective of the approach is to provide a method that views people and communities on the basis of their daily needs, instead of implementing ready-made, general interventions and solutions without acknowledging the various capabilities that poor people offer (de Haan and Zoomers, 2005).

Although the sustainable livelihood approach underlines the multiple interactions that determine the ability of a person, social group or household to cope with and recover from stresses and shocks, it remains abstract. The transforming structures and processes in particular, including influences and access aspects, remain very general. De Haan and Zoomers (2005, p. 33 and p. 45) emphasize that access and the role of transforming structures are key issues which have not been sufficiently examined so far. In particular, the flexibility of the interchanges of different capitals and assets (human capital, financial capital, social capital) has to be more closely considered, meaning that the configuration of power around these assets and capitals, as well as the power and processes of transforming structures, needs to be explored in greater depth. They argue that access as a key element in the sustainable livelihood framework heavily depends on the performance of social relations, and therefore more emphasis in sustainable livelihood research should be given to the role of power relations. De Haan and Zoomers conclude that the framework has the tendency to focus on relatively static capitals and activities within different livelihoods and livelihood strategies (de Haan and Zoomers, 2005).

Furthermore, it is interesting to note that the concept of livelihoods accounts solely for positive outcomes (livelihood outcomes). Additionally, the feedback processes significantly underestimate the role of livelihood outcomes in the environmental sphere and hazard context. For example, a "more sustainable use of natural resources" can be seen as an important tool to reduce the magnitude and frequency of some natural hazards such as droughts, floods or landslides. These linkages between the human-environmental system play a major role in the resilience discourse (see for example, Allenby and Fink, 2005; Folke et al., 2002; Berkes et al. 2003; Adger et al., 2005; Folke 2006). Nevertheless, this approach, especially the five livelihood assets, can serve as an important source and checklist for other approaches aimed at identifying susceptibility and coping capacity for hazards of natural origin.

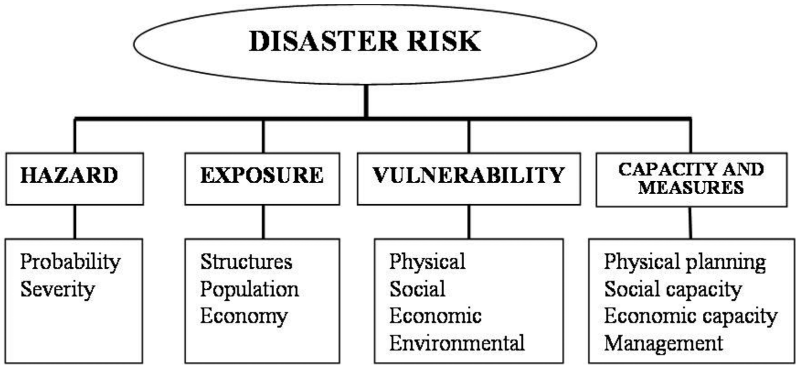

Figure 1.4 The conceptual framework to identify disaster risk
Source: Davidson, 1997: 5; Bollin et al., 2003: 67.

Vulnerability within the framework of hazard and risk

A second group of concepts used in disaster risk research defines vulnerability as a component within the context of hazard and risk. Vulnerability, coping capacity and exposure are defined as separate features. To illustrate these approaches, the definition of risk within the disaster risk framework by Davidson (1997), adopted by Bollin et al. (2003), the triangle of risk of Villagrán de León (2004), which reflects the "risk triangle" developed by Crichton (1999) and the UN/ISDR framework for disaster risk reduction (2004) are shown and discussed in the following. Davidson's (1997) conceptual framework, adopted by Bollin et al. (2003), is shown in Figure 1.4. It views vulnerability as one component of disaster risk. The conceptual framework distinguishes four categories of disaster risk: hazard, exposure, vulnerability and capacity measures (Figure 1.4).

Hence, risk is seen as the sum of hazard, exposure, vulnerability and capacity measures. While hazard is defined through its probability and severity, exposure is characterized by structures, population and economy. In contrast, vulnerability has a physical, social, economic and environmental dimension. Capacity and measures – which seem to be closely related to issues of what we would describe today as coping and adaptive capacities – encompass physical planning, social capacity, economic capacity and management. In contrast to the framework of the double structure of vulnerability developed by Bohle (2001), this approach defines vulnerability as one component of disaster risk and differentiates between exposure, vulnerability and coping capacity (Davidson, 1997; Bollin et al., 2003). Villagrán de León defines vulnerability within a triangle of

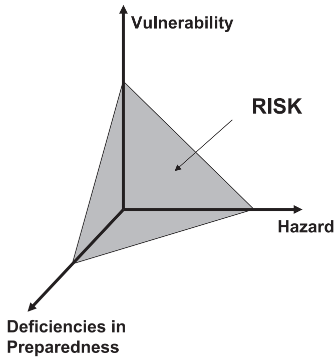

Figure 1.5 Risk as a result of vulnerability, hazard and deficiencies in preparedness
Source: Villagrán de León, 2001/2004.

risk, which consists of the three components of vulnerability, hazard and deficiencies in preparedness (Villagrán de León, 2004, p. 10). His figure reflects the “risk triangle” developed earlier by Crichton (1999).

Vulnerability in this framework is seen as one of the pre-existing conditions that make infrastructure, processes, services and productivity more prone to be affected by an external hazard. In contrast to the positive definition of coping capacities, Villagrán de León uses the term “deficiencies in preparedness” to capture the lack of coping capacities of a society or a specific element at risk (Villagrán de León, 2001, 2004). Although the term “exposure” is not directly mentioned, he views exposure primarily as a component of the hazard (Villagrán de León, Chapter 17).

The UN/ISDR framework for disaster risk reduction

A different conceptual framework was developed by the UN/ISDR. The UN/ISDR framework views vulnerability as a key factor when determining risk. According to UN/ISDR, vulnerability can be classified into social, economic, physical and environmental components (see Figure 1.6).

Vulnerability assessment is understood as a tool and a precondition for effective risk assessment (UN/ISDR, 2004, p. 14–15). Although the framework provides an important overview of different phases in disaster risk management, such as vulnerability analysis, hazard analysis, risk assessment, early warning and response, the framework does not indicate how reducing vulnerability can also reduce risk. The arrows from vulnerability and hazards only point to the direction of the risk analysis; the opportunity to reduce the vulnerabilities themselves is not explicitly shown. Additionally, the UN/ISDR conceptual framework places vulnerability and

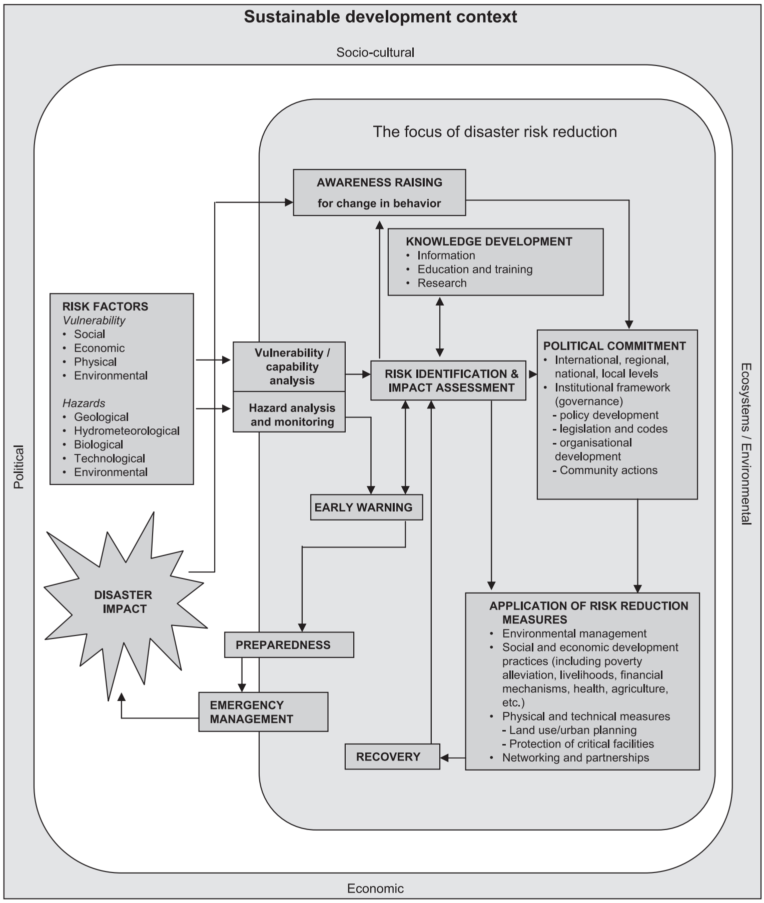

Figure 1.6 The ISDR framework for disaster risk reduction
Source: UN/ISDR, 2004.

the disaster risk reduction elements within a framework called the "sustainable development context" (Figure 1.6). Although it is important to link risk reduction with sustainable development, the perception that risk reduction is similar to and always compatible with sustainable development is inadequate. The general recommendation of "making the best use of connections among social, economic and environmental goals" is a sort of ill-defined "balancing exercise" between social, economic and environmental goals. In practice, vulnerability reduction and sustainable development are confronted with deeply rooted social, economic and environmental conflicts which cannot be wished away through a simple balancing exercise.

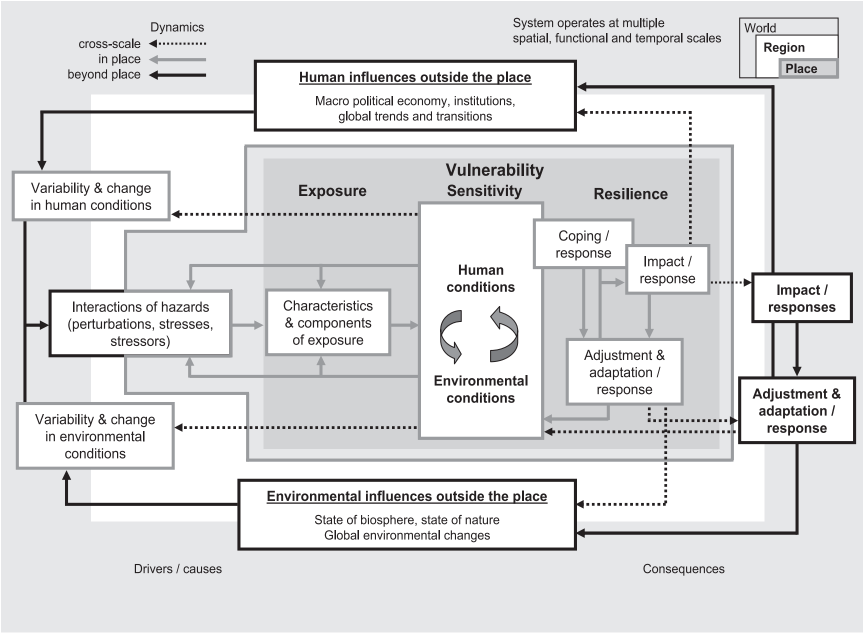

Figure 1.7 Vulnerability framework
Source: Turner et al., 2003: 8076.

Vulnerability in the context of a social-ecological perspective

The conceptual framework developed by Turner et al. (2003) can be considered as being a representative of the thinking of social-ecology, since it places the coupled human-environmental system at the centre of the vulnerability analysis (Turner et al., 2003, p. 8075; Kasperson, 2005b). In contrast to the disaster risk community, this conceptual framework defines exposure, coping response, impact response and adaptation response explicitly as parts of vulnerability (Figure 1.7). The framework takes into account the interaction of the multiple interacting perturbations and stressors.

The conceptual framework also accounts for adaptation, which is viewed as an element that increases resilience. Overall, the framework constitutes an interesting alternative to the conceptual frameworks discussed earlier. However, some questions remain, such as whether the distinction between drivers and consequences in this feedback-loop system is appropriate and whether a clear differentiation between coping, impact and adaptation response is feasible and analytically useful. Also, the consideration of different spatial levels is an important enhancement of existing concepts. At the same time, however, it raises the question of how to actually assess these cross-scale interactions.

The PAR model

The PAR model views disaster as the intersection of two major forces: those processes generating vulnerability and the natural hazard event. Hence, disaster risk can be viewed as a process involving increasing pressure on the one hand and the opportunities for relieving the pressure on the other (Blaikie et al., 1994; Wisner et al., 2004, p. 49–86).

The PAR approach is based on the commonly used equation in DRM:

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability.}$$

In this regard, vulnerability is defined within three progressive levels: root causes, dynamic pressures and unsafe conditions (Figure 1.8). Root causes can be, for example, economic, demographic and political processes which determine the access to and distribution of power and various resources. The category dynamic pressure encompasses all processes and activities that transform and channel the effects of root causes into unsafe conditions, such as epidemic diseases, rapid urbanization and violent conflicts (Wisner et al., 2004, p. 54). Interestingly, the authors of this approach stress the fact that dynamic pressure should not be labelled as negative pressure per se. Root causes implying dynamic pressures lead to unsafe conditions, which are a third column of the PAR framework. Unsafe conditions are specific forms in which human vulnerability is revealed and expressed in a temporal and spatial dimension. These conditions can encompass lack of effective protection against diseases, living in hazardous locations or having entitlements that are prone to rapid and severe disruption (Wisner et al., 2004, p. 52–80). The approach also accounts for access to tangible and intangible resources.

The differentiation of root causes, dynamic pressures and unsafe conditions underscores the author's opinion that measuring vulnerability should go beyond the identification of visible unsafe conditions; rather, it should address underlying driving forces and root causes in order to be able to explain why people are vulnerable. However, the different elements of the PAR framework are in real-world situations dynamic in that they are subject to constant change, and hence the task of identifying and verifying the causal links between root causes, dynamic pressures and unsafe conditions (in a quantitative way) might be very difficult. Also, Wisner et al. (2004) stress that in multi-causal situations and a dynamic environment it is hard to differentiate between the causal links of different dynamic pressures on unsafe conditions and the impact of root causes on

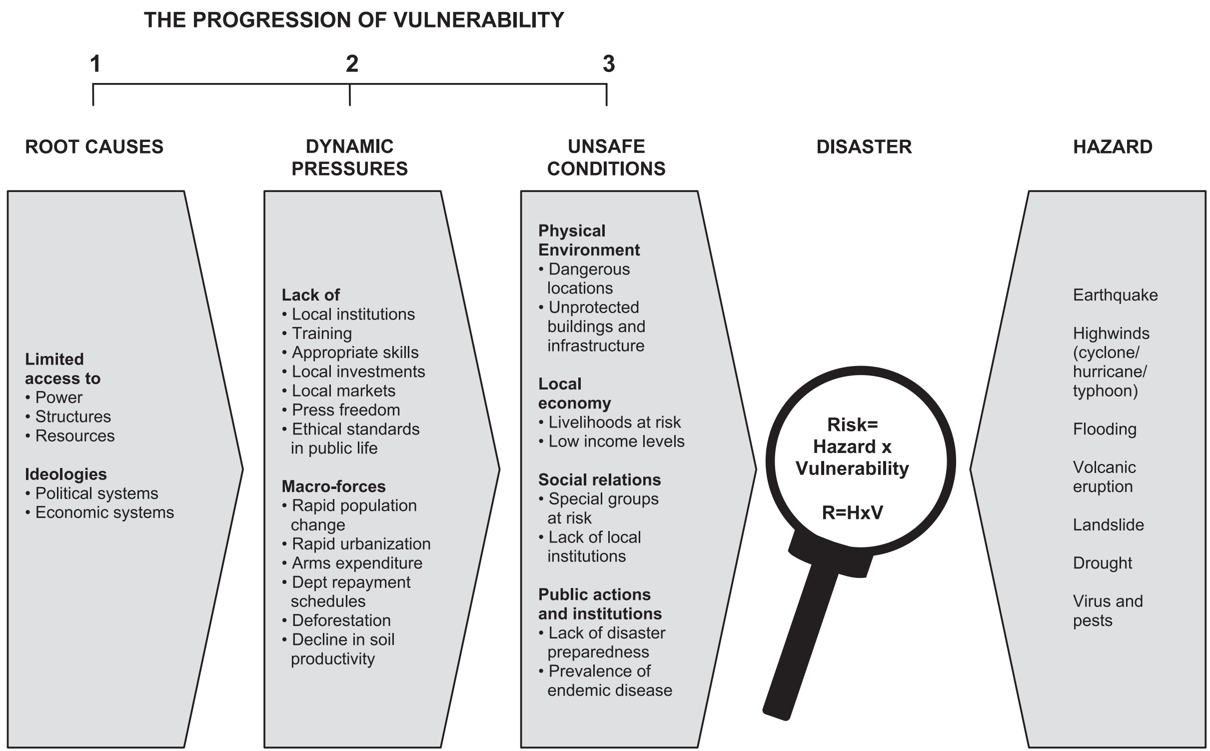

Figure 1.8 The Pressure and Release (PAR) model
Source: According to Wisner et al., 2004: 51.

dynamic pressures. For example, although urbanization as a dynamic pressure might lead to unsafe conditions in many developing countries, the general assumption that urbanization leads per se to unsafe conditions is inappropriate. Hence, trends such as urbanization might imply more nuanced and ambiguous effects on vulnerability and adaptive capacity pathways (Garschagen and Romero-Lankao, 2013). That means urbanization might in some cases even function as a driver to reduce the susceptibility to climate change and to increase adaptive capacities. In addition, Cross (2001, p. 63) argues that, contrary to popular wisdom, small cities and rural communities are more vulnerable to disasters than megacities, since megacities are more likely to possess the resources needed to deal with hazards and disasters, while in smaller and rural communities these capacities do not exist.

Overall, the PAR model is an important approach and one of the best-known conceptual frameworks worldwide that focuses on vulnerability and its underlying driving forces. It is particularly useful in addressing the release phase and the root causes that contribute to disaster situations. On the other hand, the approach underlines the fact that the real effort to reduce vulnerability and risk involves changing political and economic systems, since they are viewed as root causes of, for example, dynamic pressures such as rapid urbanization or rapid population change. Hence, the conceptual framework puts a heavy emphasis on national and global levels, although many dynamic pressures and unsafe conditions might also be determined by local conditions.

A holistic approach to risk and vulnerability assessment

The conceptual framework for a holistic approach to evaluating disaster risk goes back to the work of Cardona (1999a, 2001) and his developments with Hurtado and Barbat in 2000. In their first concept, vulnerability consisted of exposed elements that took into account several dimensions or aspects of vulnerability, which are characterized by three categories of vulnerability factors:

- Physical exposure and susceptibility, which is designated as hard risk and viewed as being hazard dependent;
- Fragility of the socio-economic system, which is viewed as soft risk and being non-hazard dependent;
- Lack of resilience to cope and recover, which is also defined as soft risk and being non-hazard dependent (Cardona and Barbat, 2000, p. 53).

According to this framework, vulnerability conditions depend on the exposure and susceptibility of physical elements in hazard-prone areas, and on socio-economic fragility as well as on a lack of social resilience and

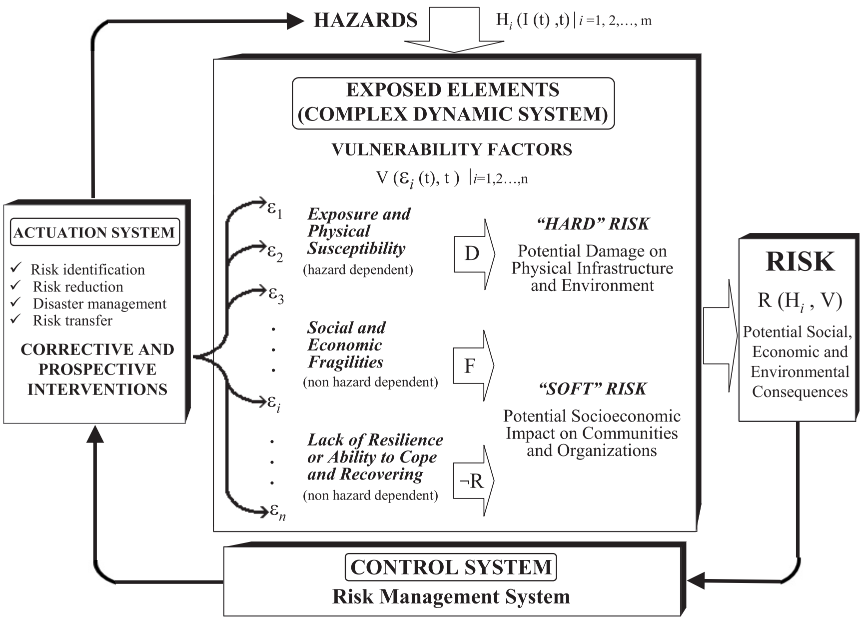

Figure 1.9 Theoretical framework and model for holistic approach to disaster risk assessment and management
Source: Cardona and Barbat, 2000.

ability to cope. These factors provide a measure of the direct as well as indirect and intangible impacts of hazard events. The framework emphasizes that indicators or indices should measure vulnerability from a comprehensive and multidisciplinary perspective. They intend to capture conditions for the direct physical impacts (exposure and susceptibility) as well as for indirect and at times intangible impacts (socio-economic fragility and lack of resilience) of potential hazard events. Therefore, the approach defines exposure and susceptibility as necessary conditions for the existence of physical (hard) risk. On the other hand, negative impacts as a result of the socio-economic fragilities and inability to cope adequately are also vulnerability conditions that are understood as "soft" risk.

Although the classification of vulnerability conditions into "hard" and "soft" risk is controversial, the conceptual framework suggests a broader understanding of vulnerability, encompassing exposure, susceptibility and lack of resilience. The consequences of the interaction of the hazardous events and vulnerabilities are defined as risks from which a feedback loop starts: it encompasses a control and an actuation system that represents risk management, including corrective and prospective interventions (Cardona and Barbat, 2000).

Carreño et al. (2004, 2005a, 2005b) have developed a revised version of the holistic model to evaluate risk that redefines the meanings of hard and soft risk in terms of "physical damage", obtained from exposure and physical susceptibility, and an "impact factor", obtained from the socio-economic fragilities and lack of resilience of the system to cope with disasters and recovery. The revised version of the holistic model of disaster risk views risk as a function of the potential physical damage and the social and economic fragilities and lack of resilience (impact factor). While the potential "physical damage" is determined by the susceptibility of the exposed elements (for example, a house) to a hazard and its potential intensity and occurrence, the "impact factors" depend on the socio-economic context – particularly social fragilities and lack of resilience. Based on the theory of control and complex system dynamics, Carreño et al. (2004, 2005a, 2005b) also introduce a feedback loop encompassing corrective and prospective interventions, to underline the need to reduce both the vulnerabilities and the hazards.

The holistic approach to estimating vulnerability was also presented by Cardona (2004a) in Geneva. However, because his presentation outlined only some elements of the approach, we examine the original model here (Figure 1.9). The model has been used to evaluate disaster risk at the national level in the Program of Indicators for Disaster Risk and Risk Management for the Americas (see Cardona, Chapter 10 in this volume) as well as at the sub-national level and for cities, including Barcelona and Bogotá (Carreño et al., 2005a, 2005b).

The BBC conceptual framework

The BBC conceptual framework combines different elements of the frameworks discussed earlier. Therefore, the presentation of this framework will also reflect on the frameworks analysed before and will stress some key aspects which are still controversial.

The term "BBC" is linked to conceptual work done by Bogardi and Birkmann (2004) and Cardona (1999 and 2001) which served as a basis for this approach. It grew from three discussions: how to link vulnerability, human security and sustainable development (Bogardi and Birkmann, 2004; see also regarding the nexus of vulnerability and sustainable development, Birkmann, 2006a); the need for a holistic approach to disaster risk assessment (Cardona 1999, 2001; Cardona and Hurtado, 2000a, 2000b, 2000c; Cardona and Barbat, 2000; Carreño et al., 2004, 2005a, 2005b, Cardona et al., 2005); and the broader debate on developing frameworks for measuring environmental degradation in the context of sustainable development (for example, Organisation for Economic Co-operation and Development [OECD], 1992, p. 6; Zieschnak et al., 1993, p. 144).

The BBC framework stresses the fact that vulnerability analysis goes beyond the estimation of deficiencies and assessment of disaster impacts in the past. It underlines the need to view vulnerability within a process (dynamic), which means focusing simultaneously on exposure, susceptibility, coping capacities and potential intervention tools to reduce vulnerabilities (a feedback-loop system). Furthermore, vulnerability should not be viewed as an isolated feature; it has also to take into account the specific hazard type(s) that the vulnerable society, its economy and environment are exposed to, and the interactions of both that lead to risk. This means the BBC framework underlines the need to focus on social, environmental and economic dimensions of vulnerability simultaneously, clearly linking the concept of sustainable development into the vulnerability framework. Within the three sustainability dimensions (social, economic and environmental spheres), additional frameworks can be integrated: for example, the sustainable livelihood framework within the social sphere.

In contrast to the model of holistic approach for estimating vulnerability and risk (Cardona and Barbat, 2000), the BBC conceptual framework does not account for hard and soft risk. Instead, the three main thematic spheres of sustainable development define the inner thematic composition in which vulnerability should be measured. In this context, the environmental dimension is not represented within the framework of the holistic approach to estimate vulnerability and risk developed by Cardona and Barbat (2000).

Organizational and institutional aspects are important, as are physical vulnerabilities, but they should be analysed within the three thematic spheres (economic, social and environmental) (Figure 1.10). The BBC conceptual framework promotes a problem-solving perspective by analysing the probable losses and deficiencies of the various elements at risk (for example, social groups) and their coping capacities as well as the potential intervention measures, all within the three key thematic spheres. In this way it shows the importance of being proactive in order to reduce vulnerability before an event strikes the society, economy or environment ($t = 0$) (Figure 1.10). Especially within the social and economic spheres of vulnerability in the BBC framework, the five livelihood assets can serve as an important orientation and as a kind of vade mecum to select relevant subthemes and indicators for assessing susceptibility and coping. Potential intervention tools could also encompass measures and processes conducive to improving access to important livelihood assets – for example, to human, social and physical capital.

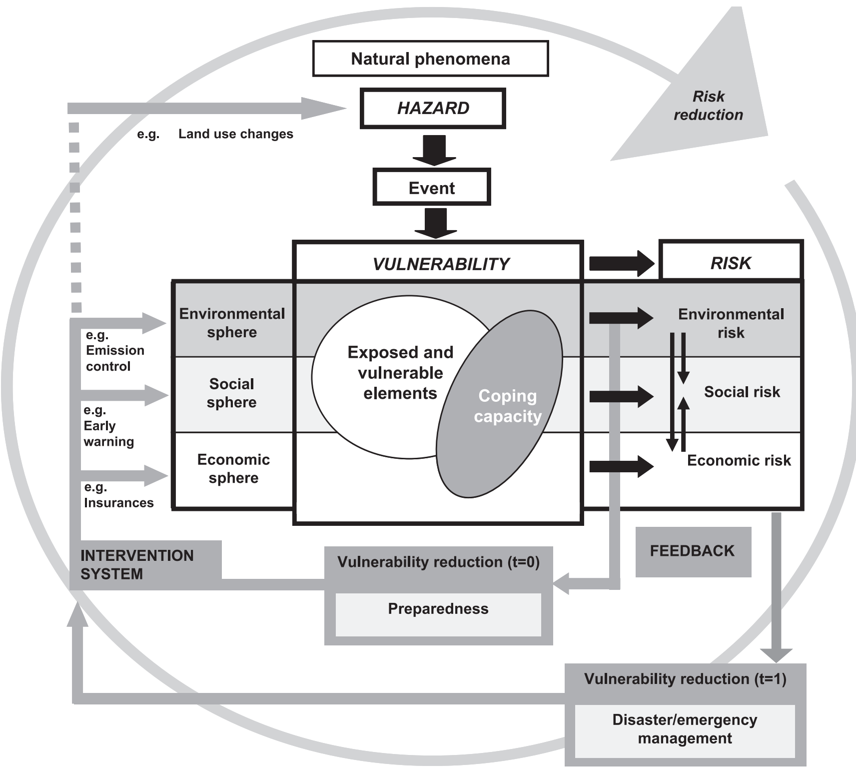

Figure 1.10 The BBC conceptual framework
Source: Author, based on Bogardi/Birkmann (2004) and Cardona (1999/2001).

While some approaches view vulnerability primarily with regard to the degree of experienced loss of life and economic damage (for example, DRI, Hotspots), the BBC conceptual framework addresses various vulnerabilities in the social, economic and environmental sphere – linked to the main pillars of sustainable development (United Nations, 1993; World Commission on Environment and Development [WCED], 1987). In this regard the BBC framework views the environment as the "event sphere" from which a hazard of natural origin starts, but, equally, the environment itself is vulnerable to hazards of natural origin and to creeping processes.

Finally, the BBC conceptual framework shows that one has two options to reduce vulnerability (t = 0) and (t = 1) (see Figure 1.10). The first option is a response before risks are manifested in specific crises or disaster events (t = 0), while the second option deals with the response needed when disaster risk has been manifested in a specific disaster event (t = 1). Although during the disaster emergency management and disaster response units play a crucial role, vulnerability reduction should give particular emphasis to responses in ($t = 0$), thus focusing on preparedness rather than on disaster response and emergency management.

Regarding the controversial discussion of exposure, the BBC framework views exposure as being at least partially related to vulnerability. Although one can argue that exposure is often hazard-related, the total exclusion of exposure from vulnerability assessment could render this analysis politically irrelevant. If vulnerability is understood as those conditions that increase the susceptibility of a community to the impact of hazards, it also depends on the spatial dimension, by which the degree of exposure of the society or local community to the hazard or phenomena is referred. Consequently, the framework considers the phenomenon of exposure, at least in part, since it recognizes that the location of human settlements and infrastructure plays a crucial role in determining the susceptibility of a community. Yet it acknowledges that within a given high exposure zone there are other characteristics that will have a significant impact on whether or not people and infrastructures are likely to experience harm.

Finally, the framework stresses that the changes of vulnerability from one thematic dimension to another should be taken into account and viewed as a problem, since these shifts do not imply real vulnerability reduction.

The MOVE framework

The MOVE framework has been developed in a recent project funded by the European Commission, involving researchers from Europe and Latin America (see Birkmann et al. 2013). The MOVE framework amplifies the discussion on how to frame vulnerability as a dynamic process involving various thematic dimensions of vulnerability and different feedback loops. It takes up the newer discourse on resilience and adaptation. The framework stresses that society is embedded into the broader context of the environment (not just subject to natural hazards), just as the environment is shaped by human action. At its core, the MOVE framework differentiates key factors of vulnerability and different thematic dimensions of vulnerability (social, economic, institutional, cultural etc.). Key factors of vulnerability encompass: (a) exposure, (b) susceptibility (or fragility), which describes the predisposition of elements at risk (social and ecological) to suffer harm and (c) the lack of resilience or societal response capacity. Susceptibility and the different categories under the lack of resilience are core factors of vulnerability, while exposure also needs to be taken into consideration. Exposure, however, is viewed as a hybrid

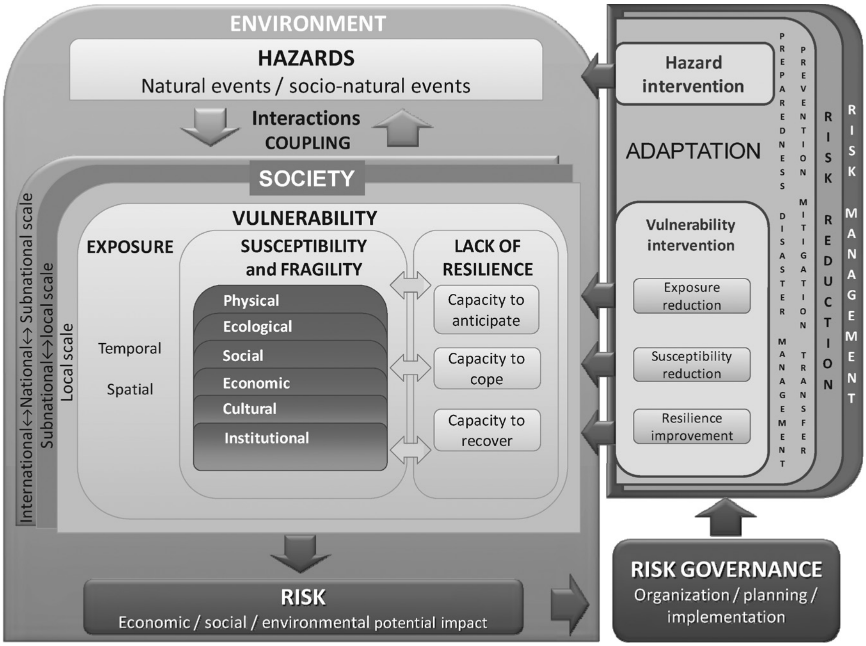

Figure 1.11 The MOVE framework
Source: (own figure, based particularly on concepts of Cardona, 1999a: 65; Cardona, 2001; Turner, et al., 2003; Bogardi and Birkmann, 2004; IDEA, 2005; Birkmann, 2006b; Carreño, et al., 2007a).

between vulnerability and the hazard. The framework stresses that, compared to adaptation processes and adaptive capacities (that transform and change systems (communities, households or livelihoods at risk), coping capacities focus mainly on the ability to maintain the system as it is in the light of a hazard event impacting the exposed system or element. The term "coupling" in the MOVE framework emphasizes that any defined hazard is given form and meaning by interaction with social systems and, similarly, social systems are influenced by their actual and perceived hazard context (Birkmann et al. 2013, based particularly on concepts of Cardona, 1999a, p. 65; Cardona, 2001; Turner, et al., 2003; Bogardi and Birkmann, 2004; IDEA, 2005; Birkmann, 2006b; Carreño et al., 2007).

Risk within the MOVE framework is defined as the probability of harmful consequences or losses resulting from interactions between hazard and vulnerable conditions. In addition, the framework emphasizes the importance of risk governance that could be seen as an overall subject of the whole framework and particularly as a part of the response process in terms of defining adaptation strategies. Risk governance deals with various actors, rules, conventions and mechanisms concerned with risk reduction and adaptation (see also Renn, 2008 for risk governance; Biermann et al., 2009).

Overall, the MOVE framework combines the notion of multidimensional and process-oriented vulnerability (feedback-loop system), differences in coping and adaptation with the concept of coupled social-ecological systems. In real-world situations it can be problematic only to assess the different dimensions of vulnerability in the susceptibility cluster – although for graphic representation this might be easier to read and follow. The framework has been tested and applied within the MOVE project (see MOVE website) and hence has demonstrated practical applicability.

Conceptual frameworks for climate change vulnerability

Vulnerability has emerged in the past two decades as a central concept in climate change research (see Füssel, 2007). Although the frameworks of vulnerability used in DRM and CCA are different, the overall goal of assessing vulnerability has, however, been similar. The goal of vulnerability assessments in climate change research is to inform policies that aim to reduce risks associated with climate change (see for example, Füssel and Klein, 2006). The framework of the second generation of climate change vulnerability assessment suggests that vulnerability is determined by the impact and the adaptive capacity of a system facing adverse consequences of climate change (see Füssel and Klein 2006, p. 319). The category of impacts is determined by the exposure and sensitivity of the system and non-climatic factors. Vulnerability in this framework is the final outcome of the interaction of climate change and climate variability that determine exposure, the sensitivity of the system and its adaptive capacity (see Figure 1.12).

Although the discussion about differences in vulnerability frameworks has also centred around the question of whether vulnerability is seen as a starting or end point (O'Brien et al., 2004; Füssel, 2006), the most significant difference between vulnerability concepts in climate change science and disaster risk research is actually linked to the question of whether or not (biophysical) vulnerability also encompasses physical characteristics of climate change. In the fourth IPCC assessment report, the vulnerability definition and respective concepts encompassed the rate and magnitude of climate change (see IPCC, 2007). Hence the integration of physical climate change in vulnerability assessments under the category of exposure (Füssel and Klein, 2006, p. 322) clearly moves the vulnerability assessment towards a risk assessment. The idea that biophysical vulnerability also accounts for the external factors of severe storms,

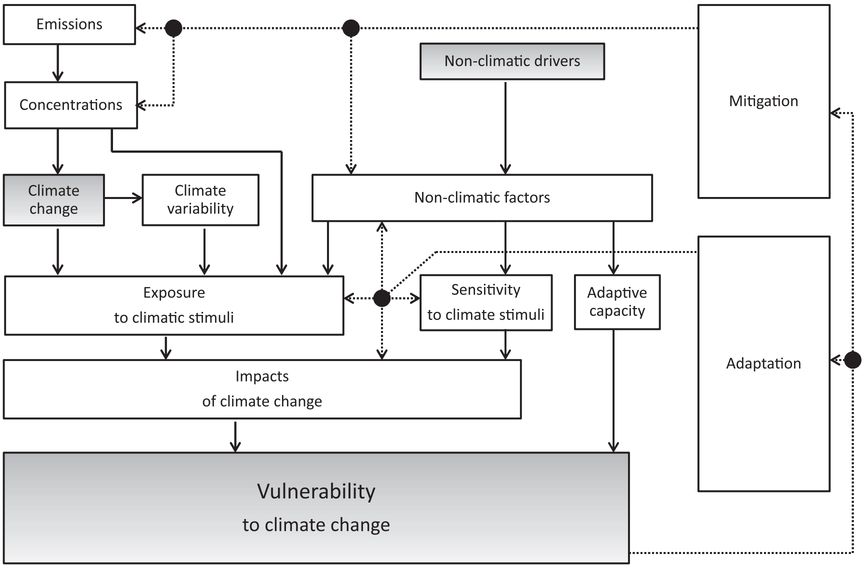

Figure 1.12 Conceptual framework for a second-generation vulnerability assessment
Source: Füssel and Klein 2006 (published in climatic change – cited in Chapter 1).

earthquakes or sea level rise (see Füssel, 2007, p. 158) is questionable. The discourse on disaster risk research for the past four decades has shown that the concept of vulnerability challenges the physical event-oriented understanding of risk. Hence, the analytic power of vulnerability is on the societal construction of risk, which would be clearly undermined by an integration of hazards or characteristics of the physical phenomena.

The IPCC SREX framework

The IPCC SREX was the first IPCC report to systematically bring together researchers and perspectives from disaster risk research and climate change science (see IPCC, 2012a, p. 545). Although different pre-analytic visions, epistemologies and frameworks were controversially discussed within the different expert meetings of the IPCC SREX report, the final framework presents a kind of consensus between the different schools of thought. The IPCC SREX figure (see Figure 1.13) – that interestingly was developed at the end by the technical support unit of the working group II of the IPCC, based on a longer discussion within a break-out group – shows that weather and climate events, for example,

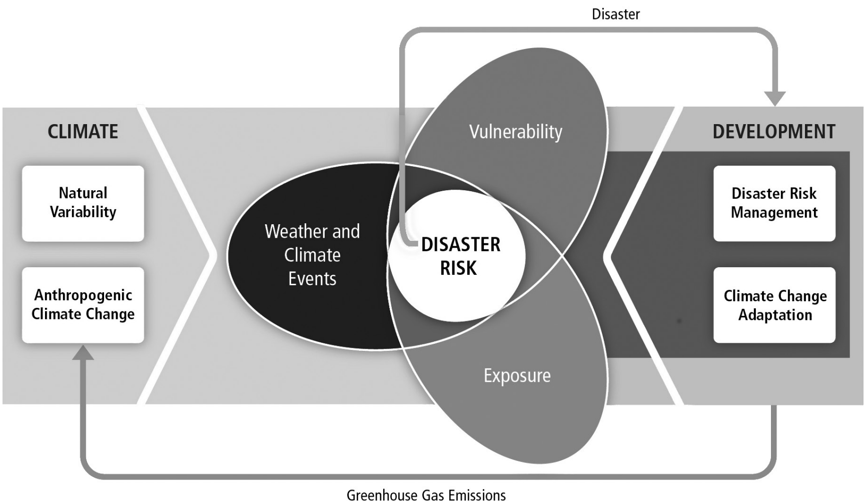

Figure 1.13 Framing of vulnerability and disaster risk in the IPCC SREX Report (IPCC, 2012)

so-called extreme events, do not necessarily lead to extreme impacts or disasters. Only when weather or climate events can affect exposed populations and assets that are potentially vulnerable to these impacts does disaster risk occur. In this regard, it is important to note that climate change and climate variability influence and drive climate and weather events, while development processes fundamentally shape and determine exposure and vulnerability of societies and social-ecological systems. Within development strategies, disaster risk management and climate change adaptation play a crucial role for reducing disaster risk.

In addition, socio-economic development processes can also increase anthropogenic climate change through greenhouse gas emissions, while at the same time disasters might also influence development processes. Overall, these interlinkages are particularly important to understand, since the assumption that extreme events directly create extreme impacts is rather problematic. The IPCC SREX framework underscores the necessity to focus on changes in the climate system, as well as to assess development processes and their implications for vulnerability and exposure in order to understand disaster risk. Particularly, Chapter 2 of the report outlines in depth the different factors and dimensions of vulnerability and exposure that present assessments take into account (see in depth IPCC, 2012a). Interestingly, the SREX framework significantly differs from former concepts used within the fourth IPCC assessment report, in the sense that physical causes such as the rate and magnitude of climate change which were part of the vulnerability definition in the AR4, are no longer associated with vulnerability. The SREX report acknowledges that a definition that makes physical causes and their effects an explicit aspect of vulnerability is misleading. Hence the report underscores that disaster risk in the light of climate change and extreme events is heavily determined by social conditions (see IPCC, 2012a, pp. 32–33).

Conclusions: frameworks of vulnerability

The discussion of different conceptual and analytical frameworks on systematizing vulnerability has revealed that different schools of thought and research fields have developed various conceptual frameworks for the assessment of vulnerability. However, it has still to be determined how far these frameworks can guide decision-making, or whether they are simply expressions of specific theoretical approaches. Based on the differentiation of: (a) basic/theoretical knowledge, (b) knowledge for orientation and (c) knowledge for decision-making (see BMBF, 2003, p. 15), it is evident that most frameworks examined provide an important bridge between (a) basic/theoretical knowledge and (b) knowledge for orientation. This means that conceptual frameworks of vulnerability are not intended to directly influence decisions or guide decision-making but are an important representation of theoretical and conceptual ideas on how to frame problems and characterize vulnerability at a meta-level. For example, the double structure of Bohle (2001) has strong links to different theories; it shows the entry points of different theories, and theoretical approaches on the double structure of vulnerability, while the concepts of vulnerability in climate change research (see Füssel and Klein 2006) were developed in close relation to policy discourses around climate change mitigation and adaptation. Hence, these frameworks show stronger links to knowledge for orientation. Furthermore, approaches that deal with the assessment of vulnerability in a holistic way (Cardona and Barbat, 2000), as well as concepts for assessing vulnerability in its various dimensions and with regard to a process-oriented view (Birkmann, 2006, Birkmann et al., 2013), bridge theoretical and orientation knowledge in the sense that they refer to theoretical approaches and concepts. At the same time, they provide a basis for systematizing and operationalizing abstract terms such as "vulnerability", "coping" or "adaptation".

The discussion of different conceptual frameworks showed that at least six different schools can be distinguished:

- The school of vulnerability frameworks that is rooted in political economy and particularly addresses issues of the wider political economy, such as root causes, dynamic pressures and unsafe conditions that determine vulnerability (for example, Wisner et al., 2004);

- Concepts that focus on the notion of coupled human-environmental systems and are linked to a social-ecological perspective and social-ecology as a research school (see for example, Turner et al., 2003; Becker and Jahn, 2006; Birkmann et al., 2013);
- Frameworks that aim to capture vulnerability within a holistic approach to risk (see for example, Cardona, 1999a and 2001; Cardona and Barbat, 2000; Carreño et al., 2005b and the BBC framework in Birkmann, 2006a);
- The MOVE conceptual framework that integrates adaptation and coupling processes into a feedback-loop system and a process-oriented perspective of vulnerability (Birkmann et al., 2013, based on Cardona and Barbat, 2000; Cardona, 2001);
- Frameworks of climate change vulnerability that focus on exposure, sensitivity and adaptive capacities as key determinants of vulnerability – including physical characteristics of climate change and climate variability (see review in Füssel and Klein, 2006 and Füssel, 2007);
- And finally, the combined framework of disaster risk research and climate change adaptation represented by the IPCC SREX concept emphasizes that development processes determine vulnerability and exposure, while climate change and climate variability influence extreme events – both generating disaster risk (see IPCC, 2012a).

Despite some similarities between the different schools of thought, such as the understanding that vulnerability is mainly concerned with the inner conditions of a society or community that make it liable to experience harm and damage, as opposed to the estimation of the physical event (hazard), it is important to acknowledge that different frameworks also represent different viewpoints. While the Turner et al. (2003) framework emphasizes the notion of human-environmental systems and PAR underscores the importance of root causes and the progression of vulnerability, the BBC and MOVE frameworks are particularly interested in feedback processes and interventions on how to reduce vulnerability and disaster risk. Consequently, different frameworks may also lead to different conclusions on how to address and reduce vulnerability. Nevertheless, many assessments hint towards some common vulnerability features, such as the issues discussed in the context of social vulnerability. Finally, the frameworks discussed in detail emerged from different methods used to assess vulnerability. While the framework of Cardona and Barbat (2000) is based on quantitative models and indicators, the double structure of vulnerability by Bohle (2001) emerged out of qualitative research. Combining quantitative and qualitative research methods in such frameworks for assessing vulnerability has still not been achieved sufficiently and remains an important task for future research.

In addition, there remain many areas for further discussion and research:

- Does vulnerability encompass exposure or should exposure be seen as a characteristic of the hazard, or even a separate parameter?
- How should the tangible and intangible aspects of vulnerability and its temporal and spatial dynamics at different scales be assessed?
- How can qualitative and quantitative methods be coherently combined or triangulated in vulnerability assessment at different scales?
- Which characteristics of vulnerability are hazard-dependent and which are hazard-independent?
- How can root causes and drivers of vulnerability dealing with different spatial and temporal scales be defined, coherently systematized and measured?
- Is resilience the flipside of vulnerability or is it an own concept that significantly differs in its conceptualization and in its view on crises and disasters?
- Should vulnerability focus primarily on human vulnerability alone or is it more appropriate to view vulnerability within multiple dimensions (for example, environmental vulnerability, institutional vulnerability etc.)?
- How far is environmental degradation a hazard or a revealed environmental vulnerability that also affects communities dependent on environmental services and resources?
- How can the various dynamics of vulnerability at different scales be captured while still being able to assess and measure vulnerability?
- How can different vulnerability factors and assessment results for decision-making processes be usefully visualized and illustrated?

Research challenges

Besides the challenge of differentiating between coping and adaptation, in the context of natural hazards and climate change there are also key challenges in the assessment and improved understanding of: (a) the dynamic changes of vulnerability and (b) the role of disasters as catalysts of change (resilience discourse). In this regard, for example, this volume examines changes in vulnerability to floods by different social groups before and after relocation. The concept of resilience and recent research emphasize that disasters or disaster risk might also influence development and socio-economic development pathways (see Birkmann et al., 2008; IPCC, 2012a), yet there is a limited acknowledgement of these interlinkages, reorganization and learning processes in present vulnerability assessments.

That means disaster events provide important laboratories and entry points for understanding those factors that have influenced the actual harm, loss and destruction. Although vulnerability assessment needs to be different from impact or needs assessment after a disaster, it is necessary to improve methods and tools for vulnerability assessment by more in-depth investigation of past disasters and their impacts. Apart from the examination of factors that contributed significantly to the emergence of a disaster, it will be key to improve knowledge of how and when disasters might also function as a catalyst for change and even for resilience-building. These aspects have not been sufficiently addressed in the past.

In this context Engle (2011) critiques assessments of vulnerability, adaptive capacity and resilience, finding that in many cases these assessments remain solely conducted at a single scale and often as snapshots in time without accurately capturing the dynamics of the system of interest (Engle, 2011, p. 651). Although this is a valid argument and issue, her contribution remains on an abstract level, without actually providing any practical guidance as to how one might capture and measure these dynamics at different scales. Nevertheless, the representation of these dynamics in conceptual frameworks and its analysis remains a key challenge for future research.

Furthermore, vulnerability research also needs to explore whether and how scenario techniques might be used in vulnerability assessment, since it is not very plausible to compare (as is done at present) future scenarios of climatic conditions with vulnerability patterns today. Thus, new research is also needed regarding the opportunities for (as well as the limitations of) using different scenario techniques in vulnerability and risk research.

Finally, future research needs to address the potential conflicts between the need for rapid and simple vulnerability assessments before and after disasters in countries and communities at risk, and the need to improve the understanding of the multifaceted nature of vulnerability, its root causes and its dynamics through longitudinal and in-depth studies of vulnerability – which are difficult to perform in crises contexts.

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2

Data, indicators and criteria for measuring vulnerability: Theoretical bases and requirements

Jörn Birkmann

Introduction

Approaches for measuring vulnerability need to be based on a systematic, transparent and understandable development procedure for dealing with the indicators and criteria used to assess vulnerability. A second challenge arises in view of the insufficiency of data that is available to measure vulnerability. Transparent information about the data used and their quality, as well as a systematic and understandable development process, are lacking in several of the current assessment approaches. Against this background, this chapter provides an overview of the main data sources dealing with disaster impacts, disaster risk and vulnerability linked to natural hazards and climate change. In addition, this chapter presents important quality criteria for such assessments and explains how to ensure that the development process of such assessments is sufficiently transparent, systematic and understandable. In this context, the theoretical foundation of indicators and the rational for developing indicators are also discussed.

Rationale behind measuring vulnerability and vulnerability indicators

The ability to measure vulnerability is an essential prerequisite for reducing disaster risk and for adaptation strategies, but it requires an ability

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both to identify and better understand exactly what are the various vulnerabilities that largely determine risk. The very complexity of the concept of vulnerability requires a reduction of potentially gatherable data to a set of important indicators and criteria that facilitate an estimation of vulnerability. The World Conference on Disaster Reduction (WCDR), held in Kobe, Japan, in 2005, stressed the need to develop vulnerability indicators. The final document of the WCDR, the Hyogo Framework for Action 2005–2015 (UN, 2005), emphasises that it is important to:

> develop systems of indicators of disaster risk and vulnerability at national and sub-national scales that will enable decision-makers to assess the impact of disasters on social, economic and environmental conditions and disseminate the results to decision-makers, the public and population at risk. (UN, 2005, p. 9)

Since the concept of vulnerability is multidimensional and often contains tangible as well as intangible characteristics, it is difficult – or perhaps even impossible – to reduce the concept to a single equation or to a universal set of indicators that could be applied at all levels and to all hazards (Wisner 2002; Downing, 2004, p. 18; Birkmann, 2006; Kienberger 2012; Birkmann et al. 2013). However, it is also important to note that global risk and vulnerability assessment approaches (see for example, Dilley (Chapter 8) or Welle et al. (Chapter 9) in this volume) have to be based on a common set of indicators but do not necessarily need to provide insights into local, specific aspects of vulnerability since these require additional or even different criteria, indicators and assessment methods (see for example, Birkmann, 2007).

In this regard, this book aims to provide insights into the different techniques and methodologies for measuring vulnerability at different scales and with different thematic focuses – and even different tools, such as quantitative indicators, indices and qualitative criteria. Although considerable research has already been undertaken, we often know too little about the advantages of the different approaches and methodologies, their applicability in different areas and their limitations.

Moreover, we are facing the problem that some areas of vulnerability, such as institutional or cultural vulnerability, encompass mainly intangible characteristics that are difficult to capture and quantify, even though they are perceived as important (see for example, Alexander 2000; Birkmann et al. 2013). That means we have to bear in mind the limitations of measuring and simplifying the complex interactions that provide a context for, and also shape, the various vulnerabilities. Morse (2004) argues in his book, *Indices and Indicators in Development: An Unhealthy Obsession with Numbers?*, that we have been far too cavalier with indicators: they are important tools, but one has to handle them with care.

Before presenting definitions of indicators and the theoretical foundation of indicator research, the following section introduces important databases that capture disaster impacts, vulnerabilities and different types of disaster risk.

Data for assessing vulnerability to natural hazards and climate change

The gathering of accurate, reliable and accessible data at different spatial scales for estimating and measuring vulnerability is a major task and challenge when applying vulnerability assessment concepts at various levels. Although the requirements for data needed for such an assessment depend on the specific approach used, after eight years of working in this area the author's conclusion is that current statistical data at the global level and in many countries, provinces or at the local level do not sufficiently account for vulnerability, especially people's ability to cope with and adapt to natural hazards and climate change. In addition to this observation, it is important to note that global and national vulnerability assessment approaches often require a larger amount of comparable statistical data to assess different characteristics of vulnerability than local or community-related approaches that can also be based on semi-quantitative or qualitative variables. These may also function independently from existing statistical data because they conduct their own qualitative surveys, or larger household surveys provide the information needed to estimate the vulnerability of different households. Some approaches also combine and triangulate statistical data with their own survey data in order to improve and validate the information gathered.

In addition to the local or national statistical data available in each community or country that might provide first insights into the demographic composition or educational issues of a community or nation, there are four main global databases that gather and systematize disaster information and the effects of past disasters due to natural hazards. These are: the EM-DAT database (Emergency Events Database) of the Centre for Research on the Epidemiology of Disasters (CRED) (see EM-DAT website: http://www.emdat.be), the DesInventar database (Sistema de Inventario de Desastres) (see DesInventar website: http://www.desinventar.org) and databases of larger reinsurance companies, such as the NatCatSERVICE of Munich Re (see website Munich Re 2001: NatCatSERVICE: http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/defaultaspx and the sigma databank and information system of Swiss Re.

While the EM-DAT database has existed since 1988 and contains information about more than 18,000 disasters since 1900, it focuses on direct disaster impacts of rather large disasters (more than 10 people killed or 100 affected), such as the number of people killed or persons missing and presumed dead, the number of people injured and affected. For some events information is also available on the loss of infrastructure.

Unlike EM-DAT, the DesInventar database was established to provide a methodology and infrastructure to monitor impacts and effects of large but also small and medium disasters and crises. DesInventar also provides local and provincial information about disaster impacts, while the large data banks of Munich Re or Swiss Re focus on single events and their distribution. In this regard DesInventar might provide more appropriate information for urban and spatial planning. Apart from the direct effects of disasters, such as the number of deaths and economic loss, losses in agriculture or the health sector etc. are captured (see in detail website DesInventar, 2012). In this regard, the DesInventar data provide a broader picture about different dimensions of vulnerability that might be revealed indirectly through such loss types. However, the DesInventar database mainly covers Latin America (overall approximately 37 countries), while the EM-DAT database has a larger global coverage (for additional information see also Lopez-Pelaez et al., 2011; Guha-Sapir et al., 2006; Tschoegl et al., 2006).

The NatCat Service of Munich Re also has a global coverage of disaster impacts and was launched in 1974. Munich Re classifies the disaster events according to an intensity scale that is based on the number of fatalities and/or financial losses in terms of property and structural damage (see Munich Re Methodology database website, 2011).

DesInventar

Until the mid-1990s, systematic information about the occurrence of daily disasters of small and medium impact was not available for Latin America. To fill this void DesInventar, which was established in 1994, aims at creating a common conceptual and methodological framework to assess disasters and disaster risk factors. Many key actors involved in DesInventar have close links with the Network of Social Studies on the Prevention of Disasters in Latin America (Red de Estudios Sociales en Prevención de Desastres en América Latina – LA RED). In order to be able to display information about disasters and crises with varying degrees of impact, DesInventar examines pre-existing data, newspaper sources and institutional reports in various countries in Latin America. DesInventar provides a toolkit for the construction of databases of loss, damage or effects caused by emergencies or disasters that includes a methodology, a database, software and often consultation processes with practitioners. In comparison to the global loss databases of Munich Re and SwissRe, DesInventar includes multihazard impacts in specific provinces or communities, giving it a stronger spatial focus, while NatCatSERVICE and sigma focus on the analysis of single events.

EM-DAT

Since 1988, the WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) has been maintaining an Emergency Events Database, EM-DAT. EM-DAT was created with the initial support of the World Health Organization and the Belgian government, aiming at supporting humanitarian action at national and international levels. EM-DAT contains core data on the occurrence and effects of over 18,000 mass disasters worldwide from 1900 to the present. The database is compiled from various sources, including United Nations agencies, non-governmental organizations, insurance companies, research institutes and press agencies. Today, the EM-DAT database is one of the largest empirical sources about the impacts of past disasters in different countries. It is used, for example, to validate risks indices or to examine the revealed vulnerability of countries in the past due to disasters. The focus of this database is clearly on rather large disasters that also cause fatalities while DesInventar also accounts for small and medium-sized crises.

NatCatSERVICE and sigma

The Munich Re database for natural catastrophes, NatCatSERVICE (NatCat) includes over 20,000 entries on material and human loss events worldwide (Munich Re, 2003). In addition to classifying each disaster and its location, the database contains information about the economic losses due to the specific hazardous event and the amount of insured losses. NatCat lists effects on people, such as being injured, homeless, missing, affected and evacuated (see Figure 2.1), that are also relevant for estimating revealed vulnerability. The damage to houses is registered, as well as the general impact on agriculture, infrastructure and lifelines (Munich Re, 2004).

Overall, Munich Re focuses primarily on damage and gives a precise picture of economic loss caused by hazards of natural origin. However, these data also have clear limitations when assessing social, economic and environmental vulnerability since the reported (economic) damage does not represent future or present economic vulnerability. Nevertheless, indicators of economic and social vulnerability can be tested and compared with the revealed vulnerabilities and loss data gathered by

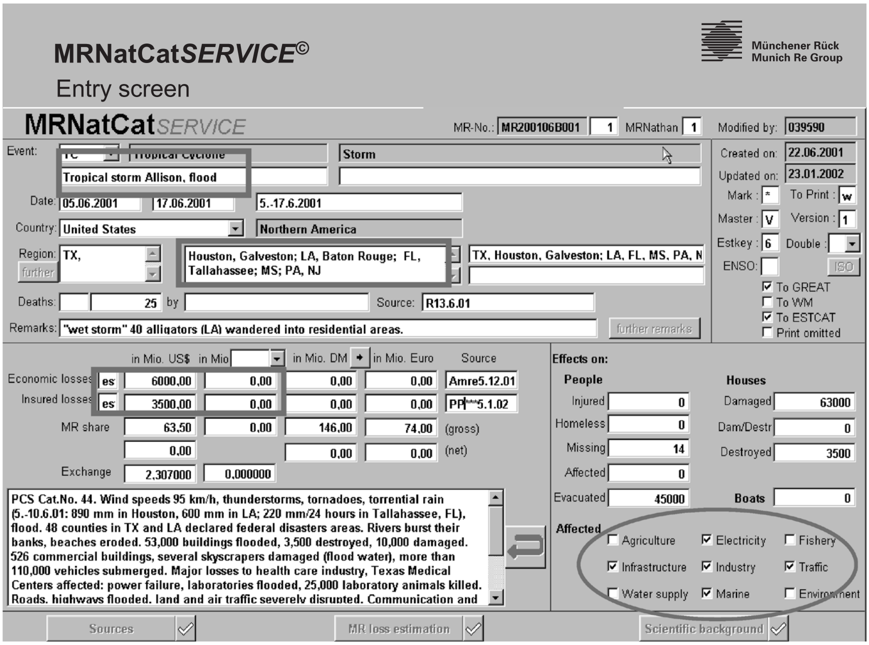

Figure 2.1 Example of the data gathered in the NatCatSERVICE
Source: MunichRe, 2004.

the NatCatSERVICE. In addition, SwissRe has developed a tool called "sigma" for accounting for and monitoring disaster risk loss. The data bank is not open to the public and focuses particularly on fatalities and economic loss due to natural hazards as well as on how much of the total loss was covered by insurance (see SwissRe 2012 website). Consequently, the approach is somewhat similar to the NatCatSERVICE of Munich Re.

Overall, the loss data banks of global reinsurance companies allow us to analyse and systematize different disasters and hazard phenomena, such as the most deadly and costly events. The most deadly events include the tsunami following the Sumatra quake (2004) and the Haiti earthquake (2010), while the most costly events, such as the Tohoku earthquake in Japan in 2011 and Hurricane Katrina in 2005, occurred in developed countries (see in-depth, Wirtz et al., 2012). Interestingly, the global loss databanks of Munich Re and SwissRe mainly capture direct economic loss while indirect loss is often not addressed – although losses due to interruptions to business and loss of production might be much higher than direct economic loss. While the direct losses due to the eruption of Vulcan Eyjafjallajökull in Iceland (in 2010) were rather minor, the indirect losses, for example to airline operators in Europe, were rather high due to aircraft being grounded for several days.

A general problem when using these data to estimate vulnerability is that reported damages predominantly focus on direct costs and losses, often excluding indirect losses, as well as the long-term socio-economic impacts of a disaster (Benson, 2004, p. 165). Additionally, the different definitions of the categories used in these statistics, such as "affected" or "injury" complicate matters when trying to make comparisons and analyses (Wisner et al., 2004, p. 65). However, recent changes to the structures of the NatCatSERVICE and EM-DAT and sigma data banks have made them more comparable. Nevertheless, it is still difficult to compare the (historic) data of the different data banks directly due to different standards, classification categories and data sources used. While these data banks are well developed for capturing tangible losses, they have limited capacities to account for intangible impacts, such as the loss of trust due to a disaster event, as in the aftermath of the Fukushima disaster (see for example, Meyer, 2011). This would require the use of different methodologies, such as questionnaires or data sampling through participatory approaches.

Interestingly, in the current literature one can find a debate about the appropriateness of social science methodologies for estimating vulnerability. While, for example Benson (2004), Hilhorst and Bankoff (2004) and other authors (see Wisner (Chapter 18) in this volume) emphasize the usefulness and benefits of using social science methods to measure vulnerability, Tapsell et al. (2002) argue that methodologies such as interviews and focus group approaches are often expensive and time consuming. However, Weichselgartner and Obersteiner (2002) point out that too little attention is being paid to the loss of local knowledge and traditional adaptation strategies that have been valid and useful in the past.

In this publication, the various approaches to measuring vulnerability show the different advantages and limitations that are implied in using methods that are either based on currently available data or that depend on gathering new data, for example through questionnaires and interviews.

Overall, it is evident that, besides the need to improve the data on the impacts of past disasters, more comprehensive and holistic approaches are essential that take into account the dynamic nature of vulnerability as well as trying to understand underlying causal factors of vulnerability at different levels for different hazards (Wisner et al., 2004; Vogel and O'Brien, 2004, p. 3). This shows the importance of distinguishing – especially from a scientific point of view – between damage, impact and vulnerability assessment. These aspects and the concept of indicators will be discussed in greater depth in the following sections.

Definition: indicator

Authors define indicators differently and one can find many ambiguities and contradictions regarding the general concept of an indicator. Within the discourse of measuring sustainable development, Gallopín (1997) developed a general, but at the same time quite comprehensive, definition. He defined an indicator as a sign that summarizes information relevant to a particular phenomenon (Gallopín, 1997, p. 14). A more precise definition views indicators as variables (not values) that are an operational representation of an attribute, such as a quality and/or a characteristic of a system (Gallopín, 1997, p. 14). Consequently, a vulnerability indicator can be defined as:

- A variable which is an operational representation of a characteristic or quality of an object or subject able to provide information regarding the susceptibility, coping and adaptive capacity and resilience of a system to an impact of an albeit ill-defined event linked with a hazard of natural origin.

It is important to remember that any indicator – whether descriptive or normative – has significance beyond its face value: i.e. the relevance of an indicator for estimating a certain characteristic of a system arises from the interpretation made about the indicator and its relationship to the phenomenon of interest (indicandum). Therefore, assigning a meaning to a variable and defining the indicating function of the indicator makes an indicator out of the variable (Birkmann, 2004, p. 62; Birkmann, 2006; Gallopín, 1997, p. 16). In principle, an indicator can be a qualitative variable (nominal), a rank variable (ordinal) and/or a quantitative variable (Gallopín, 1997, p. 17; Birkmann et al., 1999).

Current definitions of vulnerability indicators and the use of the terminology in this area are particularly confusing. Downing stresses the fact that the indiscriminate use of indicators for measuring vulnerability – pick any that seem to be relevant and/or available – must be avoided; rather, it is important to define and develop at least an implicit model to serve as a systematic basis for indicator development and selection (Downing, 2004, p. 19). Present concepts range from macroeconomic vulnerability estimation to assessment tools that focus on individuals (people or households) (see for example, Benson, 2004). The approaches presented in this volume cover a broad range of different assessment methodologies and concepts: from global vulnerability and risk assessment using quantitative approaches to national and local assessments that also encompass own household survey data or purely qualitative approaches.

The UN/ISDR suggests that measuring progress towards disaster risk and vulnerability reduction in a country or region requires different frameworks at different timescales (UN/ISDR, 2004, p. 396). This means that various concepts and methods of vulnerability assessment are not only shaped by the different scientific disciplines from which they are derived, but they are also necessary in order to capture the multifaceted nature of vulnerability to different hazards and climate change stressors, such as earthquakes, floods and droughts etc. (for example, Leary et al., 2005, pp. 1,4; Downing, 2004, pp. 18–21).

Indicator development: a historical overview

Developing and using indicators is not a new phenomenon. Economic indicators had already emerged in the early 1940s (Hartmuth, 1998; Reich and Stahmer, 1983). Today, economic indicators such as gross domestic product (GDP) or unemployment rate are broadly used (and politically accepted) to estimate and communicate the state and evolution of an economy. In the 1960s and 1970s, the development of social indicators was a hot topic in the social sciences (Cutter et al., 2003, p. 244) which crossed over into the political and social arena during the protest movements in the 1960s in the United States and Western European countries (for example, Empacher and Wehling, 1999, p. 14; Habich and Noll, 1994). The development of environmental indicators followed in the 1970s (see for example, Werner, 1977 and OECD, 1993), linked to the establishment of environmental policies. The last big impetus for indicator development emerged from the discussions about sustainable development (see UN, 1993; UNCSD, 1996; UN, 2002) as well as green and inclusive growth (Rio +20 process). In this context, various approaches to defining and operationalizing sustainable development with indicators were undertaken (UNCSD 1996; Birkmann, 2004, p. 61). However, no precise consensus emerged regarding the definition of indicators.

Indicators, goals and data

Some authors define indicators in relation to an aggregation process, starting with variables or basic data, followed by processed information and indicators, finally ending up with highly aggregated indices (for example, Adriaanse, 1995). However, defining indicators in terms of the level of aggregation is not appropriate, since an indicator can be a single variable, as well as a highly aggregated measure – for instance the result of a complex computer model. The *UN World Water Development Report* (WWDR) for example makes it clear that an indicator can be a single piece of data (single variable) or an output value from a set of data (aggregation) that describes a system or process (United Nations

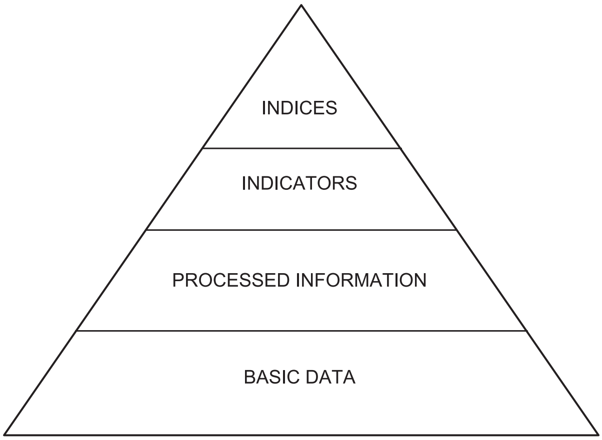

Figure 2.2 The data pyramid
Source: Author, following Adriaanse, 1995: 5.

Educational, Scientific and Cultural Organization [UNESCO], 2003, pp. 3 and 33). Overall, the definition of indicators based on the level of aggregation (Figure 2.2) neglects an essential aspect: goals.

Every indicator-development process needs to be related (explicitly or implicitly) to goals, or at least to a vision which serves as a basis for defining the *indicandum* (state or characteristic of interest). To develop scientifically sound indicators, it is necessary to formulate goals that serve as a starting point for the identification of relevant indicators. It is essential to acknowledge that the main interest is not in the indicator itself but in the *indicandum*. The close link between the indicator and the *indicandum* should be recognized. The quality of the indicator is determined by its ability to indicate the characteristic of a system that is relevant to the underlying interest determined by the goal or guiding vision. The link between the indicator and the *indicandum* should be theoretically sound. The interrelation between indicators, data and goals is illustrated in Figure 2.3, showing that any indicator development must collect data as well as formulate goals that define the underlying interest.

The figure illustrates the fact that the assumptions and judgements made in selecting relevant issues and data for the indicator development, as well as the evaluation of the indicator's usefulness, require the existence of goals, whether implicit or explicit. In the case of vulnerability indicators, general goals would include, for example, reducing the vulnerability of potentially affected communities to hazards of natural origin. More precise goals could be to reduce human fatalities or increase the financial capacity of households in order to reduce vulnerability and

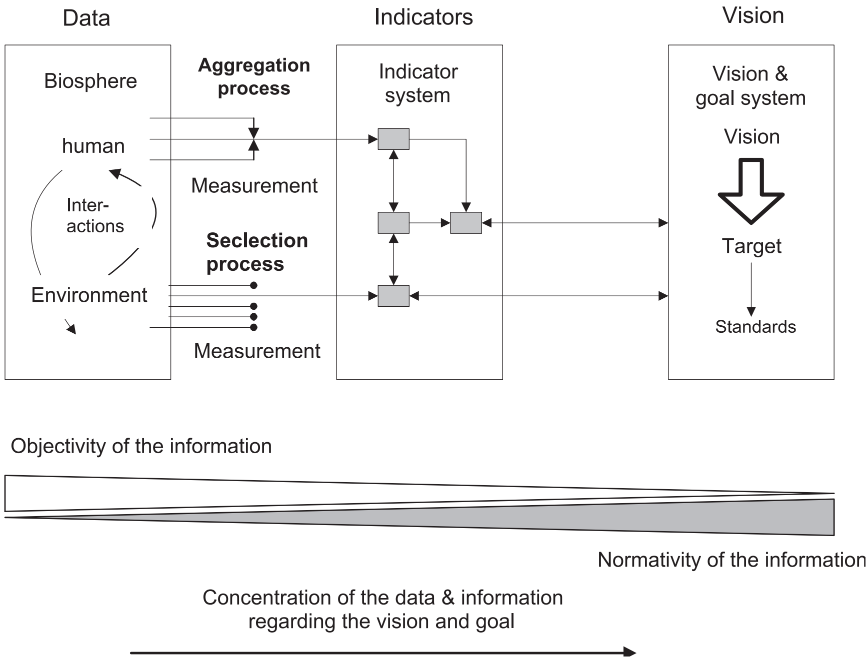

Figure 2.3 The model of the three pillars: indicators, data and goals
Source: Birkmann, 1999: 122.

improve their potential for recovering from economic loss due to a hazardous event (see for example, UNDP, 2004). In practice, one can distinguish two main types of indicator–goal relations (Weiland 1999, p. 252):

- In the first case the indicator focuses on the direction a development is taking. The assessment of the development trend allows one to evaluate its vulnerability; in other words, an increasing or decreasing development trend indicates a higher or lower vulnerability.
- In the second case the indicator focuses on a specific target that shows whether the state or the development has reached a defined value. This requires precise goals for the indicator. One has to be able to define whether or not a specific value indicates vulnerability.

The insurance industry, for example, is able to estimate precisely a value for potential economic loss to a firm or a household due to a specific event, such as a flood event of the magnitude HQ 200, and so to calculate the insurance risk (for example, Kron, 2005, p. 66). In contrast, the definition of a single value to estimate social vulnerabilities, for example, is often problematic and needs additional interpretations, such as the Social Vulnerability Index (SoVI) developed by Cutter et al. (2003, p. 249) for the United States (see in detail Cutter and Morath (Chapter 12) in this volume). Furthermore, regarding the environmental dimension, one should note that it is nearly impossible to derive values for environmental vulnerability (for example, groundwater, air, soil conditions) solely on the basis of natural sciences. Goals for environmental services and qualities depend also on the definition of the specific ecological function assigned to an area by the local community or the state, which means that quality standards also have to be based on specific sub-national and local contexts (Finke, 2003, p. 158; Kuehling, 2003, p. 2). However, there is often a lack of established environmental standards and thresholds for so-called tipping points of social-ecological systems (see for example, Renaud, Chapter 3 in this volume).

Since vulnerability assessment and deciding whether a value shows a high or low vulnerability are complex tasks, many approaches apply a relative vulnerability assessment perspective – meaning that these approaches compare and interpret vulnerability between different groups, entities and geographic areas in order to assess it. Due to the lack of precisely defined targets of vulnerability reduction in many cases, trend evaluation and comparison is a useful strategy for estimating high or low vulnerabilities. Examples of this approach include the Disaster Risk Index, the Hotspot project approach, the Americas project and the WorldRiskIndex and the SoVI (see Chapters 7–10 and 12 in this volume). All these approaches focus mainly on a single or composite indicator to measure and estimate vulnerability and risk. As an alternative, Downing et al. (2005) propose viewing the vulnerability of socio-economic groups as a profile rather than merely as a single, composite number. The idea of vulnerability profiles is, for example, applied in the analysis of vulnerability to resettlement (see Birkmann et al., Chapter 21 in this volume).

Functions of vulnerability indicators

Wisner and Walter (2005) emphasize that gathering data and information has to serve the aggregation of knowledge (i.e., the understanding of how things work or are supposed to work), which in turn is essential for being able to make the right choices. Wisner stresses that the entire process always has to aim at the final level of what he calls “wisdom”, which allows for sound decision-making – that means making a value judgement based on experience, understanding and principle (Wisner and Walter, 2005, p. 14).

In terms of a more specific focus on vulnerability indicators, one can say that their usefulness is determined by their success in achieving their objective and function, such as identification and visualization of different characteristics of vulnerability, or evaluation of political strategies and monitoring of their implementation. In this context, Benson (2004) points out that measuring vulnerability across countries, within countries and between different events linked to different hazards helps to create an understanding of factors contributing to vulnerability, although the often used ex-post focus cannot be directly equated with future vulnerability (Benson, 2004, p. 159). According to Benson, the identification and the understanding of vulnerability and its underlying factors are important goals and functions when measuring vulnerability.

Queste and Lauwe (2006) as well as Fleischhauer (2004) stress that vulnerability measurement and risk assessment are needed for practical decision-making processes, such as providing disaster managers with appropriate information about where the most vulnerable infrastructures are (see Queste and Lauwe, 2006) or advising planners about how to systematically consider risk and vulnerability aspects to climate change in planning processes. They argue that indicators should enable the administration or specific stakeholders at different levels to integrate vulnerability reduction strategies into preventive planning. While Benson (2004) views the primary function of vulnerability measurement as serving the desire for knowledge of understanding, practitioners argue that indicators should also inform and guide decision-making. In this context, Green believes that the primary interest in defining and measuring vulnerability lies in the goal of reducing it (Green, 2004, p. 324). If we cannot reduce vulnerability, the development of indicators and assessment tools would be of minor interest for political decision-makers and practitioners. Also, development and aid agencies, such the International Federation of the Red Cross or the Alliance Development Helps, stress that tools for measuring vulnerability and coping capacity are essential in order to design appropriate disaster reduction strategies and to achieve better targeting of external assistance to those countries most in need of outside help to overcome disasters (see Federation of the International Red Cross; Alliance Development Helps, 2012; Billing and Madengruber, 2006). Additional functions of indicators and assessment tools for measuring vulnerability were derived through a "straw poll" at the first meeting of the Expert Working Group of United Nations University Institute for Environment and Human Security (UNU-EHS) Kobe (Birkmann, 2005). The experts present at the workshop in Kobe defined the following functions (Birkmann, 2005, p. 13) as most important for vulnerability indicators:

- Setting priorities;
- Background for action;
- Awareness raising;
- Trend analysis;
- Empowerment.

These functions primarily address practical aspects, such as "awareness raising" and "promoting background for action". The literature on functions of indicators often encompasses more traditional features such as simplification (reduction of complexity), comparison of places and situations, anticipation of future conditions and assessment of conditions and trends in relation to goals and targets (Gallopín, 1997; Tunstall, 1994).

Besides the discussion of major functions of indicators, and of vulnerability indicators in particular, the analysis of the process of indicator development and a systematic assessment is important in order to understand the different phases and judgements that the construction of indicators and criteria as well as respective assessments are based on.

The ideal phases of indicator development

In general, one can distinguish nine different phases in the development of indicators which also apply to the development of vulnerability indicators. According to Maclaren (1996), indicator development starts with the definition or selection of relevant goals. Then it is necessary to carry out a scoping process – clarifying the scope of the indicator by identifying the target group and the associated purpose for which the indicators will be used (goals and functions). It is also important to define the temporal and spatial bounds, which means identifying the timeframe over which indicators are to be measured and determining the spatial bounds of the reporting unit (community, sub-region or socio-economic regions, biogeographical zones or administrative units).

The third phase involves the identification of an appropriate conceptual framework, which means structuring the potential themes and indicators. The different approaches to measuring vulnerability presented in this volume encompass various conceptual frameworks: such as those that focus on sectors (Villagrán de León); issue-based frameworks that focus, for example, on different factors of vulnerability (see Welle et al. (Chapter 9), Pelling (see review in Chapter 6) or on fatalities and economic losses (see Dilley (Chapter 8)); or causal frameworks, such as the one proposed by Turner et al. (2003) or by the MOVE framework (see Chapter 1 in this volume). Which framework may be most appropriate for structuring vulnerability indicators depends on the purpose for which the indicators will be used, as well as on the target group and, finally, on the availability of data.

The fourth phase implies the definition of selection criteria for the potential indicators. Although the scientific debate about indicators has led to a set of general criteria for "good-quality" indicators, such as "scientifically valid", "responsive to change" and "based on accurate and accessible data", it is necessary to link these to the theme, function and goal of the specific approach. These criteria have to be interpreted, for example, in terms of data accuracy and data accessibility. According to Benson (2004, p. 169), most disaster risk data are incomplete and based on historical disasters (past events), while the factors determining the outcome of future events are highly complex and can differ from those already experienced. Hence, it is crucial that all approaches aiming at measuring vulnerability find the right balance between the accuracy of data and the limited data available.

The identification of a set of potential indicators (phase 5) is a key step in indicator development. Thereafter, follows a sixth phase that encompasses the evaluation and selection of each indicator with reference to the criteria developed at an earlier stage, resulting, finally, in a set of indicators.

The collection of data for the indicator has to be followed in order to validate the applicability of the approach. This phase can often be the most difficult one, especially since vulnerability is characterized by many intangible factors and aspects which are difficult to capture or which can be measured only indirectly, such as social networks, confidence, trust and apathy, and institutional aspects such as good governance, appropriate early warning and appropriate legislation (Bogardi and Birkmann, 2004, p. 79; Cutter et al., 2003, p. 243). An interesting example of the challenges and limitations of assessing institutionalized capacities and practices in order to reduce flood disaster risks is given by Lebel et al. (Chapter 19 in

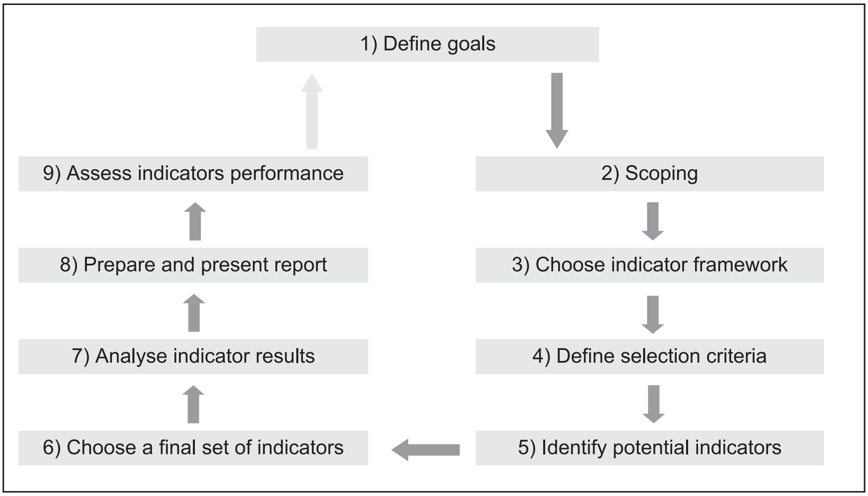

Figure 2.4 Development process of vulnerability indicators
Source: Based on the general figure according to Maclaren, 1996: 189.

this volume). The final phases of the indicator development can be seen in the preparation of a report and the assessment of the indicator performance (Maclaren, 1996, p. 184). According to Maclaren, the whole development process is an "ideal process", which in practice is characterized by an iterative procedure of going backwards and forwards. Nevertheless, the distinction between different phases of indicator development is helpful in order to analyse and understand current approaches and their development processes, including the underlying assumptions.

Quality criteria for indicator development

The development of indicators to measure vulnerability has to be based on quality criteria that support the selection of sound indicators. Standard criteria for indicator development prescribe, for example, that indicators should be "relevant", "analytically and statistically sound", "reproducible" and "appropriate in scope", while participatory indicator development often focuses on criteria such as "understandable", "easy to interpret" and "policy-relevant". In contrast, practitioners often emphasize that indicators that have to be applicable in practice should be "based on available data" as well as "cost effective" (Birkmann, 2004, p. 80; Gallopín, 1997, p. 25; Hardi, 1997, p. 29).

The different priorities and weightings of these criteria can also be viewed in current approaches to measuring vulnerability presented in this volume. While, for example, international indexing projects define the availability of already existing data as a key criterion for providing useful global information to allow comparison of different countries, the method of self-assessment of vulnerability and coping capacity presented by Wisner in this volume does not focus on available statistical data but on people's knowledge and policy-relevant recommendations (see Chapter 18).

Overall, one has to conclude that the quality criteria for indicator development presented here are general guidelines. Specific approaches might have to define their own priorities and have to weigh the different criteria according to their specific needs and functions. However, one of the most difficult points in measuring vulnerability is the gathering of appropriate quantitative and qualitative data.

Damage, impact and vulnerability assessment

In the literature and in practice, vulnerability, impact and damage assessment are often mixed or used synonymously. Although damage and impact assessments can overlap with vulnerability assessment, they generally imply different approaches. Damage assessment is based on the calculation of real losses, such as fatalities, economic loss and damage to the physical infrastructure. In contrast, impact assessment is not necessarily limited to loss or negative impacts (one impact category); it can also encompass positive impacts for social groups, specific economic sectors or the environment that result from an event linked to a hazard or from climatic change. For example, in the aftermath of the Indian Ocean Tsunami, both the construction industry and local carpenters actually benefited from the overall need for enormous reconstruction efforts. Also after the Fukushima crises, the political developments in Germany with respect to changes in energy policies might be seen by some groups as positive long-distance impacts.

According to Vogel and O'Brien (2004), impact assessment has traditionally been used to document the potential consequences of a particular event (for example, drought), while vulnerability assessment should focus also on the factors – of human or environmental origin – that, together or separately, drive and shape the vulnerability of the receptor – for example, a community (Vogel and O'Brien, 2004, p. 2).

Furthermore, Wisner et al. (2004) and Benson (2004) point out that a major difference between damage assessment and vulnerability assessment is the time dimension. While damage assessment is often conducted as a rapid survey to provide information upon which to base appropriate

Box 2.1 Standard criteria for indicator development

- measurable
- relevant, represent an issue that is important to the relevant topic
- policy-relevant
- only measure important key-elements instead of trying to indicate all aspects
- analytically and statistically sound
- understandable
- easy to interpret
- sensitivity; be sensitive and specific to the underlying phenomenon
- validity/accuracy
- reproducible
- based on available data
- data comparability
- appropriate scope
- cost effective.

(see EEA, 2004; Birkmann, 2004; NZOSA, 2004 (Internet); Berry et al., 1997; Parris, 2000) and fast responses, such as direct humanitarian aid (Wisner et al., 2004, p. 13, 128; Benson, 2004, pp. 164), vulnerability assessment should focus on the likelihood of injury, loss, disruption of livelihood and other harm in an extreme event (Wisner et al., 2004, pp. 13; Wisner, 2002). This means the focus of vulnerability assessment should be on the identification of the variables that make people vulnerable and that show major differences in the susceptibility, coping and adaptive capacities of people. While damage and impact assessments are based on an ex-post evaluation of revealed losses, vulnerability assessment can and should be a forward-looking concept, taking into account the likelihood of injury, loss and disruption (Wisner, Chapter 18; Vogel and O'Brien, 2004, p. 3; Benson, 2004, p. 167).

Vulnerability, then, cannot be estimated adequately solely through data based on past events. On the other hand, many indicators and criteria for measuring vulnerability often need to be linked, developed and tested on the basis of analysing past events and their impacts (damage patterns and revealed vulnerabilities). Various approaches presented in this volume have dealt with this complex problem: they aim to measure vulnerability through a forward-looking perspective but often have had to use data based on and linked to past events in order to derive sophisticated indicators and criteria to estimate vulnerability. Even the assessment of institutional capacities of risk reduction has to deal with this challenge: namely, that the appropriateness and effectiveness of institutional capacities to reduce risk and vulnerabilities only become evident under stress and disaster conditions (Lebel et al., Chapter 19). In order to illustrate the variety of current approaches to measuring vulnerability, a brief overview of selected approaches presented in this book will be given next.

Overview and classification of selected approaches

The following list, encompassing a systematization of selected approaches in this volume, shows their main characteristics. It is not intended to be comprehensive. The systematization and comparison is based on the following criteria:

- Spatial level of the approach;
- Function of the approach;
- Thematic focus regarding vulnerability;
- Data basis;
- Target audience;
- Link to goals;
- Level of aggregation.

Table 2.1 Overview and systematization of selected indicator approaches to measure vulnerability

Criteria	WorldRiskIndex (Chapter 9)	Social Vulnerability Index (SoVi) (Chapter 12)	Vulnerability to Natural Hazards and Climate Change in Mountain Environments (Chapter 14)	CATSIM Model (Chapter 20)	Community-based Disaster Risk Index (Chapter 15)	Self-Assessment (Chapter 18)
Spatial level	Global (national resolution)	Sub-national level (applied in USA)	Mountain regions in the Alps (sub-national level, NUTS 3-regions)	National level	Municipal level	Local community (individual or group resolution)
Function of the approach	Identification of vulnerability and risk, comparison of vulnerability and risk between countries	Identification of vulnerability and key factors that determine vulnerability in different states in the USA	Identification of vulnerability, analysis of potential intervention tools to increase adaptive capacities	Identification of fiscal vulnerability and resilience, awareness raising	Identification and knowledge generation, empowerment of people, promoting gender equity	Identification of vulnerability and capacities of people to deal with natural hazards and adverse events, empowerment of people
Thematic focus on vulner- ability	Social vulnerability, environmental, economic vulnerability governance/ institutional vulnerability, in addition analysis of selected hazards and people exposed, differentiation of coping and adaptation	Vulnerability encompasses: demographic characteristics (e.g. age); socio-economic characteristics, such as per capita income and ethnic characteristics, such as percentage of African Americans etc.	Vulnerability is specified through the analysis of potential impacts and the adaptive capacity of a community or region	Fiscal or financial vulnerability of the public sector (subset of economic vulnerability)	Vulnerability re- garding physical, demographic, social, economic and environ- mental assets	People, their assets and resources plus applications to address root causes
Data basis	PREVIEW Global Risk Data on natural hazard exposure, such as for floods, droughts and earthquakes etc.; data on vulnerability are based on various internationally available data sources, such as data of the World Bank, WHO or UNICEF and FAO or Transparency International (see in detail Chapter 9).	Statistical data (e.g., US Census data) and expert knowledge	Climate Change Scenario data at EU Level, statistical data, such as demographic data, and qualitative data through expert interviews	National data	Questionnaire- based data	Focus group discussions

Target group	International community and national states, International NGOs, media	Disaster risk management, the general public and decision-makers at sub-national and local level	Institutions in charge of adaptation in the region (South Tyrol) and the stakeholders involved in different sectors	Public authorities and private sector	Local population, local government	People at risk
Link to goals	Linked to different goals that are the basis for the different indicators and their explanatory value for vulnerability and risk	Many indicators are linked to certain goals, such as poverty reduction. However, these goals are not explicitly mentioned or formulated	Classification of vulnerability of e.g., the agricultural sector involves the consideration of goals indirectly. Also, the dimensions and indicators selected refer indirectly to goals	Scenarios, no direct link to goals	Classification of vulnerability (low, medium and high), no direct link to goals	No direct link to goals
Level of aggregation	High	High, medium, (the multi-risk map as well as the map on potential vulnerability to climate change involves several indicators and are therefore classified as high/medium aggregated)	High, (aggregated values for sub-regions and for specific sectors, e.g., agricultural sector)	Medium, financial gap compared to other potential aid and income sources	Medium, high indicators and index (47 single indicators, aggregation into 4 factor scores and 1 risk index)	Low, no aggregation

Source: Author.

Final remarks and key questions

The following conclusions reflect the foregoing discussion and raise some important questions which provide guidelines for further investigation of current approaches.

The formation of a theoretical basis of indicator development, the analysis of current data sources regarding crises and disasters – such as EM-DAT, DesInventar, NatCatSERVICE and sigma – and the examination of differences between damage, impact and vulnerability assessment have revealed that vulnerability assessment must go beyond the assessment of (direct) damages. Vulnerability assessment should focus on the characteristics that determine the likelihood of injury, loss and other harm, as well as the capacity to resist and recover from negative impacts – (coping), and even the ability to adjust or transform livelihoods and development strategies (adaptation). However, developing a more sophisticated approach to measuring vulnerability – one that promotes a forward-looking perspective – is still a challenge. For practical reasons, and also for validation of vulnerability characteristics, vulnerability assessments often also need to take into account damage known to have occurred in the past. Therefore, the strict separation between damage, impact and vulnerability becomes less rigid in the course of practical application. Nevertheless, it is important to keep in mind the differences and also to indicate how vulnerability is distinguished from a "pure" damage and impact assessment approach. Equally important is a precise understanding of what the approach focuses on in terms of "vulnerability" – vulnerability to what and vulnerability of what. In this context, it is essential to focus on the definition and perception of what is meant by vulnerability in a specific approach, such as the Disaster Risk Index, the WorldRiskIndex, the SoVI and the CATSIM model – to name just a few approaches presented in this volume.

Furthermore, the presentation of the theoretical bases has shown that there is a difference between the indicator and the *indicandum*. Thus, it is important to check whether the intention and conceptual framework of measuring vulnerability (intended *indicandum*) also correspond with the selected indicators, implying a need to examine how the perception of vulnerability in the approach corresponds with the revealed vulnerability.

One of the most important goals in developing tools for measuring vulnerability is to help bridge the gaps between the theoretical concepts of vulnerability and day-to-day decision-making. In this context, it is interesting to learn about the target group of any particular approach – the group that is expected to use the results of the measurement tool. These questions are linked with the overall function of the approach. For example, is the approach mainly intended to provide knowledge for understanding, or is it aimed at informing decision-making processes (knowledge for action)? Finally, the author also recommends keeping in mind that every approach to measuring vulnerability is based – explicitly or implicitly – on a vision or goals.

Based on these ideas, the following questions arise when more closely examining the various approaches presented in this book:

- What is meant by vulnerability in the specific approach?
- What is the pre-analytic view and conceptual framework of the approach?
- What criteria and indicators are used to measure vulnerability?
- How does the approach simplify the complex concept of vulnerability?
- What purpose and functions should the approach serve?
- How are vulnerability, exposure, coping and adaptive capacities addressed?
- How do perceptions of vulnerability (hypotheses of main characteristics and driving forces) compare with the revealed vulnerability in disasters?
- Does the selection of indicators reflect the conceptual framework of vulnerability?
- How far is the approach applied in decision-making processes?

The variety of approaches presented in this book allows for a comparison between various conceptual frameworks, methodologies and tools to measure vulnerability.

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Part II

Vulnerability and environmental change

3

Environmental components of vulnerability

Fabrice G. Renaud

Introduction

The Hyogo Framework for Action (HFA) considers environmental degradation among many other factors that contribute to disaster risk. The HFA, through its fourth priority of action, "reducing the underlying risk factors", specifically highlights the role of ecosystems and ecosystem management in terms of disaster risk reduction (ISDR, 2005). The 2009 Global Assessment Report on Disaster Risk Reduction (UN, 2009) discusses the decrease in regulating ecosystem services (as described by the Millennium Ecosystem Assessment, MA, 2005) – at the expense of provisioning services – with typically differential impacts for different wealth groups, particularly when poorer segments of a population rely on environmental resources for their livelihoods. In this context, the degradation of ecosystems potentially constitutes a double threat for poorer people: it contributes to a decrease in protection with respect to given hazards (for example coastal vegetation buffering the effects of storm surges) and adds to difficulties in sustaining a livelihood when the latter is dependent on fully functioning ecosystems. Superimposed on this, degradation of ecosystems contributes to affecting characteristics of some hazards, such as their timing, frequency and magnitude, in addition to increasing the vulnerability of exposed communities (Renaud et al., 2013a; UNEP, 2008).

Vulnerability is a component of the risk equation and is a complex concept. The term is used very loosely depending on the user's background and the context within which it is used (Thywissen, 2006; Chapter

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

24). One definition is that “vulnerability is the intrinsic and dynamic feature of an element at risk that determines the expected damage or harm resulting from a given hazardous event and is often even affected by the harmful event itself” (Thywissen, 2006:34). Vulnerability of communities to natural and anthropogenic hazards is approached from a multidimensional perspective that encompasses environmental, social and economic viewpoints and incorporates features such as susceptibility, exposure and coping capacities (see Birkmann, Chapter 1 in this volume).

When assessing the vulnerability of communities, the role of ecosystems cannot be separated from their social and economic dimensions because of the interconnectedness between human beings and the environment: human beings shape their environment while the environment plays a major role in shaping the economic activities and social norms of human beings. The concept of mutuality allows for a better understanding of how humans create their vulnerability to given hazards, and if this conceptual approach is used, vulnerability assessment captures the multidimensionality of disasters (Oliver-Smith, 2004).

Several existing vulnerability assessment frameworks incorporate the notions of ecosystems, ecosystem services and/or, more generally, environmental dimensions and their interactions with social and economic systems within their conceptualization (for example, Turner et al., 2003 – see Chapter 1 in this volume), but the extent to which this is done and the nature of the interactions considered vary from framework to framework. This interaction is best captured by considering social-ecological systems (SES) as a unit of analysis whereby an SES is defined as a system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction (Gallopín, 2006). Renaud et al. (2010) showed how subcomponents of an SES can synergistically reduce the vulnerability and increase the resilience of systems exposed to external shocks and how decisions can be taken to increase the resilience of the system for adapting to perceived new threats.

The following sections provide examples of ecosystem services in the context of environmental hazards, illustrate the links between degradation of ecosystems and hazard characteristics, and show the intricate linkage between ecosystems, livelihoods and vulnerability. For the most part, examples from work carried out in the aftermath of the December 2004 earthquake and tsunami in Sri Lanka are used to illustrate these concepts.

Ecosystem services in the context of environmental hazards

In most vulnerability assessment frameworks, the environmental dimension of vulnerability is primarily seen through an anthropocentric lens whereby the environment is a provider of services to humans; and it is the loss of capacity to satisfy human needs or the lack of entitlement to these services that are considered as to increase the vulnerability of communities to external or internal stresses. The Millennium Ecosystem Assessment report (MA, 2005) highlights the fact that human impacts on various ecosystems are such that the capacity of the latter to provide services is seriously affected in many parts of the world. By impacting directly on resources such as water, soil or the air, environmental degradation processes increase the vulnerability of communities facing environmental hazards and can constitute a hazard to populations. The concept of mutuality mentioned above (Oliver-Smith, 2004) or the coupled human–environment (or social-ecological) systems described by Turner et al. (2003) require more than just a description of loss of services from various ecosystems. They also call for understanding the dependencies of communities with respect to essential services provided by given ecosystem functions, their entitlements with respect to these resources (for example, Adger and Kelly, 2001) as well as of the sensitivity of the ecosystems to a specific hazard.

Components of ecosystems play different roles depending on the type of hazard considered and the livelihoods of communities. For example, rural communities rely much more on soils for their direct livelihoods (for example to grow crops or sustain pastures) than do urban settlers (although the latter also depend on soil resources as they purchase products that have grown on them). Furthermore, a vegetation strip (for example a mangrove ecosystem) plays different roles depending on whether we are considering a tsunami or an earthquake hazard.

If vulnerability assessment is carried out before the impact of an event (which is the primary goal), then the role and state of ecosystem components can be determined, indicating their capacity to provide the required services to communities. In some cases, vulnerability assessment is only carried out after an impact, particularly for hazards with typically long return periods. This was, for example, the case following the December 2004 tsunami that destroyed many coastal regions in South East Asia, South Asia and in Eastern Africa. Although some people knew before the day of the disaster that a tsunami could take place in the region, nobody paid much, if any, attention to this hazard before it tragically manifested itself. In the follow-up of the disastrous event, many organizations were involved in post-tsunami activities including vulnerability assessment, hoping to draw valuable lessons from this disaster. Within this context, an assessment reveals the new vulnerability of the affected communities as, according to the definition given in the introduction, vulnerability of a system is affected by a hazardous event. From an ecosystem perspective, an impact assessment can also reveal valuable information

Figure 3.1 Along the coast, Galle, Sri Lanka
Source: Author.

as to the role, exposure and sensitivity of important environmental resources in relation to a given hazard.

Examples of ecosystem services in the context of the 2004 tsunami

Examples of services provided by ecosystems are presented here using tsunami-affected Sri Lanka as a case study.

First, coastal and river bank vegetation play many important roles, not only in terms of erosion control and provision of resources (for example such as mangrove ecosystems) but also in terms of buffering populations against hazards such as floods or storm surges (Gedan et al., 2011). If we consider tsunamis, there are reported and anecdotal cases where communities were at least partially protected by mangroves during the December 2004 tsunami. However, the exact nature of the protection afforded by coastal vegetation is still being debated (for example, Kathiresan and Rajendran, 2005, 2006; Kerr et al., 2006; Kerr and Baird, 2007; Cochard et al., 2008), as it is difficult to distinguish the many coastal and settlement features that can play a role in terms of buffering impacts. For example, some preliminary attributions of the protective function of mangroves in the context of the tsunami (Kathiresan and Rajendran, 2005; Vermaat and Thanpanya, 2006) were based on statistical errors and care is required in not overstating this role (Alongi, 2008; Renaud et al. 2013b; Lacambra et al., 2013), but other analyses do show the role of coastal vegetation in terms of buffering effects (Danielson et al., 2005; Kaplan et al., 2009; Hettiarachchi et al., 2013).

Additional features at play when considering the damage extents in the context of the 2004 tsunami include the effects of distance between affected communities and the coastline, local topography, local bathymetry and the wave-energy dissipation potential of the vegetation strips, among other parameters. For instance, through spatial and statistical analysis, Chatenoux and Peduzzi (2007) found that the width of flooded land strips during the 2004 tsunami could be correlated to the distance from the subduction fault line (point of origin of the earthquake), the average depth at 10 km and the length of the proximal slope (which are both indicators of near-shore geomorphology) and the presence of seagrass beds and of corals. Chatenoux and Peduzzi (2007) could not however include in their analysis the effects of coastal vegetation as these were typically present in more sheltered areas such as lagoons. Through statistical analyses, Kaplan et al. (2009) showed that in a case study area located next to the city of Balapitya (south-west of Sri Lanka), significant differences were found between three vegetation classes in terms of water levels experienced during the tsunami and incurred damage. Another finding was that damages remained high inland because of the channelling effect of an inlet present in the study area. Finally, it can be also argued that coastal vegetation has the potential to protect populations, as the existence of such vegetation means that populations settle slightly away from the coastline, thus reducing their exposure to the hazard.

Unfortunately many affected communities in Sri Lanka were not buffered by vegetation during the tsunami as many infrastructures and houses were located close to the sea or right on the seashore. This pattern of settlement is, of course, not specific to Sri Lanka, as everywhere around the world people have settled along coasts and rivers, benefiting from all the services provided by respective water bodies (Affeltranger et al., 2005) but also being exposed to the hazards inherent to these water bodies. In Sri Lanka and in all non-landlocked countries, environmental degradation from destruction of coastal vegetation increases the exposure of communities to coastal hazards.

A second example addresses coastal aquifers. Freshwater aquifers play an important role in coastal peri-urban and rural areas of Sri Lanka as they provide water for all domestic uses, including drinking water, and in some cases also for irrigation. Before the tsunami, there were increasing pressures on this resource from greater abstraction for domestic and agricultural uses on the one hand, and the increasing pollution from domestic, agricultural and industrial sources on the other (for example, Villhoth et al., 2005; UNICEF, 2005). The tsunami affected many wells along the coast – completely or partially destroying them, polluting the groundwater with high salt concentrations (and possibly other organic and inorganic pollutants) and depositing debris of all kinds in the wells. A situation that was already delicate before the event became critical for many communities. The vital role of groundwater was such that many attempts by government and non-governmental organizations were made to restore the water quality of the wells. These activities allowed the reclamation of some of the wells, but in other cases the cleaning operations (generally pumping out the well water once or several times) aggravated the situation by encouraging saline intrusion into the freshwater lenses (for example, UNICEF, 2005).

More than a year after the tsunami, water quality was still not restored in many coastal wells. A comprehensive monitoring programme put in place by the International Water Management Institute showed that salinity in monitored wells on the east coast was higher than pre-tsunami levels some seven months after the impact – coinciding mostly with the dry season (Villholth et al., 2005). One of our studies, conducted jointly with Ruhuna University, which covered communal wells in the Galle District, showed that communities reported salinity, nauseating odours and coloured water as continuing problems more than a year after the event. Coastal communities around the country thus still relied on water purification systems or, more frequently, on water brought in by tanker lorries from outside, on a discontinuous and unreliable piped water system or on wells tapping unaffected portions of the aquifers, depending on the location of the community and the impact of the tsunami. Impacts on drinking water supplies were much less severe in cities like Galle where the water distribution system that brings water from an unaffected reservoir to houses and businesses was restored relatively rapidly after the event.

At least two pieces of information from this groundwater-related post-impact assessment are relevant for vulnerability studies. The first is the dependency of some communities on a single resource (here freshwater aquifers), and the second is the exposure and sensitivity of this resource to a specific hazard (here the tsunami and possibly storm surges). It is therefore crucial to rapidly find ways both to alleviate the vulnerability of the aquifer itself (for example by reducing the pressures on it) and to provide alternative sources of freshwater (for example by increasing the area covered by piped water systems, although clearly this would require large-scale investments, would take time and should not be done at the expense of environmental degradation in non-coastal zone areas). Since the coastal areas of Sri Lanka will remain exposed to future tsunamis and storm surges, a survey should be carried out to locate good-quality freshwater aquifers close to the coast that could be used for emergency situations (as advised, for example, by UNESCO's Groundwater for

Emergency Situations (GWES) programme; see Vrba and Verhagen, 2006).

A final example can be taken from a rural setting where the soil and in many cases the groundwater (for irrigation) play major roles in providing livelihoods for farming communities. Agricultural fields were damaged by the tsunami, whose effects included the destruction of crops and the salinization of the resource base (soil and groundwater).

However, preliminary investigations by the International Rice Research Institute[1] established that in the case of well-drained soils, these effects would be short-lived, as rain water and/or supplementary irrigation would leach the salts from the soil. Through a rapid rural assessment study carried out in collaboration with Eastern University one year after the tsunami, it was established that in two rural communities in the coastal region of Batticaloa District (east of Sri Lanka), some fields may have been experiencing salinity problems (Marre and Renaud, 2011). The problems of resuming agricultural activities were compounded by the loss of labour availability due to casualties, resettlement and daily employment offers by government and non-government organizations (GOs and NGOs), and loss of equipment and tools, to name only a few factors. Aid from GOs and NGOs helped some of the farming families, but more support was expected in the area. This example shows that although a vulnerability assessment can consider a specific part of an ecosystem, the links with the social and economic dimensions also need to

Figure 3.2 Tsunami-impacted paddy fields in Sri Lanka
Source: Author.

be understood in order to obtain a clear picture of vulnerability of social-ecological systems and of which corrective policy approaches are best suited to the specific circumstances of the communities.

The examples above relate to a post-impact analysis, but in a pre-impact assessment, the quality, quantity and availability of resources, and the dependency of communities on these resources, also need to be determined. Speaking more generally, because of increasing pressure by humans on natural resources such as land (soil) and surface- and groundwater, the environment's capacity to provide essential services (in terms of both quantity and quality) is being compromised worldwide. This in turn increases the vulnerability of communities, as they cannot rely on specific environmental resources to (1) sustain their livelihoods, and (2) allow them to minimize the impact or recover after a major hazardous event. Many examples from developed and developing countries and from rural and urban environments can be cited (see also Renaud et al., 2013a):

- Conversion of wetlands is a major driving force behind land degradation and can be a loss of a buffer zone for water flow regulation (UNEP, 2002; van Eijk et al., 2013). In some cases this can have direct implications for floodwater regulation.
- Over-exploitation of water resources in water-scarce countries induces problems of water quality and future availability (UNEP, 2002), making communities reliant on scarcer resources and reducing the diversity of water supplies.
- Land degradation harms the physical, chemical and biological properties of soils (Vlek, 2005), and therefore their productivity potential. This loss of productivity affects rural communities year-to-year but also increases the impact of extreme events such as climatic droughts.

These trends in environmental degradation can create a vicious circle whereby over-exploited or mismanaged natural resources cannot provide communities with required services. This can be followed by a tendency to increase the pressure on the resources in an attempt to make a living or recover from a preceding drought, flood or other event, further degrading the resource (Figure 3.3). A degraded environmental resource then has more difficulty withstanding a future external impact and is very difficult to restore.

Environmental degradation and hazards

In addition to affecting the vulnerability of people, environmental degradation can contribute to the amplification or increase in frequency of certain types of hazards. Climate change has affected the frequency and intensity of recorded extreme weather events, generating more frequent heat waves and heavy precipitation events globally, and this trend is likely to continue in the future (IPCC, 2007). This translates into direct impacts on the local and regional hydrological cycles, with the prospect of hydrometeorological events such as floods and droughts of higher magnitude and frequency. With respect to heat stress, Batisti and Naylor (2009) showed that higher growing season temperatures by mid- and end of the century will prevail in many regions of the world, potentially negatively affecting crop production and farm incomes and increasing food insecurity. This could also lead to potential additional out-migration of people (see Feng et al., 2011, for an example from Mexico) who would seek alternative livelihoods in other regions.

In addition to climate change, land use changes throughout the world have affected the characteristics and/or the likelihood of manifestation of some types of extreme events. The best-known example is deforestation in mountainous regions which can increase erosion and decrease the infiltration capacity of soils, thus generating more runoff and more floods locally. However, great care needs to be taken when assuming direct links between deforestation and floods as the cause–effect relationship will vary depending on scale (FAO and CIFOR, 2005). Deforestation can also be a major factor in landslides in hilly areas (Papathoma-Koehle and Glade, 2013), as tragically shown by the 2004 mud floods in Haiti and in other contexts such as landslides generated by the 2005 earthquake in Pakistan (Peduzzi, 2010). However, deforestation is by no means the only example where land use changes affect the characteristics of hazardous events as, for example, conversion of pastures to urban land uses also has an impact on local hydrological cycles and flooding patterns (Trocherie et al., 2004).

Some vulnerability assessment tools, such as the BBC framework (see Chapter 1, this volume), recognize that actions can be taken at the policy level in order to reduce the magnitude or frequency of hazards. This implies that policies such as improved land use or urban planning can reduce the overall risks that communities are facing by acting directly on the hazard side of the model – and not only on the vulnerability side as discussed in the previous sections.

Environmental degradation and society

Figure 3.3 illustrates the interrelationships between ecosystems, livelihoods and vulnerability for rural and urban systems. These systems are affected by external drivers such as climate change, financial crises, international policies and other processes which affect not only the vulnerability of

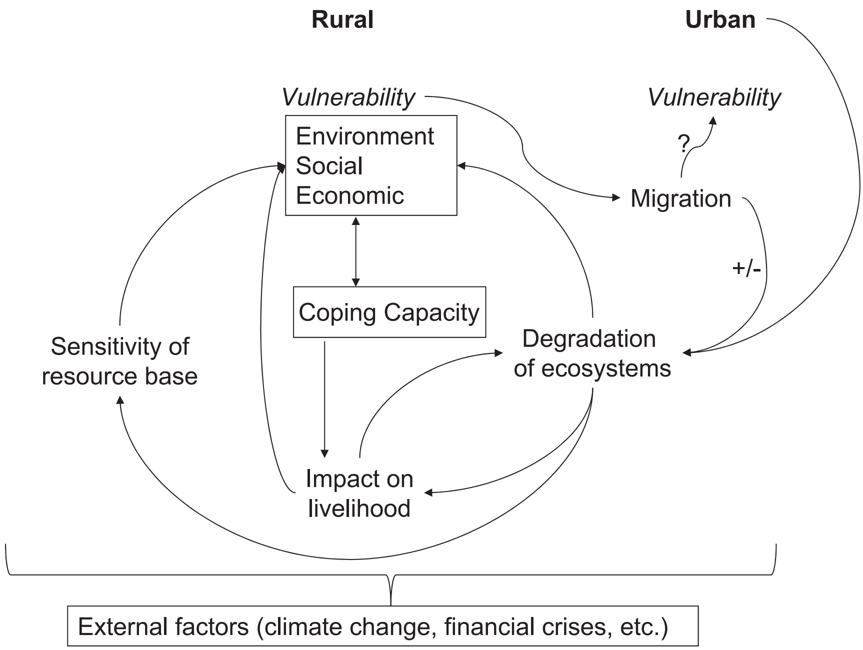

Figure 3.3 Potential effects of ecosystems' degradation on rural and urban vulnerabilities (economic, social and environmental vulnerability; coping capacity)
Source: Author.

communities but also the state and management of ecosystems. By affecting people's livelihood, degradation of ecosystems increases the vulnerability of exposed communities to environmental hazards, and can also contribute to increasing the vulnerability of other communities through processes such as migrations. For example, land degradation worsens rural poverty as it negatively affects land productivity, and the impact is greatest when coping mechanisms are weak. As a secondary impact, poverty is often a driver of migrations from rural areas to urban centres (IFAD, 2001; Vlek, 2005; Renaud et al., 2007; Figure 3.1). Migration can have either a positive or a negative role with respect to ecosystem management. An example of the former is when migration temporarily reduces pressure on the farmland and remittances allow rural families to adapt and diversify their livelihoods. An example of the latter is when remittances worsen the situation by, for example, providing greater purchasing power of livestock that increases pressure on ecosystems (see Schoch et al., 2010 for an example of such a scenario in rural Kyrgyzstan). Migration may increase pressure on urban centres where, generally, poor people who migrate tend to settle in the poorest and often most exposed neighbourhoods in large cities. There, not only are they likely to become "urban poor" but may be exposed to unfamiliar hazards and may not acquire the new culture of risk rapidly enough to cope with these hazards. Finally, as shown with groundwater resources impacted by the 2004 tsunami, the sensitivity of the natural resources to a hazard (whether intrinsic or aggravated by ecosystem degradation) also affects the vulnerability of exposed communities.

Figure 3.3 illustrates a negative cycle, but the principle holds true in reverse, whereby preservation of ecosystems provides positive feedback responses on livelihoods, vulnerability and resilience of social-ecological systems. Alternatively, communities facing ecosystem degradation may be able to adapt to the new conditions, a strategy that has been used with varied success since the beginnings of humanity. Global environmental change is a reality but not a fatality. Many technical, institutional and political solutions exist to alleviate some of the pressures placed on environmental resources. Implementing these solutions is, however, often constrained by economic costs, institutional capacity or political willingness.

Capturing the environmental dimension of vulnerability

Using the concept of a social-ecological system when addressing vulnerability automatically implies that ecosystems and their functions need to be considered. One approach is through the notion of ecosystem services as outlined by the Millennium Ecosystem Assessment. For Adger and Kelly (2001), vulnerability is related to the concept of entitlements and access of individuals or communities to resources. It is therefore important, in a first step, to determine what major services are provided by different ecosystems to individuals and communities and to examine which entitlements and access rights individuals or groups of individuals have with respect to these services. This can be achieved by various means: by discussions with key informants (for example local government agents, local NGOs, local religious leaders), through participatory exercises with the local communities and/or through specific household surveys. This information can then be used by decision-makers to determine the dependence of the community on one or several resources, and to recommend specific protection measures for those resources and/or find alternatives that could provide similar services.

It is also important to determine the current pressures exerted on ecosystems (quality, quantity). This should lead to policies aimed at reducing identified pressures. In the same process one needs to anticipate the susceptibility of the resource itself with respect to hazard impacts. This should lead to actions to either protect the resource further, improve its ability to recover to a satisfactory state (i.e. one that can provide the usual services) more rapidly, and/or to diversify the access to specific ecosystem services.

It is also vital to determine the institutional capacity needed to deal rapidly with the impact of a disaster on affected environmental resources. Finally, one needs to analyse environmental degradation processes that represent driving forces for migrations. Specific policies can then be put in place to tackle the problem at the source (Renaud et al., 2011).

A wide range of tools can be used for these, including participatory appraisals, questionnaire surveys, in-depth surveys and the use of remote sensing. Indicators to characterize the vulnerability of social-ecological systems can also be developed and represented in a way that is accessible to decision-maker. An example of this is provided by Damm (2010) in the context of flooding in agricultural and forestry sectors in Germany. Through a careful selection of indicators and the use of statistical procedures for indicator validity testing and aggregation, Damm (2010) was able to map at the national scale district-level vulnerabilities to flooding of the two sectors above, characterizing in the process ecological functions as well as social processes and their interactions.

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4

Crafting integrated early warning information systems: The case of drought

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Introduction

Drought has long been recognized as falling into the category of incremental but long-term and cumulative environmental changes, also termed "slow-onset" or "creeping" events. Similar issues include: soil degradation and desertification processes, ecosystems change and habitat fragmentation, nitrogen overloading and coastal erosion, among others. The onset and end of drought is difficult to determine. Its impacts are non-structural; in contrast to floods and hurricanes, they are spread over a larger geographical area and may linger for years after the termination of the physical event. Such creeping changes are often left unattended in their early stages since countries and communities choose or need to cope with immediate concerns. Eventually, these become urgent crises that are more costly to deal with since critical thresholds for reversibility may have been exceeded (Glantz, 2004).

Adaptations to reduce vulnerability before drought events, such as improving water use efficiency, are linked to actions as an event unfolds, differing from emergency responses for other hazards. Early warning systems (hereafter EWS) in such contexts are needed not the only for event onset, at which a threshold above some socially acceptable or safe level is exceeded but also for intensification and duration, ranging temporally from a season to decades and spatially from a few hundred to hundreds of thousands of square kilometres. Present drought-related crises, such as in the Horn of Africa (2011) and elsewhere, reveal major concerns regarding

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vulnerability and capacity, including the absence of an effective response network. In this chapter, two examples, the Famine Early Warning Systems Network (FEWSNet) and the US National Integrated Drought Information System (NIDIS) are used to illustrate the importance of: (1) understanding social vulnerability in order to identify entry points for actions to manage present conditions and to mitigate future risk and (2) the processes that support closer inter-institutional collaboration among research and agencies that direct information interventions and responses, such as extension services, development projects and non-governmental organizations (Meinke and Stone, 2005; Pulwarty, 2007).

The chapter will apply concepts such as adaptation, vulnerability and disaster risk, defined elsewhere in this volume, in operational environments relevant to early warning systems. The term "adaptation" as employed in this chapter includes practices that reduce or mitigate risks and impacts before, during and after events under consideration on an ongoing basis. Indicators used to assess physical drought conditions are described in numerous sources (for example, Heim, 2002; Dai, 2010) and are not discussed in detail here.

While the issues being discussed are "drought specific", the authors recognize the need for multihazard approaches. They have also observed the difficulties of implementing such multihazard systems in practice and ask that attention is paid to vulnerability assessment and the governance of information systems themselves as bases for action regardless of the particular hazard being addressed. The case of drought offers valuable lessons for assessment and management of climate-related risks, including climate change adaptation. We begin the discussion with a characterization of the concept of "early warning information systems".

What is an early warning information system?

Early Warning Systems (EWS) aim to reduce vulnerability and improve response capacities of people at risk. The UN International Strategy for Disaster Reduction (UNISDR) defines early warning as "the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response". Governments maintain EWS to warn their citizens and themselves about impending hazards, resulting for example, from health, geologic or climate and weather-related drivers. The seasonality of climatic hazards already provides policymakers with clear indications of regions that are potentially at risk (NRC, 1999). Numerous international and national early warning systems exist (Wilhite, 2006; UNISDR, 2006; UNEP, 2012). In addition, many early warnings directly and indirectly activate other warning systems in affected sectors and communities, a process that has been referred to as a cascade of early warnings (Glantz, 2004). For the most part, EWS have been interpreted narrowly as technological instruments for detecting and forecasting impending hazard events and for issuing alerts. This interpretation, however, does not clarify whether information about impending events is actually communicated and used to reduce risks (UNISDR, 2006; NIDIS, 2007; Pulwarty, 2011). There are multiple factors that limit current drought EWS capabilities and the operational application of data in preparedness, mitigation and response globally (Wilhite, 2000): inadequate density, quality of meteorological and hydrological data, and the lack of data networks on all major climate and water supply parameters; inadequate data sharing between government agencies and the high cost of data; user accessibility and training in applications; and inadequate indices for detecting the early onset and end of drought. The lack of specificity of information provided by forecasts, especially during non-ENSO years, limits the use of this information by farmers and others.

For most locations, drought forecasting and early warning is still a linear process based on a "sender–receiver" model of risk communication. In the following discussion, the term "early warning information system" is used to describe an integrated process of risk assessment, communication and decision support, of which an "early warning" is a central output. An early warning information system involves much more than development and dissemination of a forecast; it is the systematic collection and analysis of relevant information about and coming from areas of impending risk that (a) informs the development of strategic responses to anticipate crises and crisis evolution; (b) provides capabilities for generating problem-specific risk assessments and scenarios and (c) effectively communicates options to critical actors for the purposes of decision-making, preparedness and mitigation.

Effecting this more comprehensive vision of "early warning information systems" requires detailed examination of the root causes of the lack of early action (Verver, 2011). Monnik (2000) noted some years ago that the main constraints on system implementation include:

- Lack of a national and regional drought policy framework;
- Lack of coordination between institutions that provide different types of drought early warning;
- Lack of social indicators to form part of a comprehensive early warning system.

Countries that have not incorporated such systems, even in part, to develop and inform strategic response options, often illustrate a broader lack of institutional flexibility and preparedness and thus higher vulnerability. Given the links between near-term and long-term climate variability and change, the early warning construct is, of necessity, being applied to more extended timescales. Improving the institutional organization of the early warning information systems as well as the associated strategic response to anticipate crises and crisis evolution are closely linked to acknowledgement of long-standing developments in understanding and characterizing vulnerability and governance (see Wisner et al., 1977; Hewitt, 1983; IPCC, 2012). The chapter shows that successful drought early warning information systems have explicit foci on: (1) integrating social vulnerability indicators with physical variables across timescales; (2) embracing risk communication as an interactive social process and; (3) supporting governance of a collaborative framework for early warning across spatial scales. We turn to two cases, FEWS Net and NIDIS, in which such principles have been actively sought and tested.

The Famine Early Warning Systems Network (FEWS NET): Vulnerability and livelihoods

The Famine Early Warning Systems Network (FEWS NET) is an activity of the Office of Food for Peace (FFP) of the US Agency for International Development (USAID). In fiscal year 2008, FFP provided 2.6 million metric tons of food to 56 million people in 49 countries. FEWS NET supports the FFP goal "to ensure that appropriate emergency food aid is provided to the right people in the right places at the right time and in the right way". Basic questions that are answered by FEWS NET on an ongoing and continuous basis include:

> Which population groups are facing food insecurity, and for how long?
> What are the best ways to mitigate adverse trends or shocks to their livelihood systems? (Eilerts, 2010)

The period of 1983–1985 saw major famines in Ethiopia and the Sahel. As many as a million people were estimated to have perished, and many more suffered severe malnutrition, destitution and loss of livelihood. Drought-induced crop failure was a major factor. Though there was food potentially available from outside the region, including FFP, by the time the international community became aware of the full scope of the disaster it was well advanced – with dire effects. Even after the severity of the emergency was understood, it was unclear where and how much food aid to deliver. This experience led to the creation of the Famine Early Warning System (FEWS) by USAID in 1985.

FEWS initially undertook to compile data and information regarding crop production, food stocks and the numbers and locations of populations needing aid due to the ongoing disaster. In its second phase (1988–1994), FEWS moved beyond the immediate information needs of disaster relief to add vulnerability analysis to its scope. The purpose was to develop understanding of the predisposition of populations to food security emergencies due to livelihood shocks like drought or conflict.

In its third phase (1995–2000), the primary objectives of FEWS were early warning, vulnerability analysis, emergency response planning and capacity building. Capacity-building efforts focused on training and involvement of Africans in all phases of food security assessment. This emphasis helped lead to the complete phasing out of US expatriate staff in the field. In the 2000s, the name was changed from FEWS to FEWS NET, to emphasize the importance of networking by country representatives with a whole range of actors with a stake in famine early warning: ministries of national government, international organizations and non-governmental organizations (NGOs).

In its modern form, FEWS NET (2000–present) has been characterized by in-country representation for all countries covered. FEWS NET has maintained a presence in approximately 20 sub-Saharan African countries. In addition, representation has been added in Afghanistan (2002) and Central America (2003). FEWS NET social scientists are also supported by physical scientists in the field with regional responsibilities. The global food crisis of 2008 was a surprise to many in the international community, and put new demands on FEWS NET. The scope of the activity was adjusted to meet information needs for non-presence countries. This meant that FEWS NET social scientists had to quickly develop new protocols for remote monitoring. These include rapid data collection through short-term country visits, mapping livelihood zones and the development of in-country contacts to facilitate continuous monitoring of key variables, such as market prices for staple foodstuffs. The crisis also prompted expanded monitoring of agro-climatic variables by FEWS NET physical scientists

Partnerships are at the centre of FEWS NET. Implementing partners of FFP include the prime contractor (employing food security analysts both in-country and in Washington, DC) and federal science agencies with unique capabilities for agro-climatic monitoring in data-sparse regions using satellite data, models and geographic information systems: USGS, NOAA, NASA, USDA. All are funded by USAID to perform their FEWS NET activities.

FEWS NET country representatives typically partner with a range of ministries of national government: health, agriculture, central statistics office, meteorology, etc. They also work closely with country offices of UN agencies like WFP and the FAO, as well as humanitarian NGOs, like CARE International and Save the Children. Often, all of these agencies are brought together by a national early warning unit, and/or a national disaster management unit, which hosts regular and frequent meetings for information sharing and exchange. This networking greatly enriches the content of monthly food security reporting, as well as the issuance of alerts during periods of emergency. Such communications are often issued jointly by network partners including FEWS NET. FEWS NET regional scientists with responsibility for agro-climatic monitoring are typically hosted by a regional or national organization with responsibility in that area.

Assessment of potential crises and threats to livelihoods

FEWS NET employs a livelihoods framework to geographically characterize vulnerability and interpret hazards. The focus is to keep abreast of, and anticipate, fluctuations in household access to food, especially anomalous downturns. Access might be reduced because food is simply scarce. On the other hand, food might be available but inaccessible to poor households due to high prices or other institutional factors. Thus, before any monitoring is done, livelihoods analysis is performed to characterize the strategies households use to access food and income (see Figure 4.1). This includes preparation of a livelihood zone map that divides a country into areas with relatively homogeneous patterns of agro-ecology and food access. Within these zones, livelihood profiles are prepared that

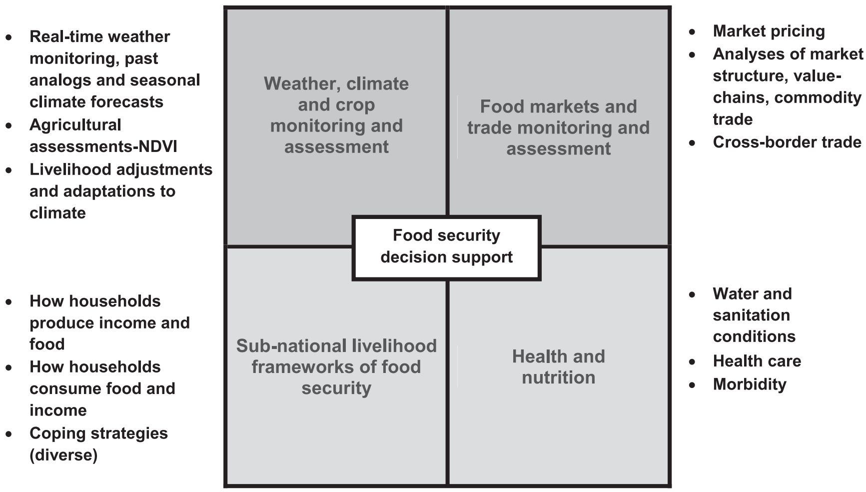

Figure 4.1 Food security factors used to support early warning and risk management
Source: Adapted from G. Eilerts, FEWS NET, pers. comm.

describe the relative importance of various sources of food and income for the principal wealth groups. The maps are accompanied by livelihood seasonal monitoring calendars that identify recurring periods of the annual cycle. Livelihood profiles characterize the population's capacity to deal with temporary adversity by shifting among available sources of food and income. In this way, the context is set for monitoring so that the significance of emerging hazards can be assessed.

Observations are focused by region and season, with the objective of detecting poor growing conditions that might suppress grain yields and lower agricultural production. The status of rangeland and forage conditions is also tracked. Unfortunately, the climate station networks in FEWS NET countries are characteristically sparse, often with late reporting from these stations that are active. To meet the needs of early warning, FEWS NET uses satellite remote sensing and models to fill the gaps and provide a basis for early detection and monitoring of agricultural drought. Given the uncertainties inherent in some of the indirect methods that must be used, a convergence of evidence approach is employed using measures that are physically independent of one of another. Vegetation indices, based on the reflectance of soil and plant canopies, provide a measure of the relative density of chlorophyll at the surface, and the seasonal green up and senescence in crop-growing areas. Daily gridded satellite rainfall estimates provide the basis for drought indicators, such as the Standardized Precipitation Index, as well as calculation of the seasonal crop water balance for principal staple crops. Land surface temperature data from satellites make possible energy balance calculations to produce estimates of crop evapotranspiration, which is directly proportional to crop yield. If drought anomalies are detected by all three of these approaches, a confident conclusion can be drawn that yields will be off and crop production down. Confirmatory data and information are sought from all sources to corroborate such a conclusion, and the FEWS NET regional physical scientists are often able to obtain this through their networks. They also participate in field surveys organized by the USDA, in some instances, and in formal Crop and Food Supply Assessment Missions conducted by FAO, WFP and the national agriculture ministry.

When agricultural drought is detected by remote monitoring methods, the products are used in conjunction with livelihood maps to help interpret the likely impacts on household economies. The percentage of all food and income lost to drought is estimated, as is the degree to which the loss can be made up from other sources. Scenarios are constructed for contingency and response planning, including numbers of persons affected, duration of need and quantities of food aid required. These are communicated to FFP and its partners in the USA and internationally.

Communication with vulnerable communities

A fundamental set of deliverables from FEWS NET is the monthly reporting by country representatives. These regular and continuous reports represent the evolving situation in each presence country. They characterize current conditions and provide a look at the months ahead in the context of livelihood monitoring calendars. Food security status is also presented in map form, with sub-national administrative units colour-coded according to the FEWS NET food insecurity severity scale. This scale is defined in terms of specific criteria for coping strategies, food access, food utilization and household reliance on external support. They are similar to those of the FAO Integrated Phase Classification, and permit meaningful comparison of food insecurity conditions from one country to the next. This latter characteristic is especially important to decision-makers who must allocate scarce resources across multiple problem areas. The maps represent the near-term conditions for the current quarter. They are accompanied by maps representing the medium-term outlook, corresponding to the next three-month quarter. In recent years, seasonal climate forecasts have become an important input to the medium-term outlooks, as they provide a basis for expected agricultural outcomes in advance of direct monitoring.

When conditions require it, FEWS NET issues Food Security Alerts to the community to prompt decision-maker action to mitigate food insecurity. They typically describe current food insecurity, and near-term scenarios of food security outcomes that are contingent on climatic and market conditions in the future. In cases with critical conditions, such as Somalia 2011, custom analyses and briefings are prepared for FFP, the USAID Office of Foreign Disaster Assistance, USAID missions in the field and international partner organizations.

Response

FEWS NET is widely acknowledged as credible in the international community as an early warning system because it is sponsored by, and communicates directly with, a response organization, FFP. Other organizations issuing warnings of food insecurity must often appeal to international institutions or foreign governments. At the same time, FEWS NET has built a reputation for reliable and objective reporting in over 25 years of operation. FEWS NET food security analyses are therefore often considered by non-US decision-makers alongside those from national, regional and international organizations. FEWS NET is valued as a trusted source by decision-makers throughout the international community.

The US National Integrated Drought Information System: Governing drought information systems

The National Integrated Drought Information System Act of 2006 (Public Law 109–430, hereafter NIDIS Act) builds on longstanding efforts among agencies and institutions that have historically been focused on drought risk assessment and response. The NIDIS Act prescribes an interagency approach, led by NOAA, to: "Enable the Nation to move from a reactive to a more proactive approach to managing drought risks and impacts." NIDIS is authorized to: (1) provide an effective drought early warning system; (2) coordinate Federal research in support of a drought early warning system; (a) to improve public awareness of drought and attendant impacts and (b) improve the capacity of counties and watershed organizations to reduce drought risks proactively. At the national level the multi-agency NIDIS Executive Council oversees the NIDIS Program Office. The NIDIS Program Office coordinates the multi-agency and multi-state NIDIS Program Implementation Team (NPIT). The NPIT is composed of representatives from, at present, federal, state and Native American tribal agencies, and academic and private entities. The group is chaired by the director of the NIDIS Program. An advisory Executive Council also acts as the interagency recipient of feedback from the Program Office on drought-related monitoring and research priorities and gaps.

NIDIS supports or conducts impacts assessment, forecast improvements, indicators and management triggers and the development of watershed scale information portals (web-based). In partnership with other agencies, tribes and states, the NIDIS teams coordinate and develop capacity to prototype and then implement regional drought early warning information systems, using the information portals and other sources of local drought knowledge.

The role of regional drought early warning systems prototypes

The functions of the NIDIS Prototypes are to derive and illustrate the benefits of (a) improved knowledge management; (b) improved use of existing and new information products; and (c) coordination and capacity development for using early warning systems. The locations for RDEWS prototypes and implementation are based on an assessment of drought sensitivity and criticality (including publicly identified information needs), drought type (snowpack or rainfall driven, short term, multi-year) and administrative unit (watershed, city, county etc.). The "prototype" framing allows for existing barriers to cross-agency collaboration to be addressed, innovations and new information to be introduced and tested, and the benefits of participation in design, implementation and maintenance to be clarified. A mature and evaluated pilot scheme becomes the implemented regional system and its lessons become more likely to be successfully transferred within or to other as yet underserved regions. NIDIS also conducts knowledge assessments to (1) determine where major gaps in data, forecasts, communication and information delivery exist; (2) identify innovations in drought risk assessment and management at state and local levels and (3) engage constituents in improving the effectiveness of NIDIS. NIDIS recently conducted the first-ever assessment of the status of drought early warning systems across the USA. There is thus significant leveraging of existing system infrastructure, data and products produced by operational agencies: for example, the Natural Resources Conservation Service snow-depth network; reservoir levels from federal agencies such as the Department of the Interior and the US Army Corps of Engineers. NIDIS also reports on advances in hazards research, advances in the development of early warning systems and in new technologies and techniques that can improve the effectiveness of existing DEWSs.

NIDIS is increasingly acknowledged by the US Western Governors and others, as providing a natural prototype for achieving effective climate services: (1) engaging both leadership and the public; and (2) establishing an authoritative basis for integrating monitoring and research to support risk management. As the first such prototype, the Colorado Basin EWS is used to illustrate the varieties of scales on which NIDIS Early Warning Systems prototyping functions.

The Colorado River Basin Early Warning System: Meeting the EWS needs of large water providers and of underserved communities

The Colorado River supplies much of the water needs of seven US states, two Mexican states and 34 Native American tribes, an area covering almost 637,000 square kilometres. These constitute a population of 25 million inhabitants at present with a projection of 38 million by the year 2020. While the basin has experienced significant droughts, the 2000–2004 period was the driest five-year interval in the record, surpassing even the famous Dust Bowl years of the 1930s. After the critical year of 2002, during which streamflow was reduced to 25 per cent of average, it became clear to the states and the federal entities that an improved process was needed to integrate federal, state and local risk assessment and early warning needs for drought impact mitigation. The influence that warmer temperatures could have were seen in the winter of 2005–2006 when, with a snowpack of 100 per cent of normal, the combination of low antecedent soil moisture and the occurrence of the warmest January–July period on record (driving snow sublimation and evaporation) resulted in a flow 25 per cent below average. This occurs as the south-western United States is experiencing very rapid urban growth and sprawl. Major southwest cities have averaged over 25 per cent growth in the past 10 years with attendant social, economic and environmental demands on water resources.

NIDIS convened a series of stakeholder workshops at different administrative units with water managers/resource specialists from federal, state, municipal, tribal and other government groups in Utah, Wyoming and Colorado to identify information gaps and initiate the development of decision support tools and processes. Three critical problems were identified as NIDIS priorities: (1) coordinated reservoir operations – low flow shortage triggering criteria on Lakes Powell and Mead, the two largest man-made lakes in the USA; (2) inter- and intra-basin transfers (to the burgeoning Front Range); and (3) ecosystem health/services. Within this, three major efforts are underway: (1) identification of federal and state-level partnerships, the decision support tools and actions needed to improve information development, coordination and flow for risk reduction); (2) assessment and consolidation of drought indicators and triggers used in the Upper Basin; (3) implementation of an Upper Colorado Basin Drought EWS. Partners and end-users of NIDIS information in this basin include: the Department of the Interior (Reclamation, USGS, FWS), USDA (Forest Service, NRCS), Native American tribes (Four Corners region), resource management personnel and state climatologists from the Basin States (Colorado, Wyoming, Utah, Arizona, New Mexico and California), State of Colorado Conservancy District and Front Range Urban Community (Denver and Aurora Water), Colorado Climate Center, Western Regional Climate Center and National Drought Mitigation Center.

NIDIS Products and Services in the Colorado Basin to date include:

- Development of new watershed-based drought indicators and triggers used in the Upper Basin;
- Improved linkages between climate and streamflow modelling during drought;
- Spatial analysis of water demand during drought;
- Low-flow impacts database for 164 NWS forecast points;
- UCRB Community Colorado Basin-specific Drought Portal
- Weekly Drought and Water Outlook webinars/early warning discussions with resource managers in the UCRB

The Colorado Basin Early Warning information now feeds into and informs the national level Drought Monitor that is updated by NOAA and the US Department of Agriculture and the University of Nebraska's National Drought Mitigation Center on a biweekly basis.

While the Colorado has been called the most managed system in the world, large areas of the basin are outside the reach of the mainstem water supply. The Navajo Nation is in an ecologically sensitive semi-arid to arid section of the southern Colorado Plateau that straddles the upper and lower Colorado Basin. It is the largest reservation in the USA. In this remote part of the United States, located at the corners of four states (Arizona, New Mexico, Colorado and Utah), traditional people live a subsistence lifestyle that is inextricably tied to, and dependent upon, landscape conditions and water supplies. Soft bedrock lithologies and sand dunes dominate the region, making it highly sensitive to fluctuations in precipitation intensity, per cent vegetation cover and local land use practices. Many residents, especially the elderly, rely on raising livestock as a significant part of their livelihood or as a supplement to food supplies (Iverson, 2002). Over half of the reservation population lives in housing without indoor plumbing or electricity (Choudhary, 2003). Before the reservation demarcation (1868–1887) and grazing allotments, families in normal years had moved their livestock around core customary grazing areas shared by networks of interrelated extended families, while during droughts they used other kinship ties to gain access to more distant places where conditions were better. This situation is becoming increasingly difficult for the more traditional elderly who tend to be the poorest of the Navajo people.

Currently, the Navajo Nation is hoping to recover from drought in the Four Corners Region that lasted officially from 1999–2009. These conditions, combined with increasing temperatures, are significantly altering the habitability of a region already characterized by harsh living conditions. More than 30 major surface water features on the reservation have disappeared. Dune deposits cover over one-third of Navajo lands, but drought conditions are producing significant increases in dune mobility. Sand and dust movement in the region is closely linked to regional aridity, ephemeral flood events in riparian corridors and regional wind circulation patterns. Climatic factors controlling dune mobility include the ratio of precipitation to potential evapotranspiration (P/PE), because of its direct link to the amount of stabilizing vegetation (Lancaster, 1988).

NIDIS is working to define monitoring needs, identify sub-regions of greatest risk of degradation and develop scenarios of future ecological conditions in the Four Corners region as part of the Colorado River Basin early warning system. The problem was brought to international attention by NIDIS as a featured case in the UNISDR Global Assessment Report on Disaster Risk Reduction 2011 (UNISDR, 2011). Work began to enhance tribal drought monitoring capabilities by developing additional weather monitoring stations along with a more detailed historical climatology for determining appropriate drought triggers. The governance approach undertaken by NIDIS focuses on building longer-term collaborative partnerships and is also responsible for maintaining the structure for supporting ongoing indicators development and public engagement. NIDIS engages water resources and community level groups in:

- Setting goals/priorities, and involving partners in problem definitions;
- Using professionals from relevant agencies etc. to build and secure a common basis for action;
- Producing collectively authored gaps knowledge and information gaps assessments agreement on the way forward;
- Integrating different types of knowledge in EWS, particularly in terms of linking scientific and local knowledge; and
- Revisiting major or landmark drought events to show benefits of new information and coordination processes.

Thus the Drought EWS in this organizational model does not simply involve disseminating a forecast. In each prototype location the design is polycentric. It allows for major innovations from the research community, such as new information, technologies and applications for detecting and communicating risks and warnings to be prototyped and introduced.

The centralized components of NIDIS (Program Office and Implementation Team) has oversight and fiscal responsibility, and provides political authority and policy coherence across sectors. As noted in several contexts, emergency management organizations can rarely play that role (UNISDR, 2011). The decentralized components of problem definition, capacity building and information resources are based on the location of prototype EWS development taking advantage of local practices and innovations. This is key to cost-effectiveness and sustainability at each level of governance (UNISDR, 2011). While the local social process is critical and shows important practical pathways for action, these are rarely sustained over the long term. There are, however, a growing number of positive examples of such partnerships that cross spatial scales. For other locations or countries the NIDIS approach might entail a change in the culture of public administration. NIDIS is creating similar Regional Drought EWS in other watersheds, including the US south-east and the state of California. The lessons learned and tools created from these systems are being transferred to other states and regions, for example the Columbia Basin, the lower Great Plains and the Chesapeake Bay tributaries, to create a fully "national" drought early warning presence.

Vulnerability, early warning and surprises

The success and failures of FEWS NET, NIDIS and other systems rely on understanding how and where vulnerability is produced and reproduced, and on the integration of vulnerability assessments and information interventions in the context of climate early warning to support adaptation. Vulnerability analysis provides a contextual basis for early warning by identifying structural water, energy and food insecurity attributable to disruption of primary means of access including informal community safety nets (Misselhorn, 2009). As long recognized by the disaster, food security and, more recently, climate adaptation research communities, successful early warning information systems integrate "input" and "output" indicators. Input indicators include measures of production potential, including rainfall, soil conditions, heat and crop and livestock growth. Output indicators, including nutritional indices, behavioural indicators and signals of economic activity, deal with the food supply situation or the results of scarcity (Morgan, 1985). Additional reference information includes agricultural area–planted estimates and population location at the lowest levels, conduct and performance of markets and trade and documentation of local manifestations of interannual and decadal variations. Questions of timeliness, accuracy, reliability and cost-effectiveness remain for many output indicators, such as prices and other market data (Campbell, 1990). Monitoring coping responses, that is the sequential or hierarchical strategies that households use to fend off hunger and preserve their productive assets, is critical but still in its infancy primarily because local observers are needed to determine the meaning of scarcity responses. A critical point is that effective early warning information systems do not rely on predictive information alone but on uncovering and using all relevant existing information, including careful choice of analogs from the past.

As in the Four Corners case, thresholds may be reached beyond which ecosystem service provision capacities are damaged and possibly irreversible, or require expensive built capital substitutes (Scheffer et al., 2009). Although a trend in the drought-based indicators may serve as a warning, the actual point of transition or threshold (for example dune mobilization) remains difficult to predict. Kates and Clark (1996) refer to "imaginable surprises", which they define as "an event or process that departs from the expectations of some definable community, yet is a concept related to, but distinct from risk and uncertainty". Adaptation involves not only using operational facilities to cope with immediate changes but also leaving some slack or reserve for buffering the impacts of multiple stress problems, extremes and surprises that are inherently difficult to predict accurately. Increasing the "anticipatability" of an event involves not only monitoring of key indicators from appropriate baseline data but also observing early warning signs that assumptions in risk management plans are failing and critical transitions (for example ecosystem collapse) are occurring. While a wide variety of global tools and methods is available for the monitoring of biophysical variables (for example remote-sensing methods for monitoring weather, land cover, land use, food production among others), the monitoring of local climates and of many of the socio-economic variables that describe people's food and water security at any time is often more difficult and costly. The consequences of these knowledge gaps are exposed when the institutional support mechanisms are reactive, temporary and result in disaster. If adaptive action has positive and sustainable food, water, ecological and security outcomes, such as the ability to cope with a drought in the near term, it might be considered to be enhancing the system resilience. In several regions, droughts will increasingly occur against the backdrop of a slow decline towards aridity, changing the nature of early warning information requirements for rapid transitions and surprises. Currently no desertification early warning system is fully implemented, despite the potential for desertification mitigation.

Information Interventions

Decision-making quality depends in part on the information available and the manner in which this information is processed by individuals, groups and systems (ICSU, 2008). As noted by Pulwarty (2007), the timing and form of climatic information inputs (including forecasts and projections), and access to trusted guidance and capability to interpret and implement the information and projections in decision-making processes, are as important to individual users as improvements in prediction skill.

Traditional forecasting, with justification, remains an important source of climate information in many rural communities. Over 15 years ago Agrawal (1995) observed that it had become standard practice to consider not just how the poor and the marginalized are subjected to development but also the manner in which they are able to incorporate external interventions, in this case information, within their own cultural knowledge and frame. At the community level, farmers in Zimbabwe and Malawi have identified local language radio programmes as credible and accessible mechanisms to deliver forecasts if they take place with follow-up meetings with extension agents or other intermediaries (Pulwarty, 2007). Internet-based tools, such as Google maps and graphical tools are already being used for participatory, large-scale information development. However, these tools are inherently limited in communicating the relevant local context and the consequences (positive and negative of information use). There is no prescriptive substitute for local monitoring and knowledge. In this case, the issue has not been failure by information providers to communicate but communicating complexity (from conjunctive societal and physical factors that can result in disaster) too simply.

There is indeed considerable evidence to show that if communities at risk are actively involved in information collection and analyses, then they are far more likely to rely on that information than if it is just provided to them from "outside". Both the NIDIS and FEWS NET experience illustrate that behavioural data are credible to local actors if they are collected and reported by individuals recognized by the central bureaucracy and locals as responsible observers with minimal political motives, such as teachers or agricultural extension agents (see also Campbell, 1990). Barriers to the use of local knowledge in risk management are based on the nature of local knowledge itself (it can be dynamic, informal, diverse and context-specific in both time and space), presenting challenges to identification, understanding and use (Dekens, 2007).The most effective ways to collect and transmit such specific local information for use within formalized early warning systems remains a question for research.

While warning systems can be conceptually sound on paper, they encounter bottlenecks at various nodes in the actual flow of warning preparation, to communication, to action. "Early warnings" of potentially poor seasons have been successful in producing proactive responses, primarily where closer inter-institutional collaboration between national meteorological and hydrological services and agencies that directly intervene in rural areas, such as extension services, development projects and community-based organizations and non-governmental organizations (Meinke and Stone, 2005; NIDIS, 2007). However as Prabhakar and Shaw (2008) illustrate, countries such as India have developed good institutional mechanisms to initiate drought relief measures, but forecasting the impacts of the impending drought to mitigate risks remains limited. Procedural ethical and equity issues are encountered at every stage in the early warning process. Information interventions are dynamic and there is the need "to monitor and revise them continually". The operative approach has been to ensure a continuing dialogue between authoritative decision-makers in each country or region and experts on various aspects of climate risk assessment (Hamilton, 2000). Emphasis on "authority" and "expertise" alone can reduce contending perspectives and lead to unanticipated consequences. Agrawal (1995) notes that: "How knowledge is generated, organized, stored, disseminated presupposes certain relationships of power and control." The above observations complement Habermas's notion of the colonization of the public sphere through the use of instrumental technical rationality where complex social problems are reduced to technical questions effectively removing the plurality of contending perspectives (Habermas, 1962; cited in Pulwarty et al. 2004). Grain and seed providers become de facto the most likely to benefit from forecast information. Critical issues – also in the light of institutional vulnerability – surround questions such who is engaged in deciding what kind of information is "useful" and "usable", what information is gathered, for and from whom, and how it becomes legitimized. While there has been increasing focus on the processes by which knowledge has been produced, less time has been spent examining the capacity of audiences to critically assess knowledge claims made by others for their reliability and relevance to those communities (Fischhoff, 1996; Pulwarty et al., 2004).

In a comprehensive assessment Glenn and Gordon (2001) identify key factors that contribute to timely use of early warning information. These include information that demonstrates that a crisis is pending: and that this information is communicated in a simple, clear, precise way that is can be understood by non-technical experts and within different cultural groups. In addition it is important to consider how information may affect stakeholders' goals and strategies. Furthermore, the use of appropriate indicators; testimony of respected individuals; information about probability and risks associated with the crises is key. In this regard also the attention paid to the issue by the media; clarity regarding forecasting the condition without action and the technical feasibility of a proposed action have to be considered. Highly aggregated models often omit or oversimplify important drivers of surprises elsewhere in the food system, and often reduce human behaviour solely to economic behaviour. These factors also characterize institutional vulnerability aspects in the context of early warning in the case of drought. Governments and communities often lack capacity to deal with catastrophic droughts or to act during a window provided by an event. Clearly while institutions may matter, in many cases they are simply not in place (before or after an event) and support for collaboration between knowledge and management non-existent – clear concerns for capacity-building efforts locally and nationally (Ivey et al., 2004; Christoplos, 2006). The danger is that such systems risk being driven by a "disaster response" cycle, rather than being part of a spiral up towards developing structural resilience in socio-economic conditions (Holloway, 2003). Addressing future climate change will only be effective if careful distillation of lessons of experience (current and past practices) are used to inform planning. As Verver (2011) recently showed, early warning systems are not useful without timely impact analyses to support forecasts. The question then becomes one of uncovering where in the process intervention should be initiated. As precisely posed by Huss-Ashmore (1997) the question becomes: "Should famine or ecosystems indicators merely identify the existence of a population or ecosystem at risk, or should they warn of a probable progression to increased loss of life, and/or of potentially irreversible economic and social damage to a community?"

Conclusion: Reframing drought early warning information systems in a changing environment

Climate variability and change, together within increasing development pressures, exacerbate conflicts among drought-sensitive communities and have impacts on economies and environmental systems that in some cases outpace the natural adaptation capabilities built into the existing systems (Bruce et al. 1996). Climate models project increased aridity into the twenty-first century over large parts of Africa, southern Europe and the Middle East, the south-west United States, the Caribbean, western Australia and South East Asia (Dai, 2010; WCRP, 2011).

Sustainable development prospects are very dependent on the effectiveness of the many networks of early warning systems (UNISDR, 2011). In these networks, subtle rules of interactions emerge that shape the context in which resource-related decisions are taken, and the rules are negotiated and made (Bohle et al., 2009; Sakdapolrak 2007). Agency in adaptive actor-networks improves the capacities of vulnerable communities to make their own decisions about their resources. As the experience of NIDIS, FEWS NET and other knowledge management systems illustrates, early warning represents a proactive social and political process whereby these actor-networks integrate diverse knowledge systems and engage in collaborative risk management. "Knowledge system" here is used to refer to the knowledge and perceptions generated, framed and held by a particular social group, agent or network. Such groups might include indigenous groups, civil societies, minority social groups, politicians and researchers.

There is a critical need to approach and support early warning through both Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) (UNISDR, 2011; IPCC, 2012). This requires a framework that uses climate change scenarios not above but within risk and vulnerability profiles that capture the nature of capabilities and decision-making networks. These form the basis for effective early warning systems design and implementation. The cases above, and other efforts, have demonstrated that social protection and early warning information interventions can provide disaster risk reduction while helping to meet the goals of adaptation to changes in extreme events.

For most locations, the governance context in which EWSs are embedded is key. The links between the community-based approach and national and global EWSs are weak at present (Birkmann et al. 2011). Improving the complementarities and legitimacy of both approaches is a new challenge to address, especially in developing the institutional foundations for global climate early warning information systems envisaged by the Global Framework on Climate Services. Governments and partners such as NGOs and community groups should identify areas where they can collaborate within the broad spectrum of drought risk mitigation. The integration of early warning systems with scenario planning can help to uncover potential impacts of hazards that might otherwise have caught decision-makers by surprise. At present, most "climate-impacts scenario planning" occurs at high levels of aggregation and cannot be used for reducing local vulnerability. As a basis for linking international, national and community-level drought information systems, this collaborative process should:

- Frame the goals and objectives of international, country and local-level programme intervention strategy;
- Strengthen the scientific and data foundations to support early warning for drought onset, severity, persistence and frequency;
- Develop risk and vulnerability profiles of drought-prone regions and locales, including impact of climate change adaptation interventions on food and water availability, access and use;
- Inventory and map local resource capabilities (infrastructure, personnel and government/donor/NGO-supported services) available to complement food programme operations;
- Develop indicators and methodologies to assess the value of ecosystem services in reducing mitigation and emergency response costs and assess the social and economic costs of environmental degradation on water, energy and food security
- Map decision-making processes and identify policies and practices that impede or enable the flow of information among information system components
- Place multiple indicators within a statistically consistent triggering framework-cross-correlation among units before a critical threshold.

Capacity and capability: Some new warnings on early warnings

In an evaluation of regional early warning system performance during the ongoing (2011) East African Food Crisis, Verver (2011) showed that while FEWS NET and the Food Security and Nutrition Working Group proved to be excellent and timely tools, they were not adequately used by humanitarian actors, UN Agencies and donors. The question of why even effective regional early warning systems do not lead to earlier action before a crisis develops is dependent on the capacity and the adaptiveness of the institutions involved. Adaptive institutions display robustness through their levels of alertness, defined as monitoring the external world for early warning signs of resource depletion and critical transitions; agility, defined as the ability to react to early warning signs of problems or opportunities and to adjust strategies and tactics rapidly to meet changes in the environment; and alignment, defined as the capability of leadership at levels to align the whole organization and network of partners to a common mission (Light, 2005). Implementation is the area in which things fall apart. Idealized "solutions" so often recommended in the academic literature form unrealistic benchmarks that are unattainable in practice. Risk-based management approaches to drought planning at the national and regional levels have been recommended repeatedly over the years, but prototyping, testing and evaluation of operational implementation have been limited (Comfort et al., 1999; Agrawala and van Aalst, 2008). As repeatedly argued in the literature, an effective risk management approach would include a timely and people- and place-oriented early warning system and a focal point for dialogue between leadership and those affected. The two examples above (FEWS NET and NIDIS), while not perfect, illustrate attempts to design and implement drought-related early warning information systems with these precepts in mind. The resilience of resource systems is integrally determined by the evolving decisions and actions of people at all levels (Ingram et al., 2010). This begs for moving beyond the climate expert-practitioner framing, or even so-called two-way communication typical of many but thankfully not all consultancies, to recognize that early warning systems are embedded vertically and horizontally in an ongoing social process of risk communication.

Given a changing climate, drought early warning monitoring must continue to be strengthened at the global level, but, no less critically, greater emphasis must be given to developing capacities that are relevant, and responsive to, the needs of local communities. Contemporary applied research shows that technical and institutional innovations are of equal importance (Hall et al., 2001). Assessments should systematically scrutinize the claimed "pros" and "cons" of existing and proposed systems, distilling those lessons from past practices and landmark drought events. The goal is to uncover (a) institutional barriers and opportunities for learning and action and (b) impediments to the development and flow of knowledge among existing components before making claims of efficacy for addressing future climates. To this end there is a need to:

- Approach climate model output far more critically than at present, especially for impact assessment and scenario development at the local level; better understand whether and how best to use probabilistic information with scenarios of potential surprise and cumulative risks across climate timescales.
- Use policy exercises to revisit significant events in the recent past to show the benefits that improved early warning information and communication strategies had, and therefore could have, with regard to future events.

- Develop capacity and training focused on analytical, institutional and deliberative capabilities to support inputs, including testing prototypes, to global, regional, national and local drought and climate outlooks.

Traditional assumptions are that effective functioning of early warning systems requires: first, prior knowledge of risks faced by communities and other users of the early warning information; second, a technical monitoring and warning service for these risks; third, an effective strategy for dissemination of understandable warnings to those at risk; and finally, knowledge and preparedness to act (Traore and Rogers, 2006). Two additional elements have been introduced: awareness that risks are changing (and which new risks may arise) and the need for creating and communicating new knowledge about future conditions that can be understood, trusted and used (IFRC, 2009; IPCC, 2012). One goal is to be prepared to use windows of opportunity for engaging and providing leadership, legitimizing drought risk management and successful communities of practice that have arisen during but also between events. Assessment and evaluation exercises, described above, could serve to uncover the propagation of impacts of multiple year or sequences of droughts of different magnitudes. As Dekens (2007) observes, securing these elements requires long-term partnerships with communities, information entrepreneurs and local institutions that may not immediately trust outside information about one of the few things about which they consider themselves to be experts – what to expect from the local weather and climate. Such efforts require institutional support for long-term partnerships with communities and local institutions that bring their own knowledge and analysis to the table, and in which knowledge claims at all levels can be effectively queried in an atmosphere of respect. Such a drought early warning information system would not be simply translational but, by design, transformative.

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5

Archetypical patterns of vulnerability to environmental change: An approach to bridging scales. Lessons learned from UNEP's Fourth Global Environment Outlook

Marcel T.J. Kok and Jill Jäger

Introduction

Human vulnerability to environmental change is not new. More than 9,000 years ago, the Sumerians of Mesopotamia started irrigating their land to meet increased demand for food from a growing population; but their civilization collapsed, partly because of water-logging and salinization. Soil erosion, loss of agro-ecosystem viability and silting up of rivers contributed to the collapse of the Mayan civilization around 900 BC. More recent examples from the twentieth century are the Dust Bowl phenomenon that resulted from massive soil erosion in the United States during the 1930s and London's great smog of 1952 that killed some 4,000 people (UNEP, 2002a).

In the last decade, scientific reports (Steffen et al., 2004; MA, 2005; Rockström et al., 2009) have shown that humans are now living in an era in which negative human influences on the Earth system are happening on an unprecedented scale and that so-called planetary boundaries are being approached or have already been crossed. The provision of ecosystem services, such as food production and clean air and water or a stable climate, is under pressure. The rate of global environmental change that humans are currently witnessing has not been experienced before in human history. This "no-analogue" situation of environmental change has an increasing impact on the well-being of people and communities. In the face of this on-going environmental change, however, different people and communities face different consequences. Some people may gain

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2^{nd} edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

while others may lose, but all are to a certain extent vulnerable to these changes. However, environmental change is only one of the pressures to which humans are vulnerable, and that is why other pressures such as globalization must also be taken into account in vulnerability analysis.

The Brundtland Commission stressed the interdependence of environment and development and defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Sustainable development is thus about the quality of life and about the possibilities of improving and maintaining human well-being here and now, elsewhere and in the future. Sustainable development requires the integrated analysis of the economic, social and environmental domains (see also Chapters 1 and 2 in this volume). By showing the vulnerabilities of specific people, groups or places as part of a specific human-environment system exposed to environmental and non-environmental threats, an indication of "unsustainable" development patterns can be derived. This analysis can serve as a basis for the identification of challenges to and opportunities for enhancing human well-being and the environment without losing sight of the needs of future generations. As the Brundtland report stated: "A more careful and sensitive consideration of their [vulnerable groups] interests is a touchstone of sustainable development policy" (WCED, 1987, p. 116).

This chapter is organized as follows. We start by looking briefly at the concept of human vulnerability. Then we look at how human vulnerability has been taken up by and used in the Global Environmental Outlook (GEO) reporting by the United Nations Environment Programme (UNEP). Finally, we present an approach for vulnerability analysis that was developed as part of, and used in, the Fourth Global Environment Outlook (GEO-4) to bring together vulnerability analysis at different spatial scales. This method provides a bridge between local detail and context specificity that is required for vulnerability analysis and the often necessarily crude assumptions that are made in global assessments by identifying and analysing "archetypical patterns of vulnerability". In the conclusions we reflect on the further applicability of the concept of "archetypical patterns of vulnerability" for the field of vulnerability analysis.

Human vulnerability to environmental change

One approach taken to understand the impacts of multiple pressures acting on human-environment systems is vulnerability analysis. When the exposure to pressures is large, the system is sensitive to these pressures but the capacity to cope with them is low. As a consequence, the human-environment system has a high level of vulnerability to these pressures.

Nowadays, vulnerability analysis is widely used in the work of many international organizations and research programmes concerned with poverty reduction and sustainable development, such as the FAO, humanitarian aid organizations such as the Red Cross/Red Crescent, as well as UNDP, UNEP, the World Bank and donor agencies. Vulnerability analysis helps to identify the places, people and ecosystems that will suffer most from environmental and/or human-induced variability and change and identifies the underlying causes. It supports the development of relevant recommendations for decision-makers on how to reduce vulnerability and adapt to change.

The concept of vulnerability is an important extension of traditional risk analysis, which focused primarily on natural hazards (Hewitt, 1983, 1997; Blaikie et al., 1994; Wisner et al., 2004). Vulnerability has become a central aspect of studies of food insecurity (Watts and Bohle, 1993; Bohle et al. 1994); poverty and livelihoods (Chambers, 1989; Chambers and Conway, 1992; Prowse, 2003); and climate change (Downing, 2000; Downing and Patwardhan, 2003). While earlier research tended to regard vulnerable people and communities as victims in the face of environmental and socio-economic risks, more recent work has placed increasing emphasis on the capacities of various affected groups to anticipate and cope with risks, and the capacities of institutions to build resilience and adapt to change (Bankoff, 2001).

In studies of vulnerability over the last few decades at least two main strands of research can be distinguished. The first originated in the field of natural hazards research, looking at human vulnerability related to physical threats and disaster reduction (for example, Cutter (1996) or World Bank (2005)). The second strand of research looked at socio-economic factors in relation to human vulnerability (for example, Adger and Kelly (1999) or Watts and Bohle (1993)). It has shown that in the face of (non-)environmental threats, socio-economic factors are equally important. In recent years, these two strands of research have been combined in a number of studies, in recognition that these aspects – natural hazards and environmental changes and socio-economic factors – together determine human vulnerability to environmental change. It is increasingly recognized that many of the environmental problems in the world cannot be seen as distinct from social and economic problems (and vice versa), and that the human-environment system through which humans interact with their environment should be approached in an integrated manner.

Although there are differences of terminology, the different analytic vulnerability frameworks distinguish between exposure, sensitivity and coping capacity and adaptive capacity, which are the main components of vulnerability. Exposure refers to the pressures on the human-environment system and to the frequency, duration and intensity of the pressures. The pressures can be due to environmental change (for example, climate change) or socio-economic "events", such as economic collapse or price changes to commodities. Sensitivity determines the extent to which each system is susceptible to exposure to that external stress – for example, entitlements to natural resources or proximity of an environmental threat, such as a floodplain. Coping capacity and adaptive capacity determine the ability to deal with, recover from or reduce the (future) impact of pressures. These depend on a wide range of factors including the availability of social and human capital.

A related research theme to vulnerability is resilience[1]. Resilience is defined as the potential of a system to remain in a particular configuration and to maintain its feedbacks and functions, and involves the ability of the system to reorganize following disturbance-driven change (Walker et al., 2002). It determines the capacity to cope with the impact of a stressor, depending on, for example, institutional capacity or financial resources. This approach is not focused on the desired future outcome, given that drivers are largely unpredictable, but on creating a system that is able to cope with this unpredictability in many different situations. Resilience is also used as a component of vulnerability analysis; for a further discussion of the relation between both concepts see Turner (2010).

The factors that shape human vulnerability vary among communities and individuals, making human vulnerability to environmental change inherently different for each community or individual (Vogel and O'Brien, 2004). This is the consequence of the fact that vulnerability is:

(1) *Multidimensional*. Communities and people can be subject to different stresses at the same time. For instance, climate change and globalization place multiple stresses on farmers who face changing weather patterns and a new economic reality (O'Brien and Leichenko, 2000).
(2) *Scale dependent*. Factors determining vulnerability operate over different spatial scales. They can be at global, local or individual levels (for example, lack of entitlements leading to low coping capacity). An important element is the spatial heterogeneity of where people are. Poor people tend to be in specific places. Aggregated data mask much of this variation, which is pertinent for analysing human vulnerability to environmental change (Henninger and Snel, 2002).[2]
(3) *Dynamic*. Vulnerability to environmental change and socio-economic pressures is also a dynamic process. Stresses on the human – environment system are constantly subject to change in response to environmental change and socio-economic developments. This can take place over a longer period (for example the pressures of climate

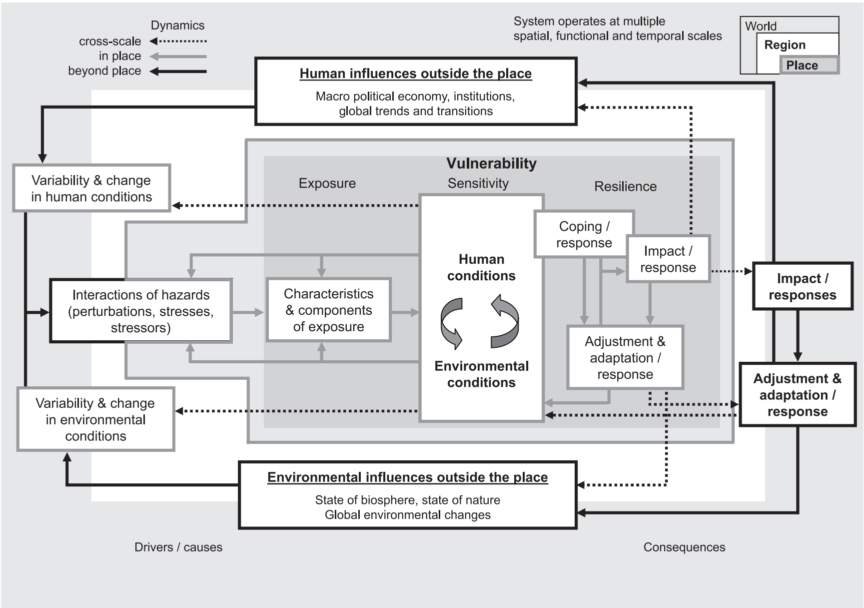

Figure 5.1 Vulnerability framework
Source: Turner et al., 2003.

change or trade liberalization) and/or develop on a short time scale as a result of extreme events (for example earthquakes)

Few frameworks have incorporated all these different aspects. An example of a framework that tries to capture these aspects is the vulnerability framework developed by Turner et al. (2003). It assesses the human-environment system as a whole, describing its vulnerability as a combination of exposure, sensitivity and resilience. It also takes a multi-scale and multidimensional perspective, making it an elaborate, though complex, framework to use (see Fig. 5.1). This framework provided a useful starting point for developing an approach for vulnerability analysis using Global Environmental Outlook (GEO). In the next section we provide further background on how vulnerability analysis was introduced into GEO-4.

Vulnerability analysis in UNEP's Global Environmental Outlook

The Global Environmental Outlook (GEO) environmental reporting system consists not only of global reports but, even more importantly, also includes regional, national and sub-national environmental assessment reports. GEO was set up to fulfil UNEP's mandate to keep the state of the environment under review and to strengthen the scientific basis of international environmental governance. The reports were originally intended to provide policymakers with an early warning and monitoring capacity, but increasingly the focus has been moving into an assessment of possible actions for realizing environmental goals.

The GEO process got underway in 1995 with a mandate from the Governing Council of the United Nations Environment Programme. It evolved into a consultative and participatory assessment process, involving a worldwide network of collaborating centres and scientists. The intention was to approach sustainable development from the environmental perspective. Global GEO reports were published in 1997, 2000, 2002 and 2007. GEO-5 was recently published in the run up to Rio+20 in 2012 (UNEP, 1997, 1999, 2002a, 2007, 2012).

The Global GEOs report on environmental trends, driving forces and policy responses across UNEP's seven regions: Asia and the Pacific, West Asia, Europe, Latin America and the Caribbean, North America, Africa and the Polar Regions. GEO reports employ the DPSIR framework for integrated environment assessment linking drivers of environmental change (D), the resulting pressures (P), state of the environment (S), impacts (I) and responses (R). This framework is not, however, conducive to including vulnerability analysis, as its main focus is on drivers and pressures and resulting changes in the state of the environment and subsequent impacts and possible responses. The important small-scale differences in sensitivity, coping capacity, adaptive capacity and exposure to multiple stresses that determine vulnerability of a human-environment system cannot be analysed using the standard DPSIR framework.

GEO-3 was the first global GEO-report that started to include vulnerability to environmental change. It identified three critical areas as being closely related to vulnerability: human health, food security and economic losses. A case was also made for assessing and measuring vulnerability and developing systems of early warning. In addition to the Global Environment Outlook, the issue of human vulnerability to environmental change also started to feature in many of the regional GEOs. The amount of attention given to this topic varies for each report, but when comparing the most recent reports with earlier publications it is clear that human vulnerability to change is receiving increased attention. In the reports of Small Island Development States, human vulnerability to environmental change is an important topic (UNEP 2005a,b and c). This is considered in the face of a growing threat of natural disasters attributed to climate change. The issue of human vulnerability to environmental change has also been increasingly taken up in the North American, Arab, African and Latin American Environment Outlooks (UNEP, 2002b, 2002c, 2006). The African Environment Outlook in particular has a focus on human vulnerability to environmental change. Main themes were poverty and the direct dependence of people in Africa on their natural resource base. The detailed case studies that provided the basis for this analysis can be found in UNEP (2004).

In 2004 preparations started for GEO-4, which was published in 2007 (UNEP, 2007). The overall theme of the report was "Environment for Development". The vulnerability approach was used in a chapter on "Challenges and Opportunities" (see Jäger et al., 2007 and for a more extensive background report Kok and Jäger, 2009). GEO-4 applied the vulnerability approach to be able to show the combined implications of environmental and non-environmental changes for human well-being. It sought to identify policy options for improving coping capacity and making development more sustainable within the environmental policy domain but also in non-environmental policy domains, such as trade and poverty alleviation. We build on the Turner framework presented above. However, in developing the chapter it became clear that more concrete methodologies for vulnerability analysis were needed that do justice to the multi-scale character of vulnerability. This is especially pertinent for an assessment like GEO that operates at different spatial scales. In the next section we present the method that was developed in GEO-4 to address this scale issue.

Identification and analysis of archetypical patterns of vulnerability

This section elaborates the approach followed in GEO-4 to analyse and highlight the vulnerability of people and the environment to multiple stressors resulting from environmental and socio-economic changes. The question was how best to analyse vulnerability in a global environmental assessment (see Wonink et al., (2005) for an overview of initial discussions on this). Vulnerability analysis is usually place-based and very context specific, and hence much of the academic knowledge not easily generalized. However, it was also recognized that recurring vulnerable situations can be found in numerous places around the world. This raised the question of how to bring in local analysis in a global assessment like GEO and how to bridge the different scales that are relevant in vulnerability analysis.

On the one hand, detailed local vulnerability case studies face the question: to what extent are the outcomes of such studies relevant for similar cases elsewhere? As important policy decisions with a wider impact are not taken at local level, this is a challenge. On the other hand, global vulnerability assessments, even when dealing with a fine spatial resolution, are necessarily based on aggregated data and rather crude assumptions of the underlying mechanisms. The question is whether and how local specifics can be adequately represented and understood at this scale – a prerequisite for successful policy that can influence at the local level. To our knowledge, no specific methodologies were available to bridge the gap between local and global level analysis.

However, the recognition of recurring vulnerable situations provided an opportunity to make vulnerability analysis relevant within the scope of a global assessment such as GEO. Inductively an approach was developed during the production of GEO-4 that entailed the identification and analysis of what we labelled as *archetypical patterns of vulnerability*.

An "archetypical pattern of vulnerability" was defined as "a specific, representative pattern of the interactions between environmental change and human well-being". It does not describe one specific situation but focuses on the most important common properties of a multitude of cases that are in that sense "archetypical". As stated previously, recurring patterns of vulnerability can be found in numerous different places around the world.

This approach is founded in and inspired by the "syndrome approach", which looks at non-sustainable patterns of interaction between people and the environment, and unveils the dynamics behind them (Petschel-Held et al., 1999; Lüdeke et al., 2004). The archetype approach, however, is more anthropocentric as it based on different components of vulnerability and opportunities offered by the environment to reduce vulnerability and improve human well-being. The question is whether and how local specifics can be adequately represented and understood at an intermediate level (between the local and global) and can be used as a basis to identify policies that can help to reduce vulnerability at different scales that are influential at the local level.

To address these issues, a number of archetypical patterns of vulnerability, were identified and analysed in GEO-4. These patterns of vulnerability have been identified as part of the GEO-4 process, ensuring regional relevance and global balance. See Table 5.1 for a concise overview. The seven archetypes presented in GEO-4 are not meant to provide an exhaustive overview of all possible patterns of vulnerability. They provide, however, a good basis for identifying challenges and exploring opportunities for reducing vulnerability while protecting the environment.

The template that was used for the analysis of patterns of vulnerability follows the main components from the Turner et al. (2003) framework for vulnerability analysis that was presented earlier.

Table 5.1 Overview of archetypes, the link to regional priorities, human well-being and possible policy options analysed in the vulnerability chapter in GEO-4

Archetype	Description	Regional priorities from GEO-4	Key issues related to human well-being	Key policy messages
Contaminated sites	Sites at which harmful and toxic substances occur at concentrations above background levels and pose or are likely to pose an immediate or long-term hazard to human health or the environment, or exceed levels specified in policies and/or regulations	Asia Pacific – waste management Polar – persistent toxics Polar – industry and related development activities	Health hazards – main impacts on the marginalized in terms of people (forced into contaminated sites) and nations (hazardous waste imports)	Better laws and better enforcement against special interests, Increased participation of the most vulnerable in decision-making
Drylands	Contemporary production and consumption patterns (from global to local levels) disturb the fragile equilibrium of human-environment interactions that has developed in drylands between sensitivity to variable water supply and at the same time, resilience to aridity, creating new levels of vulnerability.	Africa – land degradation West Asia – land degradation and desertification	Worsening supply of potable water, loss of productive land, conflict due to environmental migration	Improve security of tenure (for example by cooperatives), provide more equal access to global markets

Securing Energy	Vulnerabilities as a consequence of efforts to secure energy for development, particularly in countries that depend on energy imports.	Europe – energy and climate change LAC – energy supply and consumption patterns North America – energy and climate change	Affects material well-being which is marginalized/mostly endangered by rising energy prices	Secure energy for the most vulnerable, let them participate in energy decisions, foster decentralized and sustainable technology, invest in the diversification of the energy systems
Global commons	Vulnerability created from misuse of the global commons, which include the deep oceans and the seabed beyond national jurisdiction and the atmosphere.	LAC – degraded coasts and polluted seas LAC – shrinking forests Polar – climate change West Asia – degraded coasts	Decline or collapse of fisheries with partly gender-specific poverty consequences, health consequences of air pollution and social deterioration	Integrated regulations for fisheries and marine mammal conservation and oil exploration etc., Use of the promising Heavy Metals and Persistent Organic Pollutants' policies
Small Island Developing States	The vulnerability of Small Island Developing States (SIDS) to climate change impacts in the context of external shocks, isolation and limited resources.	LAC – degraded coasts and polluted seas Asia Pacific – alleviating pressures on precious and valuable ecosystems	Livelihoods of users of climate-dependent natural resources are most endangered, resulting in migration and conflict	Adapt to climate change by improving early warning, make economy more climate independent, shift from "controlling of" to "working with nature" paradigm

Table 5.1 (cont.)

Archetype	Description	Regional priorities from GEO-4	Key issues related to human well-being	Key policy messages
Technology-centred approaches to water problems	Vulnerability induced by the poorly planned or managed large-scale projects that commonly involve massive reshaping of the natural environment. Important examples are some irrigation and drainage schemes, the canalization and diversion of rivers, large desalinization plants, and dams.	Asia Pacific – balancing water resources and demands North America – freshwater quantity and quality West Asia – water scarcity and quality	Forced resettlement, uneven distribution of benefits from dam building, health hazards from water-borne disease vectors	The World Commission of Dams path of stakeholder participation should be further followed, dam-alternatives like small-scale solutions and green engineering should play an important role
Urbanization of the coastal fringe	Illustrates the challenges for sustainable development that arise from rapid and poorly planned urbanization in often ecologically sensitive coastal areas, in the context of increasing vulnerabilities to coastal hazards and climate change impacts.	Europe – urban sprawl LAC – growing cities LAC – degraded coasts West Asia – degradation of coastal and marine environments West Asia – management of the urban environment	Lives and material assets endangered by floods and landslides, health endangered by poor sanitary conditions due to rapid and unplanned coastal urbanization, strong distributional aspects	Implementing the Hyogo Framework of action, bringing forward green engineering solutions which integrate coastal protection and livelihood opportunities

- What are the main pressures – environmental and socio-economic? How can the archetypical pattern of vulnerability be defined and what is its global relevance?
- What are key vulnerable communities, social and economic groups involved, including gender dimensions?
- What are the major (sub-)dimensions of human well-being affected, including material assets, health, security, social relations and freedom and choice?
- How do different issues shape the vulnerability in question and which entry points do these provide to reduce vulnerability? For example, poverty, trade and globalization, science and technology, human health, institutions and governance, conflict and cooperation.
- Opportunities: policy responses at different scales and within and beyond the environmental domain.

Policy responses to reduce vulnerability can be identified at different levels. At the local level policy responses can help to reduce vulnerability by improving coping and adaptive capacity. Policies at higher levels of decision-making can support local level coping and adaptive capacity and, more importantly, by mitigating pressures that put human-environment systems at risk. These responses are within but also beyond the environmental policy domain.

Conclusions

The patterns of vulnerability elaborated for GEO-4 show how environmental and non-environmental changes affect human well-being. By looking at the diversity of human-environment systems throughout the world, it became evident that some situations share certain vulnerability-creating conditions. These patterns highlight vulnerabilities across the full range of geographic and economic contexts in developing countries, industrialized countries and countries in transition. This allows placing particular situations within a broader context – while showing important connections between regions and the global context as well as possible opportunities for dealing with these vulnerable situations at different levels and within different domains of decision-making.

Lessons learned

- The approach has been useful for multiscale analysis that includes environmental and non-environmental exposures in a coherent framework.
- The GEO process has offered opportunities for a more participatory and policy-relevant way of identifying and selecting patterns of

vulnerability for further analysis. This has strengthened the legitimacy and relevance of the set of patterns of vulnerability analysed and provides a basis for further work.
- Trade-offs between multiple goals would need further attention in research and policymaking. Policies for vulnerability reduction can help to define acceptable balances of risk and benefit, based on improved assessment of the patterns of vulnerability.
- The aim of the analysis of patterns of vulnerability was to provide a basis for strategic directions for policymaking but not to provide detailed policy advice on each of the specific situations analysed in each archetype.
- The patterns of vulnerability are therefore used in a heuristic manner for policy analysis in GEO-4. More direct policy advice based on this analysis would require that patterns of vulnerability are again contextualized and connected to specific situations.

Recommendations for further research

- There is a potential for developing a more formal methodology for analysing patterns of vulnerability that includes both qualitative and quantitative approaches.
- This would support the accurate communication within and between different academic communities, policymakers and practitioners, and eliminate misunderstandings that result from the use of ambiguous terminology.
- Ideally, the analysis of patterns of vulnerability should be carried out within the region itself, with involvement of local stakeholders. The regional, national and local GEO-processes might offer opportunities for such a participatory process in the future. UNEP's regional offices and collaborating centres could play an important role in this.
- Quantification of archetypes could be explored further: for example, by making the analysis more dynamic and including future developments in the analysis. This would allow exploration of how vulnerabilities may evolve over time under different scenarios.
- It would be useful to develop (methods for making) more systematic assessments of possible policy responses for reducing vulnerability, making use of the opportunities natural resources offer (for example ecosystem-based adaptation).

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Notes

1. See for instance the Resilience Alliance at http://www.resalliance.org/ev_en.php
2. See http://www.povertymap.net/

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Part III

Global, national and sub-national assessment approaches

6

Review of global risk index projects: conclusions for sub-national and local approaches

Mark Pelling

Introduction

Efforts to index disaster risk at the global scale with national and sub-national resolution have gained momentum. This chapter reviews the approaches taken and the methodologies for five projects: the Disaster Risk Index, Hotspots, the Americas Indexing Programme generated in the 2000s and the Global Risk Analysis and World Risk Index generated in the 2010s. Implications for sub-national and local approaches are considered.

These programmes raise a number of important issues for consideration: the limitations of using mortality as an indicator of human loss; the value of measuring economic loss in absolute terms and also as a proportion of economic capacity; difficulties in identifying the impacts of drought that are often associated with complex emergencies; and the importance of producing outputs that are meaningful for development actors, if measurements are to contribute to development planning. In return, of course, the contributions made by local and sub-national efforts to measure vulnerability and coping capacity will help improve the collection and quality of input variables for international tools.

Finally, it is proposed that our work should investigate the potential for the aggregation and scaling-up of local vulnerability and capacity assessments. This will benefit local and regional risk planning and might also prove a resource for complementing or feeding into international indexes of vulnerability and risk.

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2^{nd} edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

Introduction

Between the spring of 2004 and the summer of 2005 three international indexes of disaster risk and its management were published: the Disaster Risk Index (DRI), Hotspots and the Americas Indexing Programme (see also Peduzzi, Chapter 7; Dilley, Chapter 8; Cardona, Chapter 10 in this volume). In the early 2010s a second wave of programmes was initiated: the Global Risk Index (drawing from methods and data generated by the DRI and Hotspots teams) and the World Risk Index (see also Chapter 9 and Birkmann et al. 2011) applying hazards data collected by the Global Risk Index but using a modelling approach closer in methodological terms to the Americas Indexing Programme. The development of these initiatives offers scope for comparison, and a learning opportunity for planned sub-national and local approaches.

This chapter offers a review of these two waves of international indexing initiatives, presenting a summary of conceptual orientation, methods and results of each group in turn. We then discuss the challenges and opportunities for developing sub-national and local measurements of disaster risk on the basis of the approaches developed in the three international indexing programmes.

The first wave: Disasters Risk Index, Hotspots and Americas Indexing Programme

These initiatives had two distinct methodological orientations. The DRI and Hotspots were deductive. Their measurements of vulnerability and risk were hazard specific and tied to disaster impact data. This grounds the analysis but means that measurements cannot be undertaken where input data is lacking. The Americas Indexing Programme was inductive. Its measurement of vulnerability and capacity was built on and constrained by available socio-economic and performance variables. This means measurements could be undertaken even where disaster loss data was hard to come by – for example in places exposed to low-frequency high-impact hazards – but meant that results were shaped by the choice and quality of input variables and not grounded in recorded loss data.

The following review focuses on those aspects of methodology and results that are most relevant to the measurement of vulnerability and capacity. The DRI, Hotspots and Americas programme are presented in turn with examples presented from flood-hazard-related assessment unless otherwise stated.

The Disaster Risk Index

The Disaster Risk Index (DRI) of the United Nations Development Programme (UNDP), in partnership with UNEP-GRID, aimed to demonstrate the ways in which development influences disaster risk and vulnerability (see UNDP, 2004 for its application). While expert judgement can be used to identify such linkages, the DRI represented the first effort to produce a statistical methodology. The DRI has global coverage and a national scale of resolution. Some 22 tributarian states were also included.[1] The DRI was applied in full to earthquakes, tropical cyclones and flooding. Preliminary analysis was also undertaken for volcanoes, landslides and drought. The starting point for the DRI was to obtain or produce hazard maps for earthquakes, cyclones and flooding (and also drought) that were then overlain by population maps in a GIS system to identify national human exposure to each hazard type.

The DRI produced two measures of human vulnerability. The first, relative vulnerability, is calculated by dividing the number of people killed by the number of people exposed to a particular hazard type. Higher relative mortality equates to higher relative vulnerability. The simplicity of the model meant that no country was excluded for showing outlier characteristics.

Relative vulnerability is highest in the top left-hand corner of Figure 6.1(c). The high relative vulnerability displayed by Venezuela was a result of the large number of deaths associated with catastrophic flooding in 1999; in this case landslides were an immediate cause of many of the deaths.

The second measure of vulnerability aimed to identify those socio-economic variables that best explained recorded mortality for individual hazard types. A stepwise multiple regression was used with disaster mortality from the Emergency Disasters Data Base (EM-DAT) as the dependent variable. Independent variables included physical exposure and a list of 24 socio-economic variables selected by an expert group to represent: economic status, type of economic activity, environmental quality, demography, health and sanitation, education and human development. Those independent variables that best explained the variation in the dependent variable were chosen to describe the global characteristics of vulnerability for each hazard type. The time period of mortality data availability (21 years for flooding and cyclones) was extended for earthquakes (36 years) to compensate for the low frequency of this hazard type, thus allowing a longer time period for the registering of mortality within EM-DAT. Volcanic hazard requires a longer time span, for which reliable loss data is not available, leading to the exclusion of volcanic

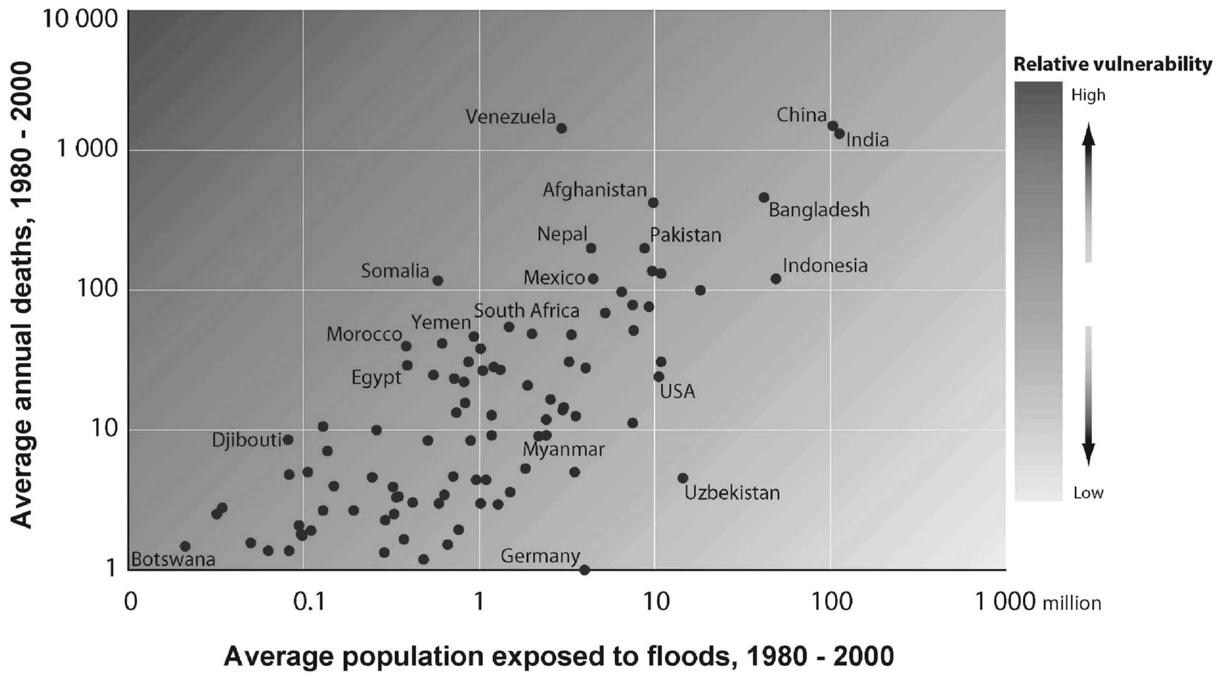

Figure 6.1 Relative vulnerability for flooding, 1980–2000
Source: EM-DAT OFDA/CRED and UNEP/GRID-Geneva (in UNDP, 2004).

Please see page 655 for a colour version of this figure.

hazard from the DRI index. The DRI analysis identified the following variables for flood risk in addition to physical exposure:

- low GDP per capita;
- low density of population.

In other words, according to the DRI, the risk of dying in a flood is greatest in countries with high physical exposure to flooding, small national economies and low densities of population.[2] This may reflect the greater difficulty of preparing for floods in low-density rural societies where large-scale public works such as river and sea defences, which require collective labour or large financial investments, are not easily delivered, and the difficulty in providing adequate emergency assistance and recovery support for low-density and widespread rural populations, such as those hit by flooding in Mozambique 2000 (Christie and Hanlon, 2001).

A DRI multihazard index combined values for hazard-specific socioeconomic variables. Hazard-specific models based on identified global vulnerability variables were run at the national level. For each hazard this allowed the calculation of expected mortality for each country and territory. The multiple-hazard risk index for each country was made by adding modelled deaths from individual hazard types. A final stage in the modelling process was to run a Boolean process to allocate one of five statistically defined categories of multi-hazard risk to each country. In order to examine the fit between modelled mortality and mortality recorded in EM-DAT, data from both sources were categorized into five country-risk classes and a cluster analysis performed to assess the closeness of fit.

Hotspots

The Hotspots project by Columbia University and the World Bank, under the umbrella of the ProVention Consortium, aimed to identify those places where risks of disaster-related mortality and economic losses were highest, on the basis of the exposure of people and GDP to major hazards, and on historical loss rates. Hotspots operates at the global level with a sub-national scale of resolution.[3] For Hotspots, which uses GIS grid cells as a unit of analysis, a decision was made to exclude grid cells with fewer than five people per km^2 and with no significant agricultural production. This reduced the number of grid cells in the global analysis from 8.7 million to 4.1 million.[4] Earthquakes, volcanoes, landslides, floods, drought and cyclones were included. Hazard severity was indicated by event frequency or probability. Exposure for each grid cell was calculated on the basis of the population and economic assets of that cell. It was assumed that all people and economic assets within an individual grid cell were equally exposed to hazard.

Two sets of vulnerability coefficients were calculated: one based on historical disaster mortality rates per hazard event, the other on historical rates of economic losses. Both vulnerability measures followed the same logic: 28 mortality and economic loss coefficients were calculated for each hazard. For both mortality and economic losses there was one loss rate for each of seven regions,[5] and four country wealth classes (high, upper-middle, lower-middle and low), defined according to standard classifications of the World Bank. For each hazard, historical mortality or economic losses per event for all countries in each region/wealth class were aggregated to obtain a loss rate for the hazard for the region/wealth class.

These rates, or weights, were aggregated for each of the 28 regions/wealth classes rather than calculated for each country individually because of an insufficient number of hazard/loss events and, therefore, loss data. Calculating the loss rates across groups of similar countries creates a larger pool of events across which to calculate them. Nonetheless, the historical loss data used to calculate the rates is thin for some hazard region/wealth class combinations.

Once calculated, and in order to obtain risk, these loss rates were used to weight hazard exposure of population or GDP for each grid cell. The weight from the corresponding region/wealth class in which the grid cell is located was used for each grid cell.

The Hotspots results were presented as relative risk values. The risk values for each of the 4.1 million grid cells were sorted into 10 equally sized deciles for each hazard, and for all hazards combined. The top 30 per cent of the values were considered relatively high risk, the middle 30 per cent as relatively medium risk and the lowest 40 per cent as relatively low risk.

Hotspots produced relative risk maps for mortality, economic loss and economic loss as a proportion of GDP. In Figures 6.2(c), 6.3(c) and 6.4(c), relative flood risk is shown as high (red), medium (yellow) or low (blue). Broadly speaking, South and South East Asia register high risks of both mortality and economic loss from flooding. In addition, Central and South America and sub-Saharan Africa show high mortality risk from flooding. Europe, North America and the Caucuses show high risk from flooding measured through absolute economic loss.

A multihazard Hotspots index aggregated single-hazard Hotspot values. A challenge for Hotspots was the lack of commensurability between measures of hazardousness for different hazard types. For example, frequency is used to measure severity for droughts and probability values for landslides. Aggregating these measures of severity would simply inflate the relative hazard values of those hazard types measured on a larger scale (for example, on a frequency of 0 to infinity compared to a probability of 0 to 1). To allow aggregation, a uniform adjustment was

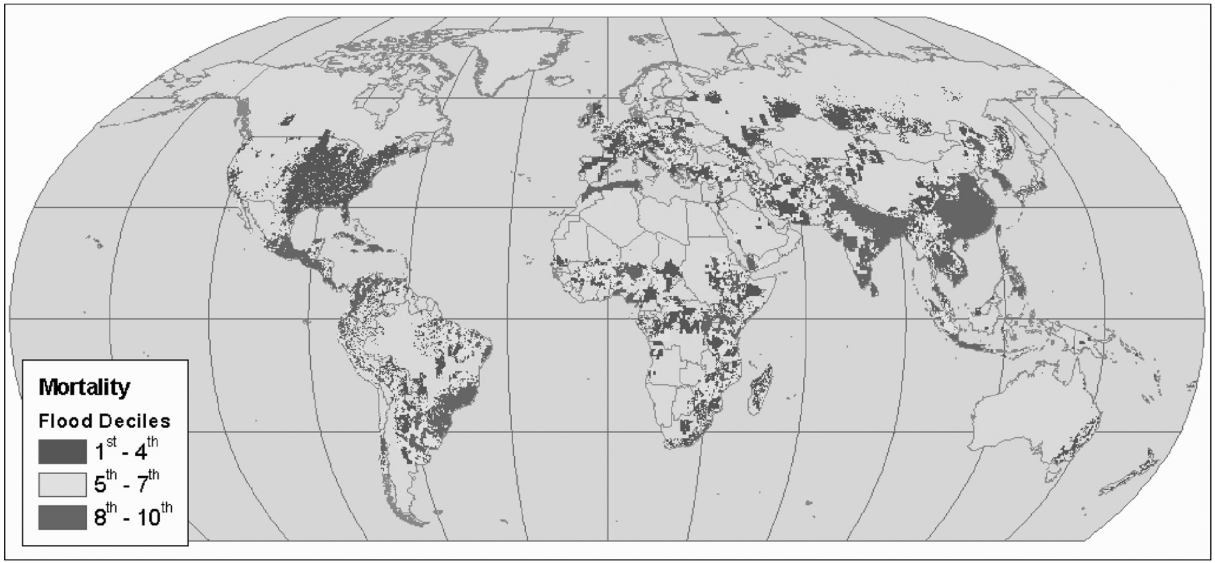

Figure 6.2 Global distribution of flood mortality risk
Source: Dilley et al., 2005.

Please see page 656 for a colour version of this figure.

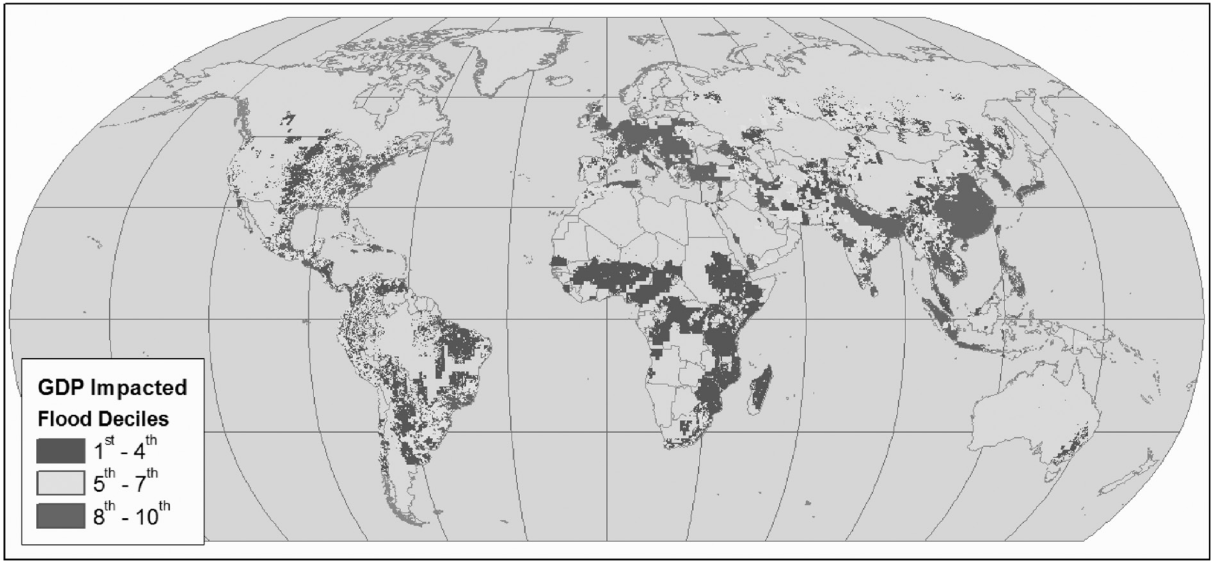

Figure 6.3 Global distribution of flood economic loss risk
Source: Dilley et al., 2005.

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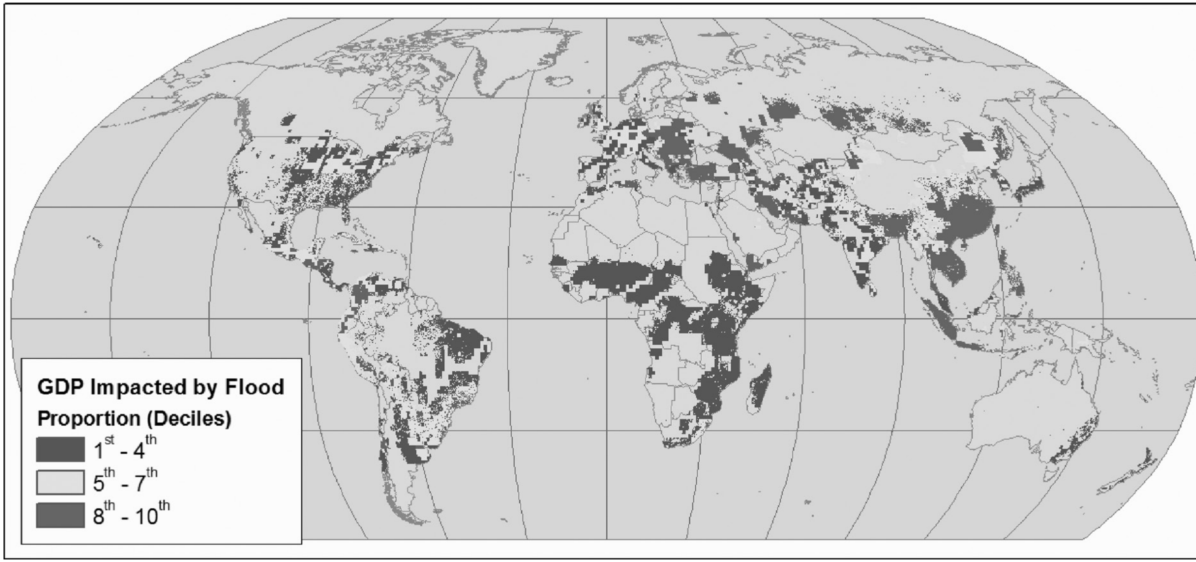

Figure 6.4 Global distribution of flood economic loss risk as a proportion of GDP
Source: Dilley et al., 2005.

Please see page 658 for a colour version of this figure.

made to all values within a given region/wealth class so that the total mortality or economic loss for the class equalled the mortality or economic loss recorded in EM-DAT for that hazard type.

The multihazard mortality-risk assessment was influenced strongly by high-risk individual hazard hotspots, for example those associated with drought mortality in sub-Saharan Africa, and flood and cyclone-associated mortality in Central America, the Caribbean, the Bay of Bengal, China and the Philippines. The Himalayas, sub-Saharan Africa and Central America show risk from two hazard sources. A comparison of multihazard mortality risk with that for total economic loss produces a familiar picture of risk shifting from low-income sub-Saharan Africa to the high-income states of Europe and North America. When risks of economic losses are calculated as a proportion of GDP compared to absolute GDP loss, multihazard risk remains high for the Middle East, is increased for eastern Africa, including Madagascar, and reduced for the Mediterranean states, North America, Europe and the Himalayas.

The Americas Indexing Programme

The Americas Indexing Programme of the Instituto de Estudios Ambientales, Universidad Nacional de Colombia – Sede Manizales, in partnership with the InterAmerican Development Bank, was designed to aid national decision-makers (in contrast to the international audience for the DRI and Hotspots). The system of indicators presented a benchmarking of each country in different periods from 1980 to 2000 and was the basis for consistent cross-national comparisons (see IDEA, 2005). Four independent indexes were developed; each represented disaster risk or disaster risk management in different ways and was targeted at specific audiences. Each index has a number of variables that are associated with it and are empirically measured:

- The *disaster deficit index* (DDI) measures a country's financial exposure to disaster loss, and the financial resources available for recovery.
- The *local disaster index* (LDI) represents the proneness of a country to locally significant disaster events, and their cumulative impact. Spatial variability and sub-national dispersion of disaster risk are also indicated.
- The *prevalent vulnerability index* (PVI) represents prevailing conditions of national-level human vulnerability.
- The *risk management index* (RMI) measures a county's performance in disaster risk management.

The suite of indexes was originally applied to 12 countries in Latin America and the Caribbean (Argentina, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Ecuador, Guatemala, Jamaica, Mexico, Peru and Trinidad and Tobago) (see IDEA, 2004). By 2012 all countries in Latin America had been reviewed with work ongoing in Brazil and the Caribbean.

The DDI is a function of the expected losses suffered by the state and the capacity of the state to generate reconstruction funds from private, government and international sources when hit by a maximum considered disaster event (MCE). MCEs with return periods of 50, 100 and 500 years related to rapid-onset hazards are considered. Vulnerability is formally included as part of the derivation of the DDI. It is used to represent the proportion of an asset that is calculated as likely to be lost in an event of a given intensity (the MCE). A DDI value greater than 1.0 indicates a lack of financial capacity to cover the costs of the disaster's impact. In a parallel presentation of this index, MCE losses are also expressed as a proportion of annual national current account budgets.

The DDI index has two elements. Figure 6.5 shows a ranked presentation of national financial capacity to cope with an MCE. Figure 6.6 presents calculated absolute economic losses. Both are for an MCE with a 50-year return period (an 18 per cent probability of occurring in any 10 years). Peru and the Dominican Republic are shown as not able to cope with such an event, with El Salvador a very marginal case. Absolute economic losses are greatest for Mexico.

With an MCE of a 100-year return period (5 per cent probability of occurring in any 10 years), seven countries were unable to cope. At a

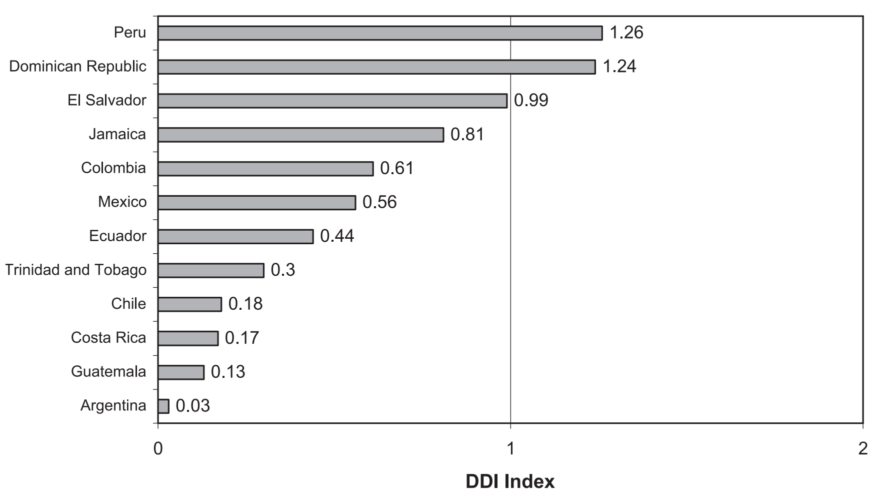

Figure 6.5 National financial exposure to catastrophic disaster
Source: Cardona, 2005.

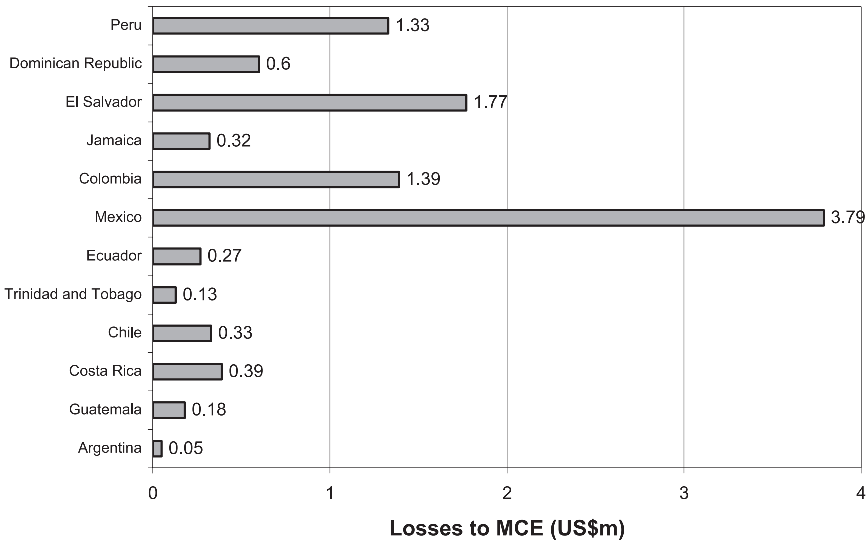

Figure 6.6 Absolute economic exposure to catastrophic disaster
Source: Cardona, 2005.

500-year return period (2 per cent probability of occurring in any 10 years) only Costa Rica could cope.

A complementary assessment, called the "DDI prime", was developed to indicate MCE losses as a proportion of current annual investment. In El Salvador, for example, future disaster losses are the equivalent of 32 per cent of the annual capital budget; in Chile the figure is 12.5 per cent, with only four countries below 5 per cent.

The LDI includes four hazard types (landslides and debris flows, seismo-tectonic disturbances, floods and storms, and other events[6]), based on the categorization of hazard used in the data source for this index: the DesInventar database, managed by La Red.[7] Values of local disaster magnitude and geographical distribution are calculated from three sub-indexes: mortality, people affected and physical loss (housing and crops) applied to sub-national regions or municipalities. Local data is combined to build the national LDI. A high LDI indicates high regularity in the magnitude and geographical distribution of disaster events recognized in the local reports and media across the country.

Figure 6.7 presents recorded mortality, people affected and economic loss associated with disaster events recorded in local and national media and reports, from 1996 to 2000. Colombia and Ecuador show a high incidence of deaths, with Guatemala and the Dominican Republic showing high numbers of people affected. Within the LDI an additional measure

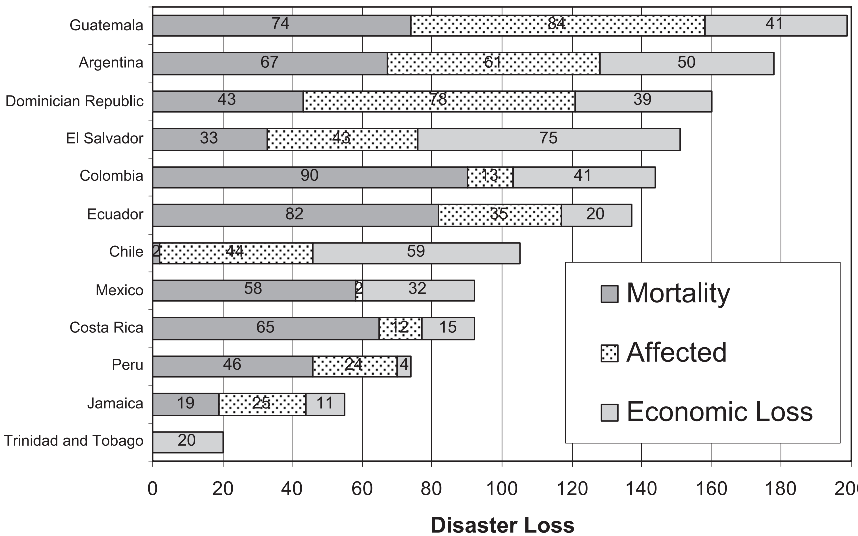

Figure 6.7 Loss from locally and nationally recognised disasters, 1996–2000
Source: Cardona et al., 2004 (in UNDP, 2004).

of the geographical concentration of disaster losses was calculated. This shows that losses were most evenly distributed within El Salvador. On the other hand, Ecuador, Chile, Colombia and Peru had the most geographically uneven distribution of losses.

The PVI is a composite index of inherent vulnerability at national level. It was derived from the aggregation of measures collected at the national level for three dimensions of human vulnerability: exposure and physical susceptibility, socio-economic fragility and lack of resilience. The PVI measures inherent (or intrinsic) vulnerability – no specific hazard type or scale of impact is required, nor is any disaster response capacity considered. Each dimension of vulnerability was calculated from eight quantitative components, which were weighted and aggregated to provide a final index value.

Figure 6.8 shows PVI values for the year 2000. Jamaica is shown to have had the highest vulnerability, scoring highly in each of the three measures. Guatemala and El Salvador also registered high composite vulnerability, with Guatemala having shown very high levels of lack of resilience.

The RMI is also a composite index. Four dimensions of disaster risk management were included in its calculation: risk identification, risk reduction, disaster management and governance, and financial protection. Each dimension had six qualitative components, to be valued at the

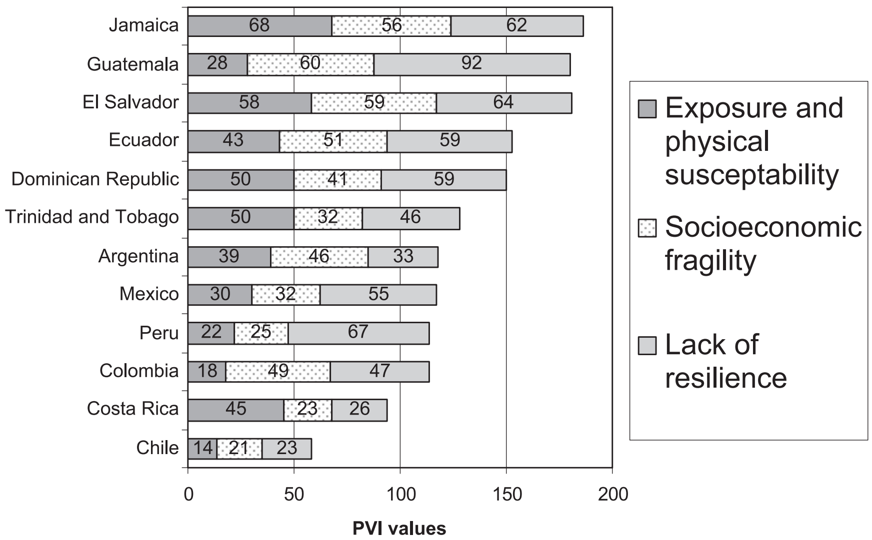

Figure 6.8 Socioeconomic vulnerability in the Americas, 2000
Source: Cardona et al., 2004 (in UNDP, 2004).

national level by expert judgement. The components were weighted and aggregated to arrive at the final index value. A sensitivity analysis was used to test for the influence on the results of the chosen weightings.

Figure 6.9 shows RMI values for the year 2000. Chile and Costa Rica performed relatively well on all indicators. Chile returned particularly high scores for disaster management and governance and financial protection. Other countries returned a less even performance: Argentina and Ecuador, in particular, had weak scores for governance and financial protection, and the Dominican Republic for risk identification. In 2012 an application in Guyana was the first to extend the RMI to explicitly include adaptive capacity. The Adaptive Capacity Index was developed by Pelling (see Pelling et al., 2012) to follow the format of the RMI. Both indexing tools are complementary, RMI providing base institutional data and the ACI focusing on learning capacity and experience.

The ACI as developed for Guyana has five components:

1. Improving foresight (horizon scanning for unexpected risks);
2. Critical self-reflection (the ability of policy and implementing agencies to reflect on practice outcomes);
3. Organizational structure;
4. Support for experiments in risk reduction and response;
5. Availability of resources for flexible vulnerability management.

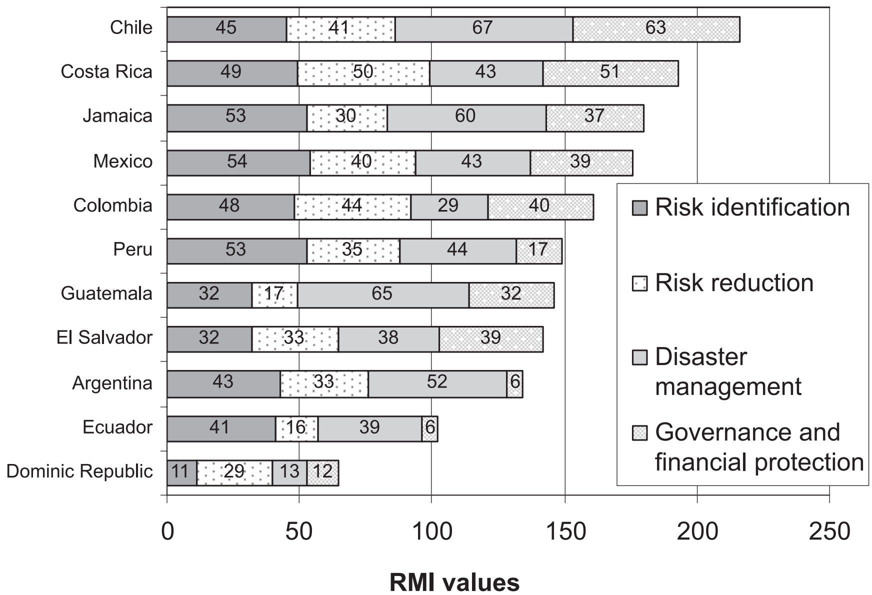

Figure 6.9 Disaster risk management performance in the Americas, 2000
Source: Cardona et al., 2004 (in UNDP, 2004).

Given the importance of local and sectoral resources and culture in shaping adaptive capacity and actions, the ACI is applied across a split sample. Samples can be organized by scale (national, local), sector (agricultural, urban etc.), mode of delivery (public, private, charity) or a mixture of these, depending on the resources available to the research team. In Guyana a national/local comparison was possible which highlighted the very low levels of capacity at the local level. Given that adaptation is an inherently local activity, the ability to disaggregate findings by scale of sector in this way is particularly useful for policymakers.

The second wave of indexes: The Global Risk Analysis and World Risk Index

Most recently, two international approaches to the measurement of vulnerability and risk have been developed that build on the experiences of the DRI, Hotspots and Americas models. The Global Risk Analysis (GRA) and underlying PREVIEW data archive were developed by the DRI and Hotspots teams (led by UNEP/GRID-Europe, UNISDR, the World Bank, the Norwegian Geotechnical Institute and Columbia University) to support the ISDR Global Assessment Report on Disaster

Risk Reduction in 2009 and 2011. The World Risk Index (WRI), led by the United Nations University, Bonn, incorporates data from the GRA PREVIEW archive. These two models, drawing from the same hazards database but applying different conceptual frameworks, analytical metrics and input variables to describe vulnerability, offer an opportunity for comparative analysis and for reflection on preceding DRI, Hotspots and Americas models.

The Global Risk Analysis

This account draws on Peduzi et al. (2010) and ISDR (2011). The GRA includes six hazards: earthquakes, landslides (with distinction made between landslides triggered by earthquakes and precipitations), tsunami, tropical cyclones (including wind and storm surge hazards), floods (excluding flash floods and urban floods) and meteorological drought.

Improved outputs have been made possible through a combination of enhanced data allowing more refined analysis. The GRA made use of higher resolution and more complete data on geographic and physical hazard event characteristics (especially for floods, tropical cyclones and earthquakes), higher resolution exposure data using population and economic assets (sub-national GDP) and new global datasets (on governance and corruption). In addition, enhanced geographic and physical modelling of hazard extents, frequency and severity – especially for floods, landslides and tsunamis – allowed hazard intensity or severity to be calculated for the first time, moving beyond vulnerability calculations based on the averaging of events. The DRI and Hotspots analysis was compiled to generate hazard and risk based on a 21-year return period. By explicitly linking event losses with the geographic, physical and socio-economical characteristics attributed to the event the GRA was able to model more adequately the contextual conditions in which each disaster occurred. The result is a more locally sensitive set of findings.

Comparing the results from the GRA with the DRI and Hotspots can illustrate trends in this school of global assessment. Some constraints remain: data shortfalls still exclude urban and flash flooding from global analysis. But results are interesting; new datasets have shown an average of 53.2 million people worldwide are exposed each year to included flood events with mortality closely associated with the size and growth rate of exposed rural populations. Lack of voice and accountability were also identified as significant factors. Smaller, more concentrated floods appear to cause relatively greater economic damage than floods with a larger extent. The former may affect areas with higher population density more severely, while the latter might mainly impact relatively lower-value agricultural lands. This reinforces the importance of including flash and urban flooding which are likely to offer among the highest economic losses – and often to overlap. The effect of a country's wealth was found to be much less pronounced for floods than for other disaster types. While mortality was concentrated in Asia (the top ten countries on the Mortality Risk Index for floods and their respective values are India, Bangladesh, China, Viet Nam, Democratic People's Republic of Korea, Afghanistan and Pakistan), significant economic damages from floods were also recorded in North America and Central Europe.

Multihazard risk was calculated with national resolution applying the DRI relative vulnerability calculation (for tropical cyclones, floods, earthquakes and landslides). Comparison with the 2004 DRI shows the sensitivity of this approach to individual large-scale events falling within the time-period of data availability, reminding users that this is not an easy tool for use in estimating future risk distributions. For the 2004 and 2011 DRIs, among those countries showing high relative risk Iran and Afghanistan are constant, new high risk countries include Myanmar, Colombia, India and China (all countries beset by large-scale events since 2004), with several countries showing less relative vulnerability (DP Korea, Ethiopia, Sudan, Venezuela and Honduras). The effect of this is to give greater emphasis to the vulnerability of Asian states on a global scale, a finding consistent also with the WRI.

The GRA analysis has mainly served to reinforce existing knowledge and key trends in risk geographies. It shows that disaster risk is geographically highly concentrated and very unevenly distributed; that for hazards of a similar severity, countries with higher incomes and, importantly, higher human development levels, generally experience lower mortality and smaller losses, and that poorer countries have disproportionately higher mortality and economic loss risks, given similar levels of hazard exposure. The greater time period open to analysis compared to the 2004 Hotspots and DRI shows that for most hazards, risk levels are increasing, dominated by growing vulnerability. Growth in vulnerability is tied to higher numbers of people and assets exposed through processes of rapid economic and urban growth, especially in cyclone prone coastal areas and earthquake prone cities. It might be that vulnerability can decrease as countries develop, but currently this is not observed.

For the GRA, as for the DRI and Hotspots, geophysical and drought hazards remain the most difficult to model. The analysis of earthquake risk in the GRA was constrained by the infrequency of events compared to the available data period (1973 onwards), though the Global Earthquake Model project is currently working to address this. Drought is difficult because of its very character being slow to develop, with unclear start and end points, and wide-ranging sensitivities to rainfall variability making it difficult to associate meteorological drought with food insecurity in a standardized approach. These and other challenges mean that the predictive quality of the GRA and its utility for local planning remain limited, and it should principally be seen as a guide for global and potentially national scale risk analysis.

The World Risk Index

The World Risk Index was developed by Birkmann et al. (2011) and Welle et al. (2012) for the *Bündnis Entwicklung Hilft* (an alliance of German development and relief agencies providing long-term aid in the aftermath of major disasters and in emergencies). It includes four component indicators used to describe exposure, susceptibility, coping and adaptation. The index uses globally available data with national scale resolution.

Exposure was calculated by the number of people exposed to a certain hazard divided by the total population of the country or community analysed. Exposure data was drawn from the GRA PREVIEW dataset, and applied to a more extensive list of hazards including earthquakes, storms, floods, droughts and sea-level rise. Sea-level rise is especially novel, and does not appear on PREVIEW. To estimate this value, global georeferenced population (http://geodata.grid.unep.ch) was combined with information regarding the sea-level rise scenarios (https://www.cresis.ku.edu/data/sea-level-rise-maps) for a 1m sea-level rise scenario – an approach limited by providing data only for existing populations and taking no account of future demographic change.

The *susceptibility* sub-indicator was defined as describing those conditions of exposed communities or other exposed elements (infrastructures, ecosystems, etc.) that determine the likelihood of experiencing harm and so being negatively affected by a natural hazard or by climate change. Five input categories were used: nutrition, public infrastructure, housing conditions, poverty and dependencies, economic capacities and income.

Coping was defined as the ability of an impacted society, group, organization or system to use its own resources to face and manage emergencies, disasters or adverse conditions. It was populated by variables describing government and authorities, disaster preparedness and early warning, medical services, social networks and economic coverage.

Adaptation was defined as a long-term strategy associated with a particular hazard risk. Input variables were: education and research, gender equity, environmental status/ecosystem protection, adaptation strategies and financing.

Across these four sub-indicators data limitations prevented the use of four sub-categories (housing conditions, disaster preparedness/early warning, social networks and adaptation strategies) unavailable at the global level with national resolution. Some small island developing states were also excluded because of unreliable hazard data. Surviving input variables drawn from global databases were transformed between 0 and 5, and weighted to provide four sub-indicator scores.

Results of the WRI presented in Table 6.1 indicate the significance of exposure on this calculation of vulnerability, with seven of the WRI top ten also appearing in the hazard top ten. In contrast, the appearance of Bangladesh and Timor-Leste and the absence of Japan and Chile (high exposure but also high capacities to cope and adapt) among the more risk prone demonstrate the successful compound methodology of the WRI. As with the GRA, Asian countries dominate. Sub-Saharan Africa is shown to be a region of very high susceptibility and with gaps in coping and adaptive capacity and therefore potentially very vulnerable should climate change lead to shifts in global hazard distribution. Within Africa it is important to note that Botswana and South Africa show good values for coping capacities. It is hypothesized this is due to stable political systems and well-developed heath systems. The low visibility of sub-Saharan African countries in the WRI top ten also highlights the challenge of dealing with drought, which remains associated with more mortality than any other hazard but escapes easy indexing.

Lessons and open questions

The following discussion considers lessons to be learned and open questions from the international indexing initiatives for developing subnational and local measurements of vulnerability and coping capacity. In DRI, Hotspots and GRA, vulnerability was calculated in relation to specific hazard types before aggregating to multihazard analysis. Consequently, challenges in representing hazards led to difficulties in measuring vulnerability. For the Americas programme vulnerability was measured as an intrinsic status. The WRI was a hybrid with exposure included but independently so that other aspects of vulnerability could be analysed without being tied to hazard data. Below, we shall look in turn for lessons and opportunities when measuring hazards and vulnerability, and in aggregating for multihazard analysis.

Measuring hazards

Sub-national data is fed into each of the indexes. Hotspots, DRI and GRA mapped local data on hazards and people exposed to hazards into GIS systems and then aggregated to GIS cell and national levels

Table 6.1 Results of the World Risk Index and its sub-indicators

Multihazard exposure	Susceptibility	Lack of coping capacity	Lack of adaptive capacity	Vulnerability (aggregated susceptibility, coping and adaptation)	World Risk Index
Vanuatu	Niger	Chad	Afghanistan	Afghanistan	Vanuatu
Tonga	Mozambique	Afghanistan	Comoros	Niger	Tonga
Philippines	Liberia	Guinea	Niger	Chad	Philippines
Costa Rica	Madagascar	Central African Republic	Mali	Sierra Leone	Solomon Islands
Japan	Eritrea	Sudan	Chad	Eritrea	Guatemala
Guatemala	United Republic of Tanzania	Burundi	Sierra Leone	Central African Republic	Bangladesh
Solomon Islands	Sierra Leone	Guinea-Bissau	Djibouti	Liberia	Timor-Leste
Brunei Darussalam	Chad	Niger	Yemen	Mozambique	Costa Rica
El Salvador	Haiti	Haiti	Mauritania	Burundi	Cambodia
Chile	Burundi	Timor-Leste	Pakistan	Haiti	El Salvador

respectively.[8] This data could be available to be verified or used as input data for sub-national assessments.

Of the hazards for which analysis was attempted, flood, earthquake and drought hazards proved the most difficult to capture. For floods this was due to the lack of a comprehensive global database (flash floods and urban floods are still excluded). DRI was forced to overestimate; it used EM-DAT to identify floods and considered all those people living in floodplains as exposed. Hotspots was forced to underestimate; it used satellite imagery to identify flood events. However, the speed of local flash floods makes it likely that many of these may have been missed.

It is assumed that mapped hazard events will spatially overlap with sites of recorded losses. As the resolution of assessments increases, this assumption becomes harder to support. This is especially the case with slow-onset and long-duration events such as drought, where hydrological and socio-economic systems can spread mortality and economic loss attributed to a drought to distant areas. Greater input from local knowledge and the possibility of mapping indirect and secondary socio-economic impacts presents opportunities for local vulnerability and capacity assessments to refine international measurements in this regard.

Care must be taken not to use DRI, Hotspots, GRA or WRI to predict future risk distributions. All models used past hazard exposure (as well as past data on disaster impact, population and socio-economic variables) to calculate vulnerability and risk values. The assumption is that places where hazard, vulnerability and disaster impacts were recorded in the past are those most likely to experience them in the future. This assumption becomes less tenable at finer resolutions where development pressures, such as rapid urbanization and local environmental changes linked to global climate change, have the potential to radically alter local distributions of population, wealth, hazard and vulnerability over a short time period relative to hazard frequency. It is also possible that losses during past disasters will lead to a local learning process and the building of resilience, rather than the continuation of vulnerability, so that past impacts might locally be associated with future security, rather than vulnerability. Regular assessments accompanied by contextual analysis of pressures shaping hazard, vulnerability and disaster risk management can help overcome this challenge for measuring local risk.

An exception to the retrospective calculation of risk comes from work on landslides by the Norwegian Geotechnical Institute (NGI). Here, hazardousness was identified though the analysis of the geophysical and hydrometeorological characteristics of each grid cell in Hotspots, not by counting past events. In the inductive approach of the Americas programme's DDI, the use of an MCE instead of a past event meant that financial capacity was measured against hypothetical future risk, not past losses, allowing infrequent hazards such as earthquakes to be included in the analysis.

Drought is associated with more loss of life than any other hazard.[9] It has also proved to be the most difficult hazard to index. More than in other hazards, additional human and environmental processes can intervene between a hydrometeorological event and the recording of losses. Conceptually, this gap is not fundamentally different from that experienced in other hazard-specific disasters (which led Hotspots to include drought in their analysis). However, when the pilot DRI results showed that exposure to drought was not among the socio-economic variables explaining recorded drought losses as listed by EM-DAT, it was clear that the influence of other factors – particularly armed conflict, chronic illness and poor governance – was of a magnitude greater than that found with disasters triggered by other types of hazard. For this reason drought was left out of the final DRI analysis. Sub-national measurements will also have to contend with the politicized nature of deaths attributed to drought, although being closer to data collection and having the possibility of verifying data and index outputs with local actors can add validity to higher resolution studies.

Volcanic hazard was excluded from the DRI because the extremely low frequency of volcanic eruptions meant that many countries where the hazard was found had no records of loss in EM-DAT. Consequently, it was not reasonable to undertake the regression analysis to identify socio-economic variables. Local assessments often include a review of past losses but should not be tied to it, focusing instead on present conditions and trajectories of socio-economic and environmental change so that low frequency and potential future hazard types can be considered in multihazard vulnerability analysis.

Hazards can interact with each other. The concatenation of hazards occurs when one hazard triggers another. An example might be a landslide triggered by a flood, which was in turn caused by a cyclone. Recognizing concatenation effects was a challenge for international indexes where databases did not uniformly record the immediate and proximate hazard causes of loss. Figure 6.1(c) shows a DRI identifying Venezuela as a country highly vulnerable to flood risk. This result was greatly influenced by high mortality from landslides following a single episode of heavy rain. In this case the landslide factor was recognized by the DRI and incorporated in the analysis of results. Once again, the challenge is to develop local vulnerability measurements that can include much more contextual information, and use local knowledge to verify results. This also shows the necessity for multihazard-based analysis. This is likely to be especially important in the multihazard environment of urban settlements (Pelling, 2005c).

Measuring vulnerability

DRI, Hotspots, GRA and WRI use mortality in calculations of vulnerability. Mortality is arguably the most reliable comparative indicator of human loss at the global scale. Data on people affected, injured or made homeless are far less reliable. Reliance on mortality gives statistical rigour but limits policy impact. This can be seen most clearly in drought events, where complex interactions between drought, political violence, chronic disease and economic poverty can make it very difficult to ascribe causes of mortality. It is more reasonable to account for the livelihood impacts of a drought. But this can only be measured on the ground and at the local scale. A good deal of work in southern Africa, in particular that coordinated by the Famine Early Warning Systems Network (FEWS NET, see http://www.fews.net), has developed methodologies for measuring drought vulnerability up to the national scale.

In the Americas programme, the LDI included the number of people affected and economic loss alongside mortality. This extension is helpful, particularly because the three elements remain disaggregated. But the reliability of information on people affected is problematic: a clarity and adherence to the definition of an affected person is required if meaningful national comparisons are to be made, but these are notoriously difficult to achieve. The same will be true for any studies hoping to aggregate local vulnerability or capacity assessments that include a measure of past losses in their assessments.

Hotspots and GRA also used economic loss as an indicator of disaster impact. Three constraints face the use of economic measures of loss:

- There is very rarely any account of long-term economic impacts (sometimes called secondary losses), including changes in national balance of payments, international debt or fluctuating levels of employment or price inflation in the years following a disaster.
- The focus on economic impacts excludes assessments of local economic loss, and thus the destruction or erosion of household livelihoods is not accounted for.
- A focus on GDP means losses to the informal sector – which can reach 50 per cent or more of the financial capacity of states in extreme cases, and often exceeds 50 per cent of the economic exchange in subnational units – will remain very difficult to account for. This is partially addressed in Hotspots through measuring impact as a proportion of GDP.

It is likely that local measures of economic loss will be able to respond to the latter two gaps but will find it difficult to track secondary disaster impacts through the macro-economy; this is a task for national-scale economic analysis undertaken some time after an event (Pelling et al., 2002).

The DDI and LDI indexes of the Americas programme also incorporate elements of economic loss. In the DDI, spending on the social sector (particularly housing) following disasters was included in measures of financial exposure and goes some way towards recognizing the national consequences of damage to the informal sector.[10] The LDI measure of economic loss included an assessment of housing damage, which explicitly included estimates of loss in the informal housing sector.

Hotspots aimed to calculate vulnerability for individual grid cells where data was only available at the national level. Hotspots resolved this by allocating each grid cell to one of 28 wealth regions. This approach might be useful for sub-national calculations where local data is not uniformly available. A key problem with this type of approach is that exceptional areas within each group will be lost within the averaged vulnerability value of their group. In sub-national assessments the degree of suppression of extremes could be uncovered by rapid ground-truthing exercises and presented as a health warning on results. The overall approach is useful where local vulnerability data is lacking but where key indirect indicators are nonetheless available. When brought together with hazard data this method can help identify areas of high risk for more detailed local study – exactly the aim of Hotspots.

The inductive approach taken by the Americas programme and in part by the WRI is quite different from the deductive approach of the DRI, Hotspots and GRA. In the Americas programme regarding the PVI and RMI and the WRI measures for susceptibility, coping and adaptive capacity, five considerations have been identified that can inform future inductive work at the sub-national and local levels:

- When choosing input variables there are dangers of overlap, leading to double counting of a particular attribute, and to omission when no suitable input variables can be found. The PVI includes many socio-economic variables but has been less successful in finding variables that capture the governance and political aspects of vulnerability. This leads to the measurement of a specific understanding of vulnerability that is shaped as much by variable availability as by vulnerability theory.
- The mechanism for choosing input variables must be transparent to prevent the political manipulation of findings. In the PVI, the indicator for exposure and susceptibility is built from three population, four macro-economic and one poverty input variables. One can imagine that a shift in policy priority could lead to the selection of alternative input variables producing different results. This can be an advantage, lending the method to policy flexibility. But care is needed to ensure

that changes are based on technical rationality, not political expediency.
- The larger the number of components within each sub-index, the more difficult it becomes to attribute index characteristics to individual component indicators. This in turn makes it more difficult to provide clear policy advice.
- New variables may be needed and existing variables discarded as the context of vulnerability generation and data availability changes through time. The WRI identified several input variables not yet globally available that had to be disregarded. The choice of input variables should be constantly under review.
- Vulnerability and coping capacity should not be expected to have a linear relationship. Good risk management performance does not lead necessarily to low recorded vulnerability. For example, Jamaica has a high PVI and a high RMI. It takes time for risk reduction policy to translate into reduced vulnerability, because disaster losses are influenced as much by variability in hazard frequency and severity as by vulnerability.

Building multihazard measurements

The DRI, Hotspots, GAR and WRI generated hazard-specific measures of vulnerability and risk and then, through aggregation, produced multihazard assessments. For these approaches the biggest challenge was how to combine hazards measured on different metrics: for example, Hotspots devised a statistical method for combining the hazardousness of drought (measured by frequency) and landslides (measured by probability).

In the Americas programme, PVI and RMI measured vulnerability and capacity as intrinsic values, not specific to any hazard type. This avoided any problem of combining hazards but meant that measurements could not take the individual characteristics of particular hazard types into account. Both the hazard-specific and intrinsic measurements of vulnerability and capacity have advantages and disadvantages. Intrinsic measures are perhaps most useful for assessing capacity, which in this form can be presented as a generic value and resource for any future danger, including new hazards as yet unknown in a particular location.

Key contributions

What potential is there for developing sub-national risk indicators from the three approaches?
- In the DRI, a sub-national measure of relative vulnerability would not be difficult to generate. Exposed population is already mapped with

fine resolution by DRI and Hotspots and could be combined with local loss data. Local loss data is harder to come by but is available for those countries covered by La Red's DesInventar database; in addition, MunichRe records the local place of loss in its global NatCat database. UNDP has already begun to work with national representatives to build national DRI indicators.

The DRI approach to identifying socio-economic vulnerability indicators could be applied sub-nationally to any collection of socio-economic variables that are considered relevant and accessible. A common pool of variables is only needed when comparison across cases or time is required. This is helpful when constructing composite risk maps but not necessary when looking to characterize the principal development pressures shaping risk in a specific location at a particular time.

- The Hotspots analysis already produces sub-national scale maps of risk. However, for many places the meaningfulness of a sub-national resolution is limited by large numbers of contiguous cells having identical values: large areas of China and India, for example, have common risk values. This suggests that data scarcity means local variability is not being fully represented in the current analysis; while data scarcity is less of a concern for a global analysis, it becomes more important as the resolution increases.

  Hotspots' separation of loss into mortality, economic loss and economic loss as a proportion of GDP is valuable and could be deployed at the sub-national level where sub-national measures of GDP exist or can be calculated. The Hotspots approach for calculating local area values from national data could also be deployed in sub-national level studies.
- Each of the Americas programme's indexes speaks to a particular policy community. This is especially valuable at the national level where disaster risk needs to be presented in a user-friendly way, using metrics already known and applied in the everyday planning processes of economic, social and infrastructural development. The methodologies for Americas programme indicators can be applied to lower scales where data is available and decentralized disaster risk-planning authorities and resources have made sub-national analysis worthwhile. The conceptualization of vulnerability and capacity as intrinsic properties can be useful at sub-national and local scales, possibly in conjunction with hazard-specific measures. Indeed recent work under the EU FP7 programme MOVE has applied a variant of the RMI to describe risk management capacity for drought and heat wave in London (www.move-fp7.eu/)

Conclusions and outlook

These approaches to the calculation of vulnerability and risk highlight those that exist in our data and understanding, and also the range of ways around these problems. Many of the challenges facing international disaster risk indexing are also relevant to sub-national and local measurement of vulnerability and risk.

From the deductive approach of the DRI, Hotspots and GRA we learn that:

- Local hazard maps exist, but the speed of flash flooding and urban flooding and the high secondary impacts of drought have yet to be incorporated.
- Care should be taken if retrospective data is used to assist forward-looking policy decision-making.
- Political and business interests can distort loss data, particularly in slow-onset and complex disasters such as drought, where losses are hard to attribute to any one pressure.
- It is difficult to incorporate low-frequency and future hazards when basing assessments of vulnerability on past experience.
- The concatenation of hazard means individual hazard phenomena can result in multiple hazard types: a cyclone can result in wind, flood and landslide damage.

Higher resolution assessments can add value by:

- exposing the trail of causality from physical event to recorded impact;
- measuring livelihood loss and loss in the informal sector, alongside mortality and direct macro-economic impacts;
- providing a detailed characterization of vulnerability and capacity in high-risk locations.

From the inductive approach of the Americas indicator programme and WRI we can learn that:

- It is important to guard against double counting and omissions during selection of input variables.
- The choice of input variables must be transparent to prevent the manipulation of results.
- There is a tension between the comprehensive representation of vulnerability and capacity that comes from using a large number of input variables, and the clarity that comes from using a small number of variables.
- A constant review of input variables is needed as the causes of vulnerability and capacity and the availability of input variables change over time.
- The relationship between vulnerability and capacity is not linear.

High-resolution assessments can add value by:
- providing a verification check on input variables;
- providing a detailed characterization of vulnerability and capacity in high-risk locations;
- showing how intrinsic measurements of vulnerability and capacity play out in particular places facing specific combinations of hazard.

Two key challenges for sub-national and local measurements of vulnerability and capacity come from the reviews undertaken in this chapter. First, how can high-resolution assessments best feed into development and disaster risk reduction decision-making? There is much scope for local assessments to be part of early warning systems, but this connection influences the methodologies used and must be planned for from the outset. Second, can individual assessments be aggregated to upscale results and feed into or complement lower resolution assessments? Initial evidence suggests this is a possibility. Action Aid has already conducted aggregations of local vulnerability assessments in Sierra Leone and Zimbabwe.[11] More work on methods of aggregation can help this process, as can improved communication between the people involved in planning and undertaking local and international scale analyses of risk.

Acknowledgements

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Notes

1. For example, Montserrat and Bermuda were treated independently rather than as part of the United Kingdom. Tributarian States will also be included when the term "country" is used in discussions of the DRI method and results.
2. Vulnerability and hazard exposure variables were identified through a correlation with mortality data from EM-DAT.
3. The units of analysis are some 4.1 million 2.5 by 2.5 minute grid cells. With areas ranging from 21 km^2 at the equator to 11 km^2 at the poles, these cells cover most of the inhabited land area of the globe.
4. With a minimal number of people or assets exposed to hazard, calculated disaster risk would always appear low for these grid cells.

5. Africa, East Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia.
6. Other events include biological and technological phenomena.
7. http://www.desinventar.org/desinventar.html
8. See Pelling, 2005a and 2005b for reviews of internationally available data with sub-national resolution that could be used to feed into sub-national measurements of risk.
9. For a discussion of the gaps in data and in the understanding and modelling drought risk, see an ISDR report entitled "An Integrated Approach to Reducing Societal Vulnerability to Drought" on http://www.unisdr.org/
10. Indexes aim to provide technical, non-political information for decision-makers. In so doing, the DDI correctly includes social spending as an area of potential exposure from the perspective of national finances. It is hoped this might encourage financial mechanisms for risk and loss management and investment to reduce the fragility of informal housing. But such information is hostage to political prioritization. A less progressive response to the DDI could be to cut back on government support for the social sector. Such a decision would in effect transfer risk from the national exchequer to low-income groups. This concern shows the advantage of multi-dimensional benchmarking as a means of assessing national disaster risk reduction performance. In the Americas programme, any strategic shifting of disaster risk to low-income groups should register on the PVI, with a lack of comprehensive disaster management planning that such a strategy implies being flagged by the RMI.
11. Personal communication from Ethlet Chiwaka from Action Aid's International Emergencies Team in 2005.

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7

The Global Risk Analysis for the 2009 Global Assessment Report on Disaster Risk Reduction

Pascal Peduzzi

Introduction

In May 2009, the UNISDR system published the 2009 *Global Assessment Report on Disaster Risk Reduction* (GAR 2009). One component of this report consisted of a global risk analysis. This task was performed by several institutions who pooled their efforts over two years to achieve a global modelling of hazards, including new hazard models for floods, tropical cyclones, landslides, drought and tsunamis as well as a reinterpretation of the earthquake hazard model. It allowed for the computation of human and economic exposure. A totally new methodology was used to calibrate vulnerability using a so-called event-per-event analysis. This made it possible to determine the socio-economical and contextual parameters that are associated with human and economic vulnerability. This new methodology considers the intensity of each event as well as contextual parameters in order to compute the risk for different natural hazards. Risk maps were generated at a resolution of 1 × 1 km and then aggregated at 5 × 5 km for four natural hazards (i.e. floods, earthquakes, landslides and tropical cyclones). The methodology also allowed for the computation of an index for comparing the risk level of different countries. Trends in risk were also studied.

This chapter presents a summary of our contributions to Chapters 1 and 2 of the United Nations (UN) 2009 *Global Assessment Report on Disaster Risk Reduction* (UN, 2009c) launched in May 2009 by the UN Secretary-General. The global disaster risk analysis involved a large

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

number of scientific and technical institutions, including UNEP/GRID-Geneva, UNISDR, the World Bank, the Norwegian Geotechnical Institute and Columbia University. It also benefited from data support from multiple institutions. Major methodological innovations based on the analysis of thousands of individual events have enabled a more accurate characterization of global risk, the identification of key risk drivers and the spatial distribution of hazards, exposure and risk. Six hazards were studied: earthquakes, landslides (with a distinction made between landslides triggered by earthquakes and precipitations), tsunami (see Figure 7.1(c)), tropical cyclones (including wind and storm surge hazards), floods (excluding flash floods and urban floods) and meteorological drought (Figure 7.2(c)).

Data generated for this research have been made available online through the PREVIEW Global Risk Data Platform. This is sustained by Spatial Data Infrastructure (SDI) technology and is compliant with the OGC Web Services (Giuliani and Peduzzi, 2011).

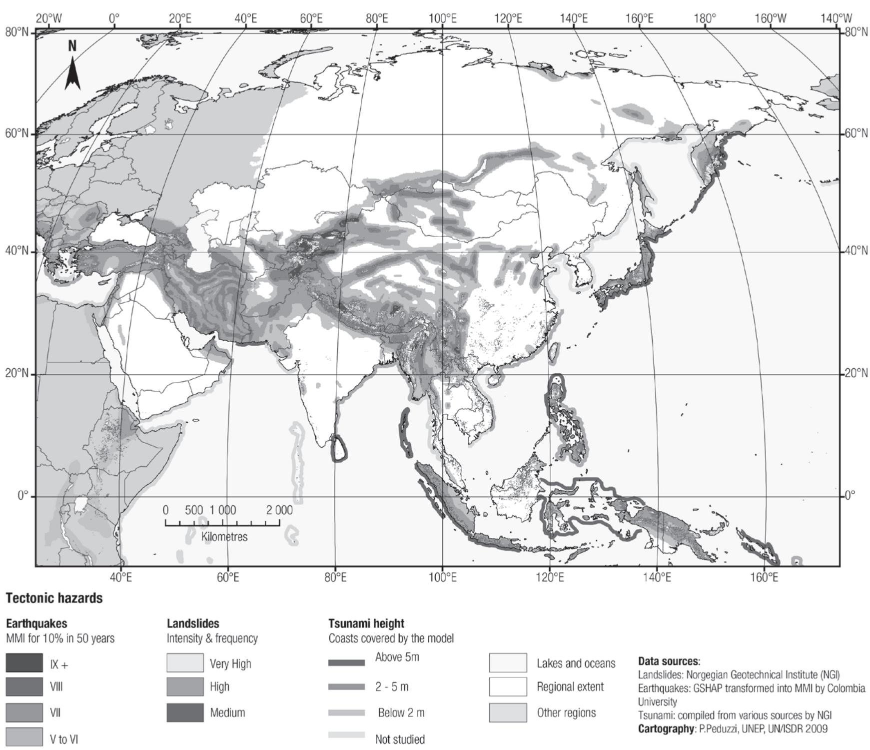


Figure 7.1 Tectonic hazards distribution for Asia

Please see page 659 for a colour version of this figure.

Two main previous studies aimed to map hazard and risk distribution. In 2004 UNDP/BCPR published the Disaster Risk Index (UNDP, 2004), which was further updated and refined (Peduzzi et al., 2009). In 2005 the World Bank published the Disaster Risk Hotspot (Dilley et al., 2005). Both studies examined multiple hazards. The authors of both studies met in 2006 and evaluated the gaps that needed to be addressed. These mostly highlighted the need to create a global flood model, as well as the need to take the intensity of hazards into consideration. Members from the two teams joined together to generate this new global disaster risk analysis.

The improvements in estimates of global disaster risk have been made possible by using higher resolutions and more complete data on geographic and physical hazard event characteristics, especially for floods, tropical cyclones and earthquakes. It has also benefited from higher-resolution exposure data on population and economic assets (sub-national GDP), as well as enhancements in geographic and physical modelling of hazard extent, frequency and severity – especially for floods,

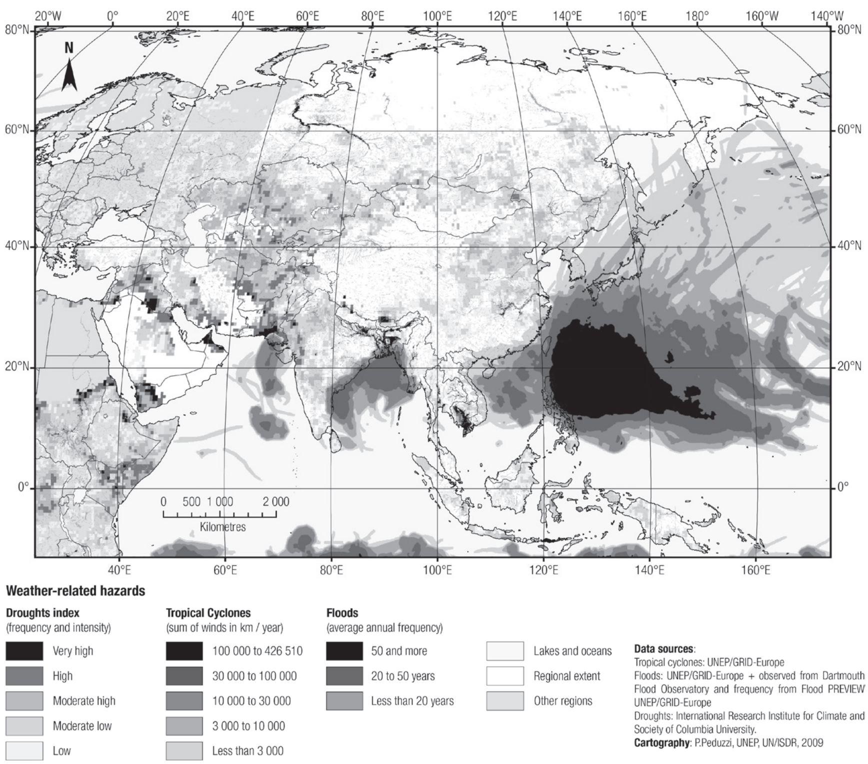


Figure 7.2 Weather-related hazards distribution in Asia

Please see page 660 for a colour version of this figure.

landslides and tsunamis – allowing hazard intensity or severity to be calculated (Herold and Mouton, 2011). Additionally, there has been incorporation of new global data sets of social, economic and other vulnerability factors, such as governance and corruption.

However the main improvement came from the so-called event-per-event analysis. Earlier global studies were based on averages over a 21-year returning period which prevented them from including the intensity of the event. By analysing each event using an explicit linking of hazard event outcomes (i.e. losses) with the geographic, physical and socio-economical characteristics of the event, the model can incorporate more adequately the contextual conditions in which each disaster occurred.

Methodology

Except for earthquakes (where the Global Seismic Hazard Assessment Program (GSHAP) was used), for all the hazards a global model was generated using geophysical and meteorological data. A detailed explanation of the methodologies cannot be included in this short summary, the hazard, exposure, vulnerability and the event-per-event risk methodology were described in detail for tropical cyclones (Deduzzi et al., 2012); details on hazards methodology were also published for flood (Herold and Moutor, 2011) and for tsunami (Levholt et al., 2012), as well as for landslides (Nadim et al., 2006 and 2013). The model required the processing of 1.5 Tb of data and more than 6,000 hours of computation. The hazard updates were reviewed by panels of international scientists under the supervision of WMO for weather-related hazards and UNESCO for geological hazards.

To model hazard frequency and severity, geographical and physical information on specific hazard events was compiled for tropical cyclones, floods, earthquakes and droughts. Models for susceptibility were generated for landslides and tsunamis. For each hazardous event and model, the footprint (or area of impact with frequency) was generated for each class of severity. Then the human and economic exposure was computed using Landscan population (Landscan, 2007) and World Bank GDP distribution models. These models were reprocessed to show population and GDP at the time of the event (1975–2008).

For risk calibration, links were made between available loss information for each hazard event (sourced from EMDAT, 2008) to the hazard event information (hazard severity and exposure) by intersecting the footprint of the hazard with country borders, using country names and dates to link with past recorded losses. This was done using previously applied methodology (Peduzzi et al., 2005).

Vulnerability and contextual parameters were added: these could be country-level indicators (such as per capita income) or spatial context data (such as distance from capital city or local GDP) for the year in which the event occurred. Using this information, a vulnerability statistical analysis was run to produce estimated empirical loss functions that relate event mortality or economic loss to risk factors (hazard characteristics, exposure and vulnerability) using statistical regression techniques.

Maps showings risk distribution were generated by applying estimates to all pixels in a geographic grid of hazard distribution. The loss estimates can be aggregated at different levels (for example, 1 km × 1 km cells). Mortality risk can be classed in deciles using a logarithmic index with values ranging from 1 = negligible to 10 = extreme risk. Finally a mortality risk index was computed by aggregating risk at national level. This was made using two axes: average absolute mortality per year and average relative mortality per year (per million inhabitants).

Results and discussion

Tropical cyclones

Disaster risk for tropical cyclones has been calculated taking into account hazard associated with both wind speed and storm surge for different categories of cyclones on the Saffir–Simpson scale. Drawing from a previous study (Nordbeck et al. 2005), more than 2,500 individual tropical cyclones were modelled using central pressure and maximum wind speed (Peduzzi et al., 2012). The areas affected by storm surge were computed using a conversion table of storm surge height according to Saffir–Simpson classes and overlaying these areas with a Digital Elevation Model (SRTM at 90 m elevation). The extraction of exposure revealed that an average of 78 million people worldwide are exposed each year to tropical cyclone wind hazard and a further 1.6 million to storm surge. Asian countries have the largest absolute population exposed, while Small Island Developing States (SIDS) have the highest proportion of their population exposed. In terms of economic exposure, an annual average of US$1,284 billion of GDP is exposed to tropical cyclones. The country with the highest absolute exposure is Japan. The countries with the highest relative exposure, however, are almost all SIDS. Governance and social equity play a critical role in economic losses. Geographically, tropical cyclone mortality risk is highly concentrated. The top 10 countries on the Mortality Risk Index and their respective values are: Bangladesh, the Philippines, India, Madagascar, the Dominican Republic, Haiti, Myanmar, Vanuatu, Mozambique and Fiji.

Floods

Disaster risk for floods has been calculated for large rural flood events (hence excluding flash floods or urban flooding). To calibrate the risk, we used past flood events detected by satellite imagery (mostly from Moderate Resolution Imaging Spectroradiometer, MODIS, at 250 m spatial resolution) processed between 2000 and 2007 and provided by Dartmouth Flood Observatory (DFO). The hazard map was produced using hydroshed at 90 m resolution as well as historical precipitations, slopes, catchment areas, type of soil and other geophysical parameters (Herold and Mouton, 2011). The extraction of exposure revealed that an average of 53.2 million people worldwide are exposed each year to flood events. Mortality from flood events is closely associated with the size and growth rate of exposed rural populations. Lack of voice and accountability were also identified as significant factors. Flood mortality risk is thus highest in heavily populated rural areas in countries with weak governance.

In the case of economic risk, smaller, more concentrated floods appear to cause relatively greater economic damage than floods with a larger extent. The former may affect areas with higher population density more severely, while the latter might mostly impact relatively lower-value agricultural lands. The effect on a country's wealth is much less pronounced for floods than for other disaster types. While mortality is concentrated in developing countries, significant economic damage from floods also occurs regularly in North America and Central Europe, for instance. The geographical distribution of flood mortality is heavily concentrated in Asia. The top 10 countries on the Mortality Risk Index for floods and their respective values are: India, Bangladesh, China, Viet Nam, Democratic People's Republic of Korea, Afghanistan and Pakistan.

Landslides

The landslide hazard model was developed by NH (Nadim et al., 2006 and 2013), while exposure and risk was produced by UNIP/GRID-Geneva (UN, 2009c). Approximately 2.2 million people are exposed to landslides worldwide. In absolute terms, exposure is very high in a number of large Asian countries, especially India, Indonesia and China. Relative exposure is highest in small countries with steep terrain including a number of small island nations. Taiwan has the highest absolute GDP, as well as the highest relative GDP exposure, both due to earthquake-triggered landslides. For precipitation-triggered landslides, the mortality is best explained by the exposure of the population and by local GDP per capita (hence related to poverty). Data limitations prevent the analysis of economic losses due to landslides.

The exposure and risk is highly concentrated: 55 per cent of mortality risk is concentrated in 10 countries: Comoros, Dominica, Nepal, Guatemala, Papua New Guinea, Solomon Islands, Sao Tome and Principe, Indonesia, Ethiopia and the Philippines, which also account for 80 per cent of the exposure.

Earthquakes

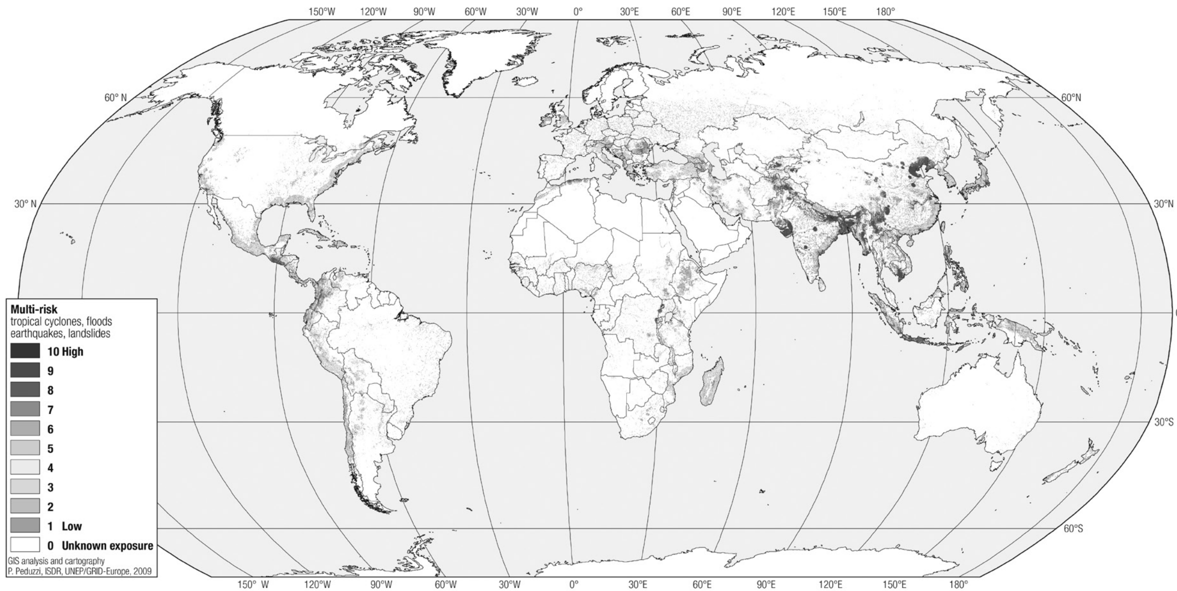
Nearly 5,700 shake maps from past earthquake events (ShakeMap, USGS) from 1973 to 2007 were used for extracting exposure and calibrating the model. Although earthquakes typically have a long returning period, for comparison with the other hazards a yearly exposure was computed. On average, more than 100 million people are exposed per year (103.2). Most of them are exposed to low-intensity quakes. MMI categories V–VI and VII include 93.0 per cent and 5.8 per cent respectively of the population exposure but account for only 0.6 per cent of the mortality risk. This is in line with the observation that of the 246,200 people killed by earthquakes over the last 10 years, 226,000 (91.8 per cent) were killed in just five mega-disasters (EM-DAT, 2008).

Earthquake mortality is correlated with exposure GDP per capita, rapid urban growth, and voice and accountability. Poorer countries with high exposure, rapid urban growth and weaker governance have the highest mortality. The top 10 countries on the Mortality Risk Index for earthquakes and their respective values are: China, India, Indonesia, Colombia, Myanmar, Guatemala, Pakistan, Afghanistan, Iran and Peru.

OECD countries account for 58 per cent of the modelled annual total losses. East Asia also has high absolute modelled economic losses, followed by Latin America and the Caribbean. Relative to GDP, modelled losses are most significant in the Middle East and North Africa, followed by Eastern Europe and Central Asia.

Multiple risk

By adding the value of mortality from each individual hazard, a multi-hazard risk was computed (for tropical cyclones, floods, earthquakes and landslides). Drought and tsunami risk could not be characterized. Given that drought is not represented, mortality risk is underestimated for countries in some regions, particularly in Africa. Figure 7.3(c) shows the spatial distribution of this risk. It is possible to aggregate the risk at national level. Given the level of precision of the input data, precise prediction cannot be achieved. The risk is then classified in 10 classes and rankings are provided for relative risk (number of modelled killed per million inhabitants per year) as well as for absolute risk (average number



GIS cartography and analysis: P.Peduzzi, ISDR, UNEP/GRID-Europe, 2009

Figure 7.3 Spatial distribution of mortality risk accumulated for tropical cyclones, floods, earthquakes and landslides

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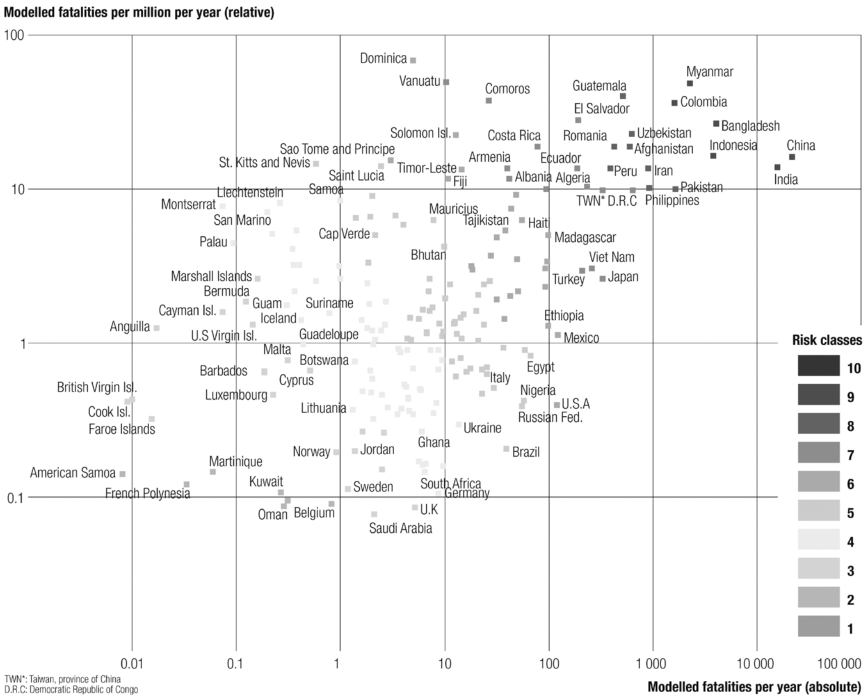

Figure 7.4 Absolute and relative multi-hazard mortality risk for tropical cyclones, floods, earthquakes and landslides

Please see page 662 for a colour version of this figure.

of modelled killed per year). Figure 7.4(c) shows the comparison between countries for both relative and absolute risk. This was used to produce the mortality risk index by averaging the classes in both axes.

DATA ACCESS: The PREVIEW application

To provide free access to all the data generated, the PREVIEW Global Risk Data Platform (PGRDP) was generated (see: http://preview.grid.unep.ch). Users can look at, download or extract data on past hazardous events, human and economic hazard exposure, and risk from natural hazards. It covers tropical cyclones and related storm surges, drought, earthquakes, biomass fires, floods, landslides, tsunamis and volcanic eruptions.

The PREVIEW application includes several modules, such as an interactive map application, a graph module, data download (with most used GIS formats) as well as the latest SDI technologies following the Open

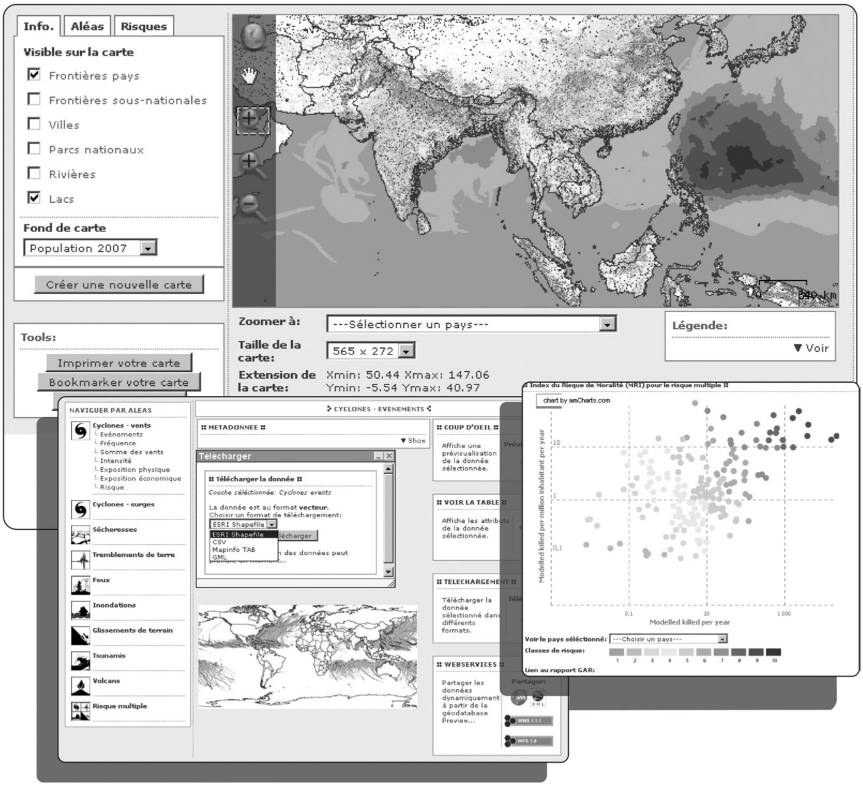

Figure 7.5 The PREVIEW Global Risk Data Platform

Geospatial Consortium (OGC) standards, such as use the Web Map Service (WMS), Web Feature Service (WFS) for vectors and Web Coverage Service (WCS) for raster.

Results and discussions

Key findings

Disaster risk is geographically highly concentrated. A very small portion of the Earth's surface contains most of the risk and most future large-scale disasters will occur in these areas. Risk will increase further if exposure continues to increase.

Disaster risk is very unevenly distributed. Hazards affect both poor and rich countries. However, for hazards of a similar severity, countries with higher incomes and, importantly, higher human development levels generally experience lower mortality and smaller losses when measured against the country's total wealth. In absolute terms economic losses are higher in richer countries but less so once they are seen as a share of overall wealth.

Risk drivers also include income and economic strength as well as governance factors, such as the quality of institutions, openness and government accountability. Wealthier countries tend to have better institutions, more effective early warning and disaster preparedness and response systems.

Risk levels for most of the hazards are increasing over time, even assuming constant hazard frequency and severity. Economic loss risk is increasing faster than mortality risk. These increases in risk are being driven by the growing exposure of people and assets, for example through rapid economic and urban growth in cyclone-prone coastal areas and earthquake-prone cities. Vulnerability decreases as countries develop but not enough to compensate for the increase in exposure.

Globally, disaster risk is increasing for most hazards, although the risk of economic loss is increasing far faster than the risk of mortality. For example, assuming constant hazard it is estimated that global flood mortality risk increased by 13 per cent between 1990 and 2007, while economic loss risk increased by 33 per cent. The main driver of this trend is rapidly increasing exposure. As countries develop, and both economic conditions and governance improve, vulnerability decreases but not sufficiently rapidly to compensate for the increase in exposure, particularly in the case of very rapidly growing low-income and low- to middle-income countries. When economic development stabilizes and slows down, the rate of increase in exposure may decelerate and be overtaken by reductions in vulnerability, leading to a lowering of risk.

This study confirms that poorer countries have disproportionately higher mortality and economic loss risks, given similar levels of hazard exposure. For example, globally, high-income countries account for 39 per cent of the exposure to tropical cyclones but only 1 per cent of the mortality risk. Low-income countries represent 13 per cent of the exposure but no less than 81 per cent of the mortality risk.

Countries with small and vulnerable economies, such as many Small Island Developing States (SIDS) and Land-Locked Developing Countries (LLDCs), not only suffer higher relative levels of economic loss with respect to the size of their GDPs. They also have a particularly low resilience to loss, meaning that disaster losses can lead to major setbacks in economic development. The countries with the highest economic vulnerability to natural hazards and the lowest resilience are also those with very low participation in world markets and low export diversification.

Some potential for improvements

Reports on economical losses are still not very accurate for such precise evaluation. GDP is measuring revenues not assets; an individual hazardous event can damage assets representing several decades of revenues. On earthquakes, the frequency was based on 5,700 earthquakes only (from 1973 to 2007), hence areas without seismic activities in this period were not taken into consideration. A large consortium (Global Earthquake Model) is currently reprocessing all the data to address this issue among others. However, as a result, what was achieved is a realized risk map for 1973–2007 where we found that the mortality risk was exaggerated (about four times higher than recorded losses).

Drought hazard was modelled by Brad Lyon (IRI: Columbia University) using different indices models such as the Soil Moisture Index (SMI) and the Standardized Precipitation Index. However, drought is a very difficult hazard to study. The conclusion from our study was to set up an international group of experts to improve the hazard modelling. This hazard differs from other hazard types in several ways: drought develops slowly; it is difficult to tell when it starts. It has fuzzy boundaries (unlike floods or landslides which affect delimited areas). A 50 per cent decrease in precipitation leads to a drastic difference if in places with 3,000 mm or 600 mm yearly average. These call for differentiated approaches. Few droughts lead directly to mortality. Those that do cause mortality have generally occurred during a political crisis or civil conflict where aid could not reach the affected population. In these cases the mortality should more properly be attributed to the conflict than to the drought. Completely new approaches are needed for drought based on agricultural drought. This was performed in the most recent GAR (UN, 2013) for six countries.

From the beginning of the study it was clear that tsunami risk would not be characterized. The event-level analysis requires a large sample of events, and tsunamis are relatively infrequent with only 5–10 events reported globally per year. The aim was to attempt to generate a global hazard model from different sources (Levholt et al., 2012). The tsunami exposure analysis therefore focuses on extreme events generated by large earthquakes with return periods of approximately 500 years (formally, a probability of 10 per cent of an event occurring in 50 years). About 38,000 people are yearly exposed to tsunamis; 19 million inhabitants live in tsunami prone areas.

Conclusions

This Global Risk Analysis published in Chapter 2 of the 2009 GAR provided a new evaluation of risk at the global level. The whole chapter can be accessed online (see UN, 2009b). The 2009 GAR was launched by UN

Secretary-General Ban Ki-moon in Bahrain (May 2009). It was further presented in several countries worldwide. More than 250,000 copies of chapter 2 were downloaded.

Based on best available data and newly generated datasets, flood, storm surge and tsunami hazards were mapped with a global coverage for the first time. The hazards and exposure are provided at a very fine resolution. The innovation of the "event per event" analysis allows for the inclusion of intensity in computing the risk. Still, despite the use of the most detailed global datasets, this is a global study and data should not be used for local land planning.

In 2011 these models were updated and a trend analysic was produced (see UN, 2011). And in 2013 a new study based on probalistic approaches was run to produce economic risk (UN, 2013). All these new datasets are available through the Preview Global Risk Data Platform. The update includes the use of more complete datasets for tropical cyclones, with individual events from 1970 to 2009. Frequency, exposure and risk were recomputed. All the physical events from 2008 to 2009 have been added. Finally, a new trend analysis at regional level also has been provided, including trends on people living in hazard-prone areas, exposure, numbers killed and vulnerability proxy.

Acknowledgements

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8

Disaster risk hotspots: A project summary

Maxx Dilley

Introduction and rationale[1]

The Global Natural Disaster Risk Hotspots project was undertaken to assess disaster risks globally. The assessment focused on two disaster-related outcomes: mortality and economic losses. Relative risks of these two outcomes were assessed for major natural hazards on a 5×5 km global grid.

The project also generated a set of more localized and/or hazard-specific case studies. The case studies demonstrate that the same theory of disaster causality that underpins the global analysis also applies at local scales, and that more localized analyses can inform national and local disaster risk management planning.

The Hotspots analysis was intended to provide evidence about disaster risk patterns to improve disaster preparedness and prevent losses. High-risk areas are those in which disasters are expected to occur most frequently and losses are expected to be highest. Making risks foreseeable provides motivation for risk reduction (Glantz, 2002). Identification of risk levels and risk factors creates possibilities for shifting emphasis from reliance on ex-post relief and reconstruction after disasters towards ex-ante prevention and preparedness in order to reduce losses and recovery time. The Hotspots results provide an evidence base for prioritizing risk management efforts and bringing attention to areas where risk management is most needed.

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The Hotspots project was initiated by the ProVention Consortium with funding from the United Kingdom's Department for International Development. Additional support for the case studies was provided by the Norwegian Ministry of Foreign Affairs and the US Agency for International Development. The project was implemented by more than a dozen institutions, led by Columbia University and the World Bank, and involved perhaps a hundred scientists. The Hotspots project benefited enormously from interactions with the project on *Reducing Disaster Risk: A Challenge for Development* (UNDP, 2004), a collaborative effort involving the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and others.

Structure and methodology

Starting from the understanding that disaster losses are caused by interactions between hazard events and the characteristics of exposed elements that make them susceptible to being damaged (vulnerabilities), the Hotspots project estimated risk levels by combining hazard exposure with historical vulnerability for two indicators of elements at risk – gridded population and gross domestic product (GDP) per unit area – for six major natural hazards: earthquakes, volcanoes, landslides, floods, droughts and cyclones. Hazard destructive potential is a function of the magnitude, duration, location and timing of the event (Burton et al., 1993). To be damaged, however, elements exposed to a given type of hazard must also be vulnerable to that hazard: that is, the elements must have intrinsic characteristics, or vulnerabilities, that allow them to be damaged or destroyed (UNDRO, 1979). Elements of value that may have such vulnerabilities include people, infrastructure and economically or environmentally important land uses.

Relative levels of the risks of disaster-related mortality and economic losses were calculated for population and GDP based on $2.5' \times 2.5'$ latitude–longitude grid cells, providing an estimate of relative risk levels at sub-national scales. Since the objective of the analysis was to identify hotspots where natural hazard impacts are expected to be large, it was clear that a large proportion of the Earth's land surface, which is sparsely populated and not intensively used, did not need to be included. Therefore, grid cells with population densities of less than five people per km^2 and without a significant agricultural land use were masked out. The remaining grid cells (coloured orange, blue or green in Fig. 8.1(c)) represented only slightly more than half of the total landmass (about 55 per cent) but most of the world's population (about 6 billion people).

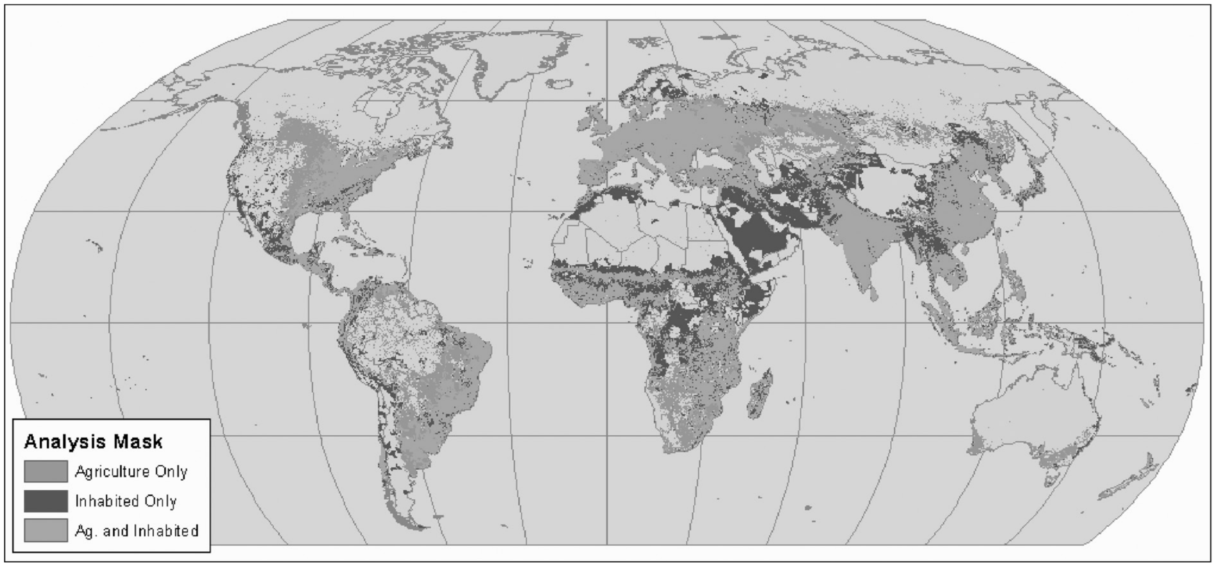

Figure 8.1 Mask used to eliminate sparsely populated, non-agricultural areas
Source: Dilley et al., 2005.

Please see page 663 for a colour version of this figure.

Any global analysis is clearly limited by issues of scale as well as by the availability and quality of data. For a number of hazards, records for the entire globe are only available for the last 15 to 25 years and the spatial information for geolocating these events, and the spatial resolution, are relatively crude. Data on historical disaster losses, and particularly on economic losses, are also limited.

Keeping these constraints in mind, three indices of disaster risk were developed:

- disaster-related mortality risks, assessed for global gridded population;
- risks of total economic losses, assessed for global gridded GDP per unit area;
- risks of economic losses expressed as a proportion of the GDP per unit area for each grid cell.

Three types of data were used to calculate risks of the above outcomes:

- data on the elements at risk (population and economic product, that is, GDP)
- data on the six hazards
- data on vulnerability.

The hazard exposure of the population and GDP in each grid cell was determined by multiplying the population or GDP in each cell by the historical hazard frequency or probability for each hazard. Risk levels were calculated by weighting the result with a vulnerability coefficient.

These vulnerability coefficients were estimated from hazard-specific historical mortality and economic loss data, obtained from the Emergency Disasters Data Base (EM-DAT, see www.cred.be). Mortality and economic loss rates for each hazard were calculated for each of seven geographic regions, further subdivided into four country/wealth groups. This gave 28 vulnerability weights for each hazard, one for each region and country/wealth class combination. The appropriate historical loss rate for each hazard was used to weight the hazard exposure in each cell to arrive at the risk of mortality or economic losses.

Due to the limited time period and quality of the input data, one can say that overall it is appropriate to use the results to identify those areas at *relatively* high risk due to a particular natural hazard. Data quality and resolution dictate that the results are inadequate for assessing *absolute* levels of risk or for detailed *comparisons* of levels of risk across hazards. For a number of the available hazard datasets, such as those based on media reports, relatively small or modest events may be substantially undercounted, especially in developing countries where reporting is likely to be less complete.

To estimate relative risks, therefore, the total number of grid cells was divided into *deciles* (10 groups of approximately equal number of cells) based on the value of each calculated risk indicator (expected mortality or economic losses for each hazard). Cells with the value of zero for an indicator were excluded. When a risk indicator had large numbers of cells with the same values (cyclones, drought, floods and earthquakes), deciles were grouped together.

Results

Maps of the results can be found in Dilley et al. (2005) and the review of Pelling in Chapter 6. In these maps, the relative risk levels are shown with high-risk cells in red, medium in yellow, low in blue and undetectable in white. For each hazard, one map shows the relative risks of disaster-related mortality associated with the hazard, another the relative risks of disaster-related total (aggregate) economic losses, and yet another the relative risks of disaster-related economic losses in proportion to the GDP present in each grid cell. Patterns of risk change depending on which outcome is being assessed, with mortality risks generally higher in developing countries and risks of total economic losses higher in wealthier areas.

Some general results from the Hotspot assessment include:

- Cyclone-related risks are concentrated in coastal areas along the east sides of continents.
- Drought risk areas are much more spatially extensive, with mortality risks and risks of economic losses in proportion to GDP highest in semi-arid Africa. The risks of total economic losses are generally highest in the Americas, Europe and Asia.
- For floods, the spatial extent of the risky areas is also very extensive. Flood-related mortality risks are high on all continents, and in Asia, Europe and the Americas they are high in terms of mortality, total economic losses and proportional economic losses.
- The extent of the areas at high risk from drought and flooding suggests that managing climate-related risks is a high priority in many areas.
- The risks associated with earthquakes are more localized, largely restricted to tectonic plate boundaries: the west coast of the United States, the east coast of Asia and across central Asia. In the latter region, relative risks of all three outcomes are high.
- The risks posed by volcanoes are very localized, although wind-borne ash can affect larger areas beyond the immediate area of an eruption.
- Landslide-related risks are highest in mountainous areas.

In addition to human and direct economic losses, disasters impose costs as well. These include expenditures for disaster relief and recovery, and for rehabilitation and reconstruction of damaged and destroyed assets. In the case of major disasters, meeting these additional costs can require external financing or international humanitarian assistance.

This combination of human and economic losses plus the additional costs of relief, rehabilitation and reconstruction makes disasters an economic issue as well as a humanitarian one. Disaster relief costs drain development resources from productive investments to support consumption over short periods of time. Disaster-related losses offset economic growth and contribute to poverty.

Until vulnerability and, consequently, risks are reduced, countries with high proportions of population or GDP in hotspot areas are especially likely to incur repeated disaster-related losses and costs. In order to quantify this phenomenon, the World Bank provided data on emergency loans and reallocation of existing loans to meet disaster reconstruction needs from 1980 to 2003 for this study (http://www.worldbank.org/dmf). The total of emergency lending and loan reallocation from 1980 to 2003 was $14.4 billion. Of this, $12 billion went to the 20 countries listed in Table 8.1.

Table 8.1 Countries receiving emergency loans and reallocation of existing loans to meet disaster reconstruction needs, 1980–2003

Country	Earthquake	Floods	Storms	Drought
India	×		×	×
Turkey	×	×		
Bangladesh		×	×	
Mexico	×	×		
Argentina		×		
Brazil		×		
Poland		×		
Colombia	×	×		
Iran	×			
Honduras		×	×	
China	×	×		
Chile	×			
Zimbabwe				×
Dominican Republic			×	
El Salvador	×			
Algeria	×	×		
Ecuador	×	×		
Mozambique		×		×
Philippines	×			
Viet Nam		×		

Source: World Bank Hazard Management Unit (http://www.worldbank.org/dmf).

Conclusions and next steps

Disaster risk management therefore deserves serious consideration as an issue for sustainable development. Through the identification of risk factors, and through analysis of the correspondence between assessed risks and historical disaster patterns, the approach presented here makes these risks foreseeable, creating an incentive for action to reduce risks and losses through pre-emptive action rather than perpetuating a repetitive cycle of disaster, relief and recovery.

Following the Hotspots project and related efforts, plans are being made to seek the support of systematic analysis of disaster risks in high-risk areas to inform risk management planning. UNDP, the ProVention and a group of collaborating institutions have initiated a preparatory project for a Global Risk Identification Programme (GRIP). The GRIP will build on the results of previous analyses, with a priority for supporting the creation of evidence on disaster risk levels and factors at national to local scales, working with local authorities and experts. The GRIP will promote and support improvement in the availability and quality of data on disaster losses as well as the integration of higher-resolution, better-quality data on hazards, exposure and vulnerability in high-risk areas to support risk management decision-making.

Note

1. Portions of this chapter were taken from Dilley et al. (2005). A synthesis of the Hotspots project report may be downloaded from http://www.ldeo.columbia.edu/chrr/research/hotspots/. The full report is *Natural Disaster Hotspots: A Global Risk Analysis*, http://publications.worldbank.org/ecommerce/catalog/product?item_id=4302005/

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9

The WorldRiskIndex: A concept for the assessment of risk and vulnerability at global/national scales

Torsten Welle, Jörn Birkmann, Dunja Krause, Dora C. Suarez, Neysa J. Setiadi, Jan Wolfertz

Introduction

The research of the last 20 years in the field of natural hazards and development cooperation clearly indicates that it is not solely the hazardous event that leads to a disaster but the conditions of societies exposed to such hazards that determine whether a natural phenomenon can trigger a disaster (Wisner et al., 2004; Birkmann, 2006). Thus, instead of defining disasters primarily as physical occurrences, requiring largely technological solutions, they are better viewed as a result of the complex interactions between potentially damaging physical events – such as floods, droughts, sea level rise etc. – and the vulnerability of a society, its infrastructure, economy and environment, which is determined by human behavior (see Birkmann, 2006:10).

The concept for the WorldRiskIndex was developed in order to systematize and operationalize major characteristics of risk and vulnerability to natural hazards and climate change at a global scale. This is in line with the statement of the IPCC (2007) that the ability to measure, assess and evaluate vulnerability, coping and adaptive capacities, as well as natural hazards, is increasingly being seen as a key step towards effective risk reduction and climate change adaptation. Characteristics that have been captured within this index to derive relative risk and vulnerability levels at the scale of countries for global comparison encompass social, economic, health and environmental factors as well as governance issues, which are key when societies have to cope with natural hazards and

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extreme events. The index underlines the importance of addressing aspects of exposure, susceptibility, coping and adaptation when dealing with disaster risk at local and global scales. In this regard the index translates the abstract concept of risk and vulnerability into measurable indicators and criteria. The four key components considered encompass exposure, susceptibility, coping and adaptation.

This index was developed for the Bündnis Entwicklung Hilft [The Alliance Development Works], an alliance of German development and relief agencies providing long-term aid in the aftermath of major disasters and in emergencies, with the objective of serving as an instrument for assessing and depicting different levels of exposure and vulnerability as well as risk. In this context the index provides a first overview of countries that have high exposure to natural hazards but low vulnerablity and those that have both high exposure and high vulnerablity and are therefore at high risk. The latter include Vanuatu, Madagascar or Indonesia – to name just a few. The index is based on available global data and aims to explore the feasibility and the usefulness of a global and local risk index that accounts for both natural hazard phenomena and societal vulnerability as well as response capacities including broader issues of governance. The comparison of countries provides a first list of those countries which are more exposed or vulnerable. Additionally, the specific assessment of coping and adaptation capacities also indicates that risk or vulnerability are not given but generated and constructed by societies exposed to natural hazards. The information that the index and the different indicators provides can be useful in communicating the necessity for preventive measures towards risk reduction and climate change adaptation.

Concept and core components

The concept of the WorldRiskIndex is based on the core understanding of risk within the natural hazards and disaster risk reduction community. Hence, the term "risk" is mainly understood as the outcome of the interaction between a natural hazard event and the vulnerable conditions of the exposed element or society (see UN/ISDR, 2004; Wisner et al., 2004; Birkmann, 2006; IDEA, 2005). This definition emphasizes the fact that risk is not solely an outcome of the probability and magnitude of the natural hazard event (flood, storm, earthquake, drought and sea-level rise) but is also determined by the vulnerablity of the exposed society. In this regard vulnerability encompasses conditions and processes of societies which could be expressed in terms of susceptibility, coping capacities and adaptation capacities. Thus the concept applied within the index development also suggests that coping and adaptation are different categories and issues (see Birkmann 2011a and 2011b).

Overall, the WorldRiskIndex aims to capture and measure four major factors (see Figure 9.1):

- exposure to the natural hazard (including frequency and magnitude of hazards);
- susceptibility of the exposed communities and society;
- coping capacities;
- adaptive capacities.

The structure of the WorldRiskIndex (see Figure 9.1) builds on the work of Bogardi and Birkmann (2004), Cardona (1999/2001) and Birkmann (2006 and 2011a) dealing with integrated and holistic frameworks for assessing vulnerability and with the challenges involved in assessing societal response capacities (coping and adaptation). In this context vulnerability encompasses causal factors, such as susceptibility, coping etc., and different thematic dimensions, such as social, economic, environmental and institutional vulnerability. The consideration of potential tools for intervention is also an important element of this school of thought (Birkmann, 2006; Davies, 2009; Birkmann, 2011b).

While the exposure component clearly aims to identify the number of people exposed to selected natural hazards and creeping changes, also

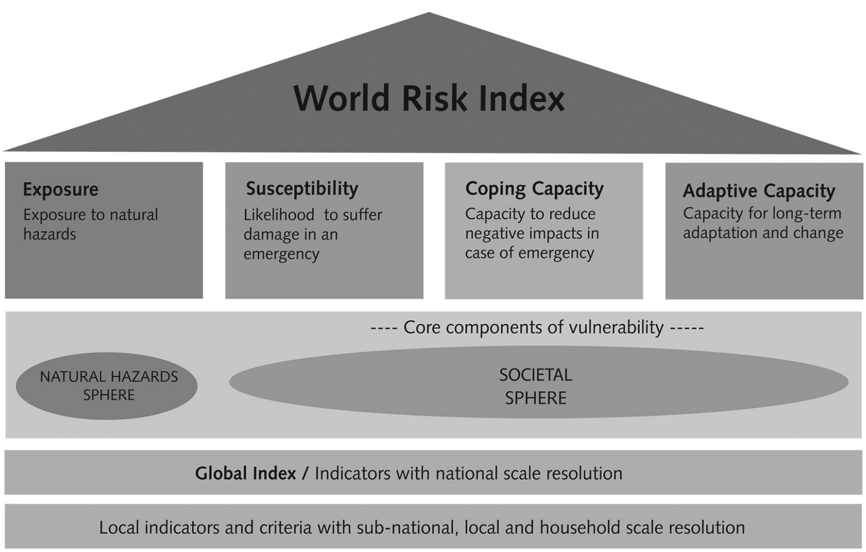

Figure 9.1 Structure of the Index and the Indicator System
Source: Own figure.

taking into account the frequency of specific hazards, such as droughts, floods, storms and earthquakes (see in-depth PREVIEW data), the other three components – susceptibility, coping and adaptation – focus more on characteristics of vulnerability and societal response capacities. It is important to note that the framing of different factors of vulnerability and adaptive capacity is still controversial and a contested terrain between, for example, the disaster risk reduction community and the climate change adaptation community. The framework used for the WorldRiskIndex for global and local scales implies an integrative and comprehensive approach, focusing on the natural hazard and respective levels of exposure as well as on societal susceptibility, coping and adaptation processes. The goal of a global comparison, however, clearly restricts the level of detail that such an approach can offer.

In contrast to hazard and exposure mapping, vulnerability assessments focus on the likelihood of injury, loss, disruption of livelihood and other harm in an extreme event and/or unusual difficulties in recovering (Wisner et al., 2004: 13; Wisner, 2002: 12–17). This means that the focus of vulnerability assessments is on the identification of variables that make people vulnerable to certain natural hazards as well as those factors that drive and shape vulnerability – including coping and adaptive capacities. Vulnerability is not just a characteristic of a system or society before a disaster occurs; it can also be modified or even intensified during and after a disaster – for example, through inappropriate disaster aid and recovery policies (Birkmann and Fernando, 2008). Additionally, the strong emphasis on coping and adaptive capacities – including local-specific interventions – promotes a problem-solving perspective, in terms of the analysis of measures to reduce vulnerability and disaster risk. Although the global index results are snapshots that only when compared over time can provide a trend analysis, the overall concept of the WorldRiskIndex is based on the notion that vulnerability is a dynamic process where levels of exposure, susceptibility, coping and adaptation are changing and highly interwoven. The examination of coping capacities and intervention tools, as well as differentiating between coping and adaptation, stresses the importance of checking the capacities of communities and societies exposed to hazards and consequently promoting a proactive approach for reducing risk and vulnerability before a disaster occurs (see Birkmann, 2006: 36; Birkmann et al., 2009).

When developing vulnerability indicators, it is sometimes difficult to distinguish precisely between aspects that decrease susceptibility and those that increase coping capacity. Certain overlaps are therefore unavoidable; however, for the scientific quality of the index, different aspects were only counted once.

Exposure

Exposure in its core meaning in natural hazard research encompasses entities exposed and prone to be affected by a hazard event. These entities include persons, resources, infrastructure, production, goods, services or ecosystems and coupled social-ecological systems, etc. (see for example, UN/ISDR 2009, website: MOVE Project). Exposure can be further differentiated in terms of a spatial (geographic exposure) and a temporal component. The concept developed and applied in this study captures exposure in terms of people exposed to a certain hazard divided by the total population of the country or community analysed. These numbers can be compared between countries and communities. Additionally, the data used (PREVIEW data) also accounts for the frequency of the hazard events, such as floods or storms. In this regard exposure is closely linked also to characteristics of the hazard phenomena. The data set "physical exposure" of the PREVIEW Global Risk Data Platform that was used within the index development is based on different data sources and model calculations (see in detail Peduzzi et al., 2009). The data estimates the number of people exposed to hazards such as earthquakes, floods, droughts and cyclones per year. It results from the combination of the annual frequency of hazards (ex-post focus) and the total population living in the spatial unit exposed for each event. That means it indicates how many people per year are at risk. Additionally, the emerging hazards due to climate change, such as sea-level rise, were also taken into account in the concept. Regarding sea-level rise, the exposure was calculated using data that display 1 m sea-level rise in 100 years and combining it with global population data from 2010. This calculation lacks the probalistic component used for the other four hazards in terms of the estimation of annual population exposed. Despite this, in homogeneity of data used the future risk of sea-level rise was considered within this concept in order to strengthen this issue in risk analysis.

The WorldRiskIndex clearly prioritizes those hazards that are widely spread around the globe and also account for major harm in terms of people killed. For the period, 1970 to 2005, the most frequent and devastating natural hazards reported were floods, storms, earthquakes and droughts, accounting for 74 per cent of all events and 88 per cent of all reported fatalities (see CRED EM-DAT, 2011). In this regard the following five natural hazards were taken into account:

- earthquakes
- storms
- floods
- droughts
- sea-level rise.

Susceptibility

The susceptibility component of the model refers to the conditions of exposed communities or other exposed elements (infrastructures, ecosystems, etc.) that make them more likely to experience harm and to be negatively affected by a natural hazard or by climate change. Thereby susceptibility is closely linked to structural characteristics such as nutrition, economic capacities and public infrastructure that allow primary evidence of relative susceptibilities of societies.

Thus susceptibility can be understood as the likelihood to suffer harm and damage in case of the occurrence of a natural hazard. For this concept susceptibility was divided into five subcategories that should assess the well-being, social exclusion and housing conditions of those exposed to such hazards. The following five subcategories were chosen:

- public infrastructure
- housing conditions
- nutrition
- poverty and dependencies
- economic capacities and income.

Coping

Coping is defined as the ability of a society or group, organization or system to use its own resources to face and manage emergencies, disasters or adverse conditions that could lead to a harmful process caused by a hazard event (see UN/ISDR, 2009). Coping mechanisms usually build on experiences derived from past disasters. Hence, coping mechanisms are often based on the assumption that what has happened in the past is likely to repeat itself, following a familiar pattern in the future (Bankoff et al., 2004: 32). Drawing on traditional knowledge as well as on societal learning, coping is bound to very specific conditions and may become ineffective in the face of changing risks (see Bankoff et al., 2004). Coping in this conceptual framework, is – compared to adaptation – a direct response to the impact of a given hazard event. Thus it comprises the immediate reaction during a crisis or disaster (see Birkmann, 2011a; Birkmann, 2011b). Consequently, coping is hazard-related and rather short-term orientated. Characteristics of coping and coping capacities can be associated with existing resources that help to face and manage emergencies, natural hazard impacts and disasters, such as early warning systems, medical care and hospital capacities or social networks. Context conditions which hamper coping capacities, such as corruption or failed states, were also considered. Overall, the following subcategories were selected to operationalize coping:

- government and authorities
- disaster preparedness and early warning
- medical services
- social networks
- economic coverage.

Adaptation

Adaptation, within the context of this study, is defined as a long-term strategy that might be linked to a certain hazard. Thus adaptation encompasses capacities, measures and strategies that enable communities to change and to transform in order to deal with expected negative consequences of natural hazards and climate change. O'Brien and Vogel (2003) stress that adaptation is a more structured behaviour that aims to promote change and transformation. Hence, these capacities focus on resources that allow changing structures within a society: for example, improved levels of education. Indicators and criteria that can capture aspects of adaptation and adaptive capacities at the national level for global comparison in this index are:

- education and research
- gender equity
- environmental status/ecosystem protection
- adaptation strategies
- financing.

Data and methodology

This section provides an overview of the selected indicators, the available global datasets, as well as the calculation of the WorldRiskIndex and its respective components. The application of the concept is based on free, available global data which fulfil specific standards and criteria. The following criteria were taken into consideration: indicators for exposure should allow for a specific comparison of very different hazard types; vulnerability and adaptation indicators should be of a generic nature in order to be relevant for different hazards (multihazard perspective). Moreover, indicators should be reliable, analytically and statistically sound, reproducible appropriate in scope, in terms of the local level assessment, understandable, easy to interpret and comparable (Meyer, 2004). In addition (if possible), the data should be compiled on a regular basis in order to enable future monitoring of the indicators. Within the development of the Index, various statistical and spatial methods employing Geographical Information Systems (GIS) were used.

Indicators

Calculation for the WorldRiskIndex is based on suitable indicators that could be allocated to the four components: exposure, susceptibility, coping and adaptation. Figure 9.2 shows these indicators, their respective components and subcategories. The four subcategories – housing conditions, disaster preparedness/early warning, social networks and adaptation strategies – are mentioned although they couldn't be integrated in the calculation because of a lack of global data availability, but they are recognized as important elements which should be considered in the concept. The selection of indicators is related to the eight United Nations' millennium development goals and the Hyogo Framework for Action.

Various global databases provided the source for the indicators. For the aggregation all indicators have been transformed into dimensionless rank levels between 0 and 1; i.e. they can be read as percentage values. Figures 9.3–9.5 show the modular composition of the indices for susceptibility, coping capacity and adaptation capacity, including their respective weights.

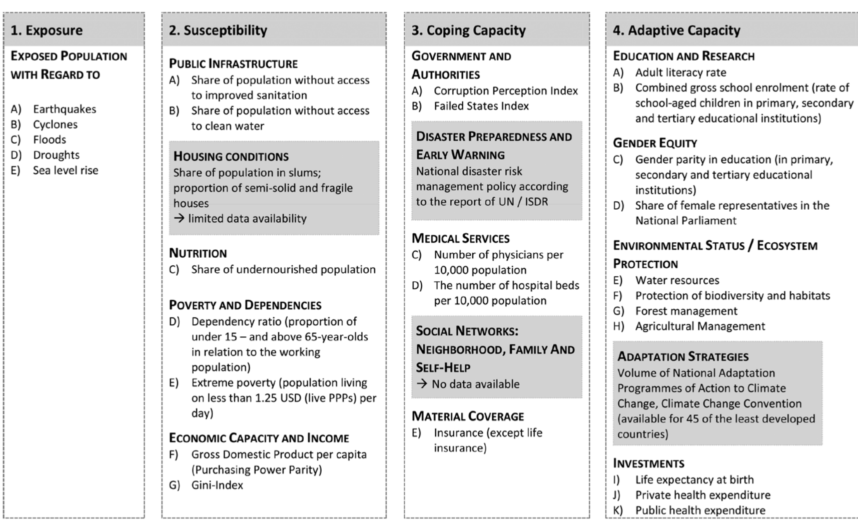

Figure 9.2 Components, sub-categories and selected indicators of the WorldRisk-Index

Exposure

As already mentioned, this Index focuses on those natural hazard types that occur most often and account for the most severe impacts in the period of 1970 to 2005. The most frequent and devastating natural hazards reported were floods, storms, earthquakes and droughts, accounting for 74 per cent of all events and 88 per cent of all reported fatalities (see CRED EM-DAT-Database, 2011). Additionally sea-level rise was taken into account, since it is very likely that due to further climate change sea-level rise will affect many low-lying coastal zones and delta regions. Already today, 13 per cent of the world population is living in coastal areas that are less than 10 m above sea level (UNHABITAT, 2011). The Index looks at two different, broader categories of natural hazards: sudden-onset events like storms, floods and earthquakes, and creeping hazards such as droughts and sea-level rise.

A globally available dataset generated by different UN agencies (UNEP, UNDP/BCPR (GRIP), UN/ISDR) and the World Bank (Dilley et al. 2005) – the PREVIEW Global Risk Data Platform – was used for the calculation of the exposure component. The PREVIEW platform is a multi-agency effort to share spatial data on global risk regarding natural hazards. Data obtained from PREVIEW represents an estimation of the annual population exposure to four selected hazards (earthquakes, tropical cyclones, floods and droughts). It comprises a probabilistic component on the frequency of the respective hazard and information on the population distribution based on the LandScanTM Global Population Database. This specific dataset in the PREVIEW database is called of "physical exposure". The number of people exposed per hazard and per country was derived by calculating the zonal statistic with ArcGIS 9.3.

It must be said that these global data for exposure are based on model calculations, therefore implying that some uncertainties within the model calculation have to be taken into account. A novelty of this concept is the integration of emerging risks in the context of climate change, such as sea-level rise. Since no information about the physical exposure to sea-level rise is available in the PREVIEW data platform, this information had to be derived from existing global datasets like the gridded population of the world and the exposed area due to a 1 m sea-level rise scenario. The population data were gathered from the Global Rural-Urban Mapping Project (GRUMP) (CIESIN, 2012), whereas the information regarding the sea-level rise scenarios was obtained from the University of Kansas Center for Remote Sensing of Ice Sheets (CReSIS) (https://www.cresis.ku.edu/data/sea-level-rise-maps). These two datasets allow for an estimation of people exposed to future sea-level rise. It has to be noted, however, that the indicator on population exposed to sea-level rise measures the proportion of population currently living in an area that would be affected by a 1 m sea-level rise. It is thus lacking the probabilistic component intrinsic to the other four hazards, estimating the exposed population. The exposed population per country was estimated by calculating the zonal statistics; however, in order to reduce the impact of the sea-level rise exposure on overall exposure, this indicator was weighted with 0.5. Otherwise, this indicator would have dominated most countries' exposure to hazards. The same weighting (0.5) was applied to exposed population in terms of droughts, since this calculation and present data might overestimate the number of exposed people (see Peduzzi et al. 2009). Finally, all exposed people per hazard were added up and divided by the total population of the country in order to obtain one exposure index per country (see Figure 9.8(c)).

Susceptibility

The susceptibility index is calculated based on Figure 9.3. Indicators (A–G) have been chosen to characterize the susceptibility of social groups on a national scale but with a global focus. Important indicators for measuring susceptibility at the national level for global comparison were, among others, extreme poverty, the dependency ratio, access to sanitation, undernourishment and the gini index showing income inequalities in nations. The housing conditions data couldn't be integrated in the index aggregation due to a lack of data. Moreover, all indicators have been transformed into values between 0 and 1. It has to be noted that the indi-

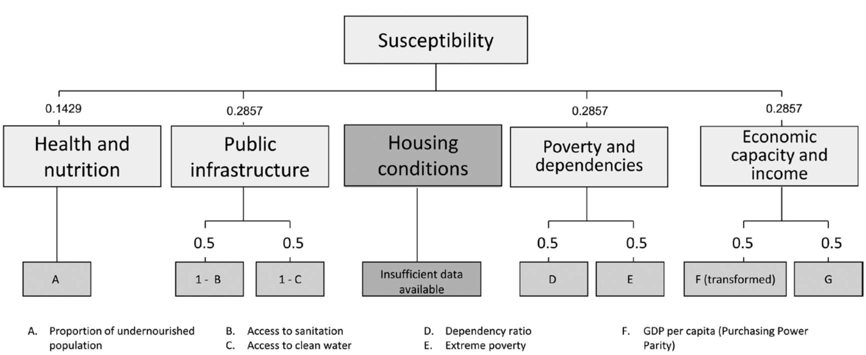

Figure 9.3 Composition of the susceptibility component

cators for B (access to sanitation) and C (access to clean water) feature a positive character. Therefore, in order to describe the susceptibility the measurement was reversed and thus the "lack of access" to sanitation and the "lack of clean" water was calculated. The susceptibility index is aggregated according to the stated weights in Figure 9.3 and displayed as a map in Figure 9.9(c).

Coping capacity

The calculation of coping capacity is based on several indicators that determine the capacity of a given population and/or nation to immediately react to or manage the impact of a hazard event. On the one hand coping capacity, such as medical services or material protection, is an important resource in an emergency, while other structures such as, for example, corruption, failed governance and deficient social networks can hinder the coping capacity of a national state or an exposed population. Figure 9.4 provides an overview of the selected indicators for coping (A–E). Additionally, their weights as well as their allocation in subcategories are presented. The subcategories disaster preparedness/early warning and social networks could not be matched at the moment with appropriate data at the global level, even though some studies on early warning systems are available. For the aggregation of the WorldRiskIndex, the lack of coping capacities is included – since the overall sum of the vulnerability components will be a measure of deficiencies in societal capacities to deal with natural hazard impacts and climate change. In this regard the calculated value for coping is subtracted from 1 and displayed in a separate map (see Figure 9.10(c)).

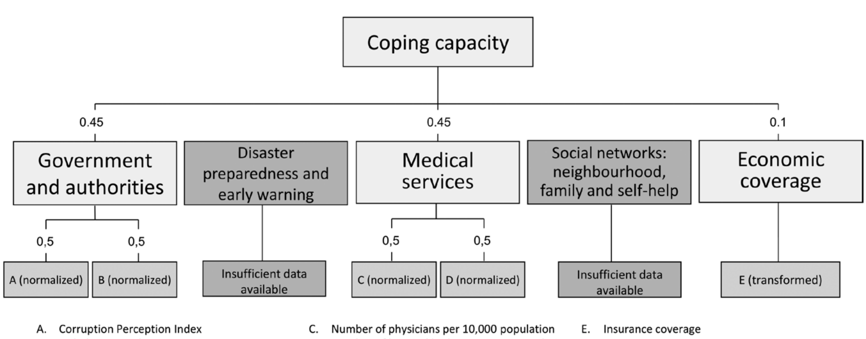

Figure 9.4 Composition of the component Coping Capacity

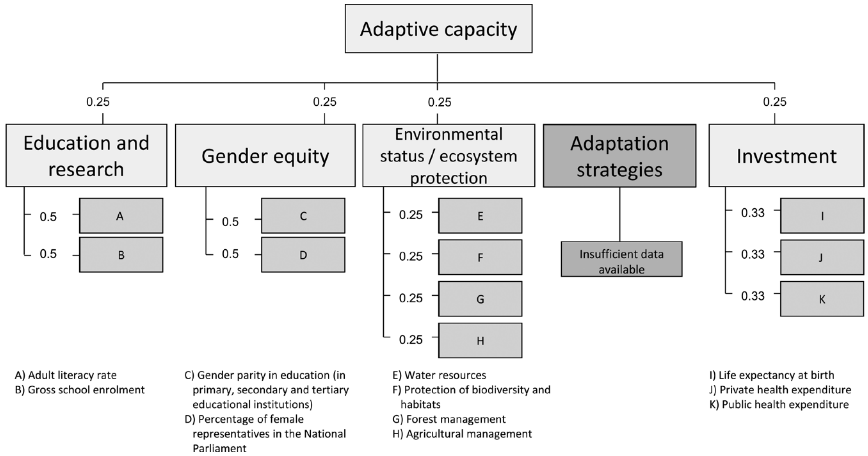

Figure 9.5 Composition of the component Adaptive Capacity

Adaptive capacity

Indicators for capturing aspects of adaptive capacity of a state and its population need to portray the long-term response capacities to natural hazards and/or environmental change. They should indicate the ability of a society or community to transform or adapt, in order to alter (reduce) vulnerability to this change. The component on adaptive capacity contains five subcategory groups: education and research, gender equity, environmental status or ecosystem protection, adaptation strategies and investments. The indicators defined for adaptive capacity (A–K) are listed in Figure 9.5, which also illustrates the indicators and the weights for the aggregation. For adaptation information about the National Adaptation Programmes of Action (NAPAs) was considered as an additional subcategory, although it wasn't included in the actual application of the assessment due to insufficient data. As with the calculation of the "lack" of coping capacity, the adaptive capacity was also aggregated into the index in terms of the lack of adaptive capacity (see also Figure 9.11(c)).

Calculation of the WorldRiskIndex

As demonstrated above, each component of the WorldRiskIndex – exposure, susceptibility, lack of coping capacity and lack of adaptive capacity – has been calculated separately. In order to obtain an overall

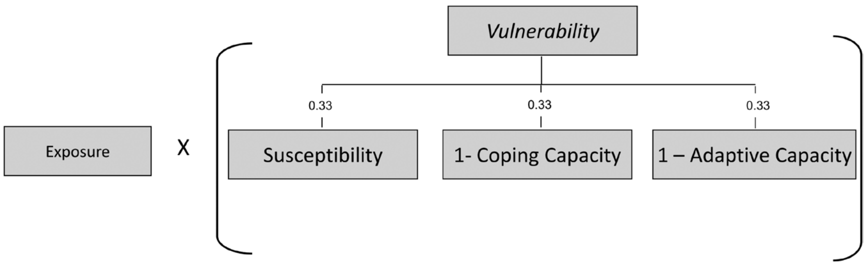

Figure 9.6 Calculation of the WorldRiskIndex

picture of vulnerability, the component's susceptibility, lack of coping capacity and lack of adaptive capacity were aggregated into one vulnerability index that characterizes conditions and processes of societies that are key when dealing with disaster risk in the light of climate change and natural hazards. Finally, the vulnerability index was multiplied by exposure, comprising the magnitude and frequency of hazards, to obtain the risk. The underlying hypothesis for the multiplication of exposure is that if a vulnerable society is not exposed to a hazard, the level of risk will be zero. Figure 9.6 shows the formula that outlines how the WorldRiskIndex was calculated, including its weights for the different components.

EXCURSUS: Local scale assessment

The global/national resolution assessment focuses primarily on a ranking of different countries and the identification of the major deficits that the indicators suggest. The local resolution assessment also serves as a basis for identifying potential measures to improve disaster risk reduction (for example, preparedness) and climate change adaptation. However, the local indicator set also encompasses a core set of indicators that should allow comparing general patterns of exposure, susceptibility, lack of coping capacity and lack of adaptation capacities. Furthermore, many indicators also refer to the assets and capacities individual households have for facing and managing the consequences of natural hazards and climate-related creeping changes, such as sea-level rise.

Exposure

In this context, the set of exposure indicators remains the same as for the global assessment in order to keep a comparable standard and use the data available (earthquakes, cyclones, flooding, drought, and sea-level rise). Nevertheless, it is important to consider that the frequency and intensity, as well as the impacts on the population of such hazards, will have a different connotation at this level, and in some cases other sets of hazards, not yet included, could be causing higher effects in districts, cities, etc.

Susceptibility

Indicators selected for susceptibility at the local level considered first the global assessment indicators. The next step analysed the data available, particularly for Indonesia which was selected as a case study. According to the quality and scale of this information, indicators for the different theme groups were defined as follows –

- Public Infrastructure: population without access to sanitation, population without an improved water source;
- Housing Conditions: the use of strong materials for construction of house walls (cement, etc.);
- Poverty and Dependencies: poverty (combined indicator of extreme poverty and assistance for the poor, with the same weights), dependency ratio and households with a female head;
- Economic Power and Income Distribution: regional domestic product per capita, poverty severity (which is an index proposed by Foster et al. (1984) as a measure of inequity; see Maksum, 2004). Unfortunately, it wasn't possible to find an adequate indicator for malnutrition.

Coping capacity

The assessment of coping capacity at the local level followed in general the methods and structure of the global index for coping capacities. While the information for disaster preparedness and early warning was not available at the international level, the data obtained for districts in Indonesia was interesting but turned out to be of limited quality. Therefore, also at the local level these issues could not be filled with data. Additionally, the medical services indicators were represented by a proxy that captured the number of physicians and midwives; however, the sensitivity analysis of this indicator revealed that the component would have a wrong effect and therefore was not further considered in the assessment. However, additional indicators on violent conflicts were obtained and used, as well as issues such as landownership, which were not available for the global assessment but which were available for Indonesia at the local level. The indicators used encompass the following issues:

- Government and agencies: sustainable security (proportion of villages with at least one riot);
- Social networks: social organizations (composed an indicator confirmed by the number of social cooperatives and NGOs with social activities);
- Material coverage: unemployment, job security (composed of an indicator covering jobs per economic sector per household and number of jobs per household), landownership, income per capita. In particular this component addresses coverage from different levels and perspectives: first of all as an individual (unemployment, income per capita), then as a family group (job security, landownership), as well as a possible relationship with savings and insurances.

Adaptive capacity

In terms of long-term capacities that also have the potential to promote change in societies, the following indicators could be obtained at the local level in Indonesia:

- Education and research: combined gross school enrollment; education attainment index (developed using numbers completing secondary school and higher education);
- Gender equity: proportion of households/villages headed by a female;
- Environment: ecological footprint (The ecological footprint has been widely used as an indicator of environmental sustainability. The method used for calculating the Ecological Footprint of Indonesia is the one developed by the Global Footprint Network in 2003 that was applied by the Ministry of Public Works, Directorate General of Spatial Planning in 2010.);
- Adaptation strategy: economy diversification (number of jobs by economic sector/number of all jobs, at the province level).

The components and indicators of the Local Risk Index are presented in Figure 9.7.

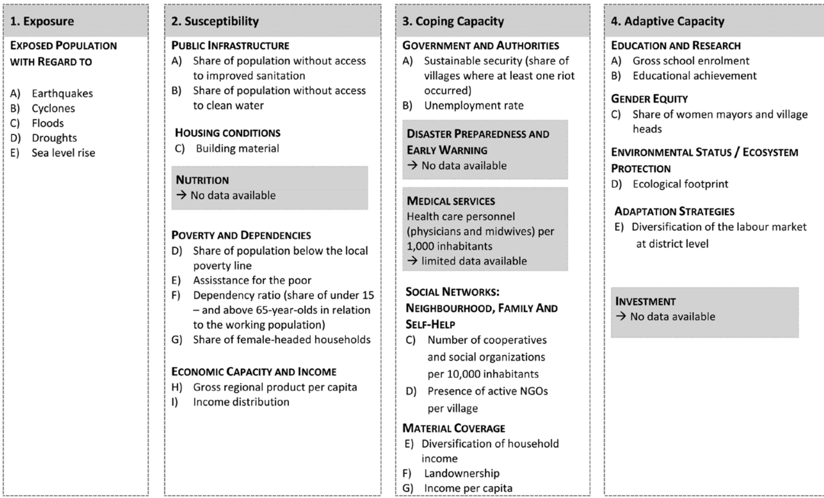

Figure 9.7 Indicators and Structural Components of the Local Risk Index and Vulnerability Index

The calculation of the risk index for the local level is the same as that for the WorldRiskIndex, presented in Figure 9.6.

Results

The application of the model was made at the global level for comparison between countries. Additionally, the local index was evaluated for Indonesia at the district level, to explore the possibility of linking global and local assessments using nearly similar core components. For the spatial analysis and the development of maps, all calculated indices were divided into five classes. The classification method used was the quantile method which is integrated in the software ArcGIS 9.3. Based on the calculated values, each class was also described in a qualitative way, following the classification schema: very high – high – medium – low – very low (see Figures 9.8(c)–9.12(c)).

Results of the global assessment

According to the data available, 173 countries were assessed and evaluated, using the most recent data for each indicator. The results are

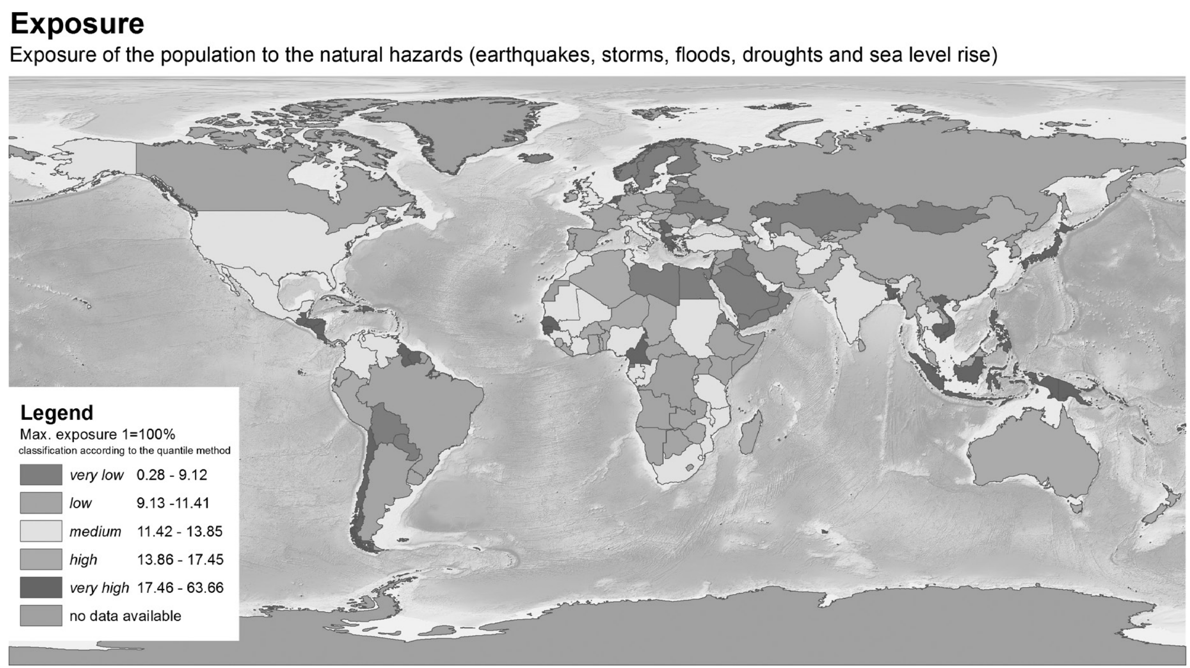

Figure 9.8 Exposure Map

Please see page 664 for a colour version of this figure.

shown in maps and tables. Overall, the results provide an overview of the level of risk of different countries based on available global data; however, these maps cannot shed light onto the specific components that are responsible for the low or high risk shown in the map. A more in-depth analysis can be derived by decomposing the numerical indices into indicators again. Unfortunately, some island states, which are highly exposed to sea-level rise, are not considered in the assessment due to a lack of plausible and reliable data for the exposure to natural hazards.

Exposure

The results of the exposure analysis of individual countries to natural hazards selected – namely earthquakes, storms, floods, drought and sea-level rise – show that South East Asia and Central America as well as Cameroon, Chile, Japan and the Netherlands are highly exposed to natural hazards and sea-level rise. Table 9.1 gives an overview of the 10 most exposed countries. It should be stressed that Tonga and Brunei Darussalam are mainly affected due to the strong influence of sea-level rise in the top 10 ranks.

The results for the exposure index can be analysed per natural hazard when going back to the indicators composing it. Particularly for the top 10 countries with highest levels of exposure, it is possible to compare the percentage of population affected by earthquakes, cyclones, floods, droughts and sea-level rise.

Susceptibility

Figure 9.9(c) displays the map for susceptibility where relative high values can be identified for the Sahel and the tropical part within Africa. In addition, hotspot regions with high susceptibility are South and South East Asia, except for Thailand and Malaysia, which both have relative low susceptibility values (21.96 for Thailand and 20.87 for Malaysia). Table 9.2 provides an overview of the most susceptible countries. Particularly, at the global scale it is evident that many countries in Africa are highly susceptible, as well as Afghanistan and Haiti which also rank among the countries with the highest susceptibility values.

Lack of coping capacity

Similar to the susceptibility map, a clear North–South divide can be seen in terms of lack of coping capacity (Figure 9.10(c)). Within Europe, the countries of Albania, Bosnia and Moldavia tend to show poor values for coping capacities, which is partly due to poorer insurance against natural hazards in these countries. Within Africa, Botswana and South Africa

Table 9.1 The 10 most exposed countries (values in percentage)

Country (Top 10)	Earthquake	Cyclones	Floods	Droughts	Sea-level rise	EXPOSURE
Vanuatu	37.84	12.66	0.00	6.92	6.25	63.66
Tonga	14.99	7.22	0.00	0.00	33.07	55.27
Philippines	12.35	26.57	1.39	11.51	0.63	52.46
Japan	9.94	22.94	0.10	11.61	1.32	45.91
Costa Rica	29.60	0.08	0.04	12.73	0.16	42.61
Brunei Darussalam	0.00	0.00	0.03	11.99	29.09	41.10
Mauritius	0.00	26.95	0.00	10.39	0.00	37.35
Guatemala	20.33	0.03	0.12	15.72	0.11	36.30
El Salvador	17.45	0.00	0.07	14.92	0.07	32.20
Bangladesh	0.95	2.81	16.34	11.12	0.47	31.70

Table 9.2 The 10 most susceptible countries

Land (Top 10)	Susceptibility
Mozambique	67.63
United Republic of Tanzania	67.34
Eritrea	66.62
Liberia	65.11
Niger	64.87
Chad	64.69
Madagascar	64.39
Haiti	62.70
Sierra Leone	62.48
Burundi	61.99

Table 9.3 The 10 countries with highest lack of coping capacity

Land (Top 10)	Lack of coping capacity
Afghanistan	92.07
Chad	91.80
Sudan	91.70
Haiti	90.43
Guinea	90.16
Myanmar	89.82
Burundi	89.53
Central African Republilc	89.43
Yemen	88.92
Iraq	88.83

show relatively good values for coping capacities probably due to a stable political system and a well-developed heath system.

Lack of adaptive capacity

Afghanistan is the country with the highest value, but nevertheless Africa is again one global hotspot regarding the lack of adaptive capacities, underlined by having seven countries within the top 10 (see Table 9.4). In the Americas, Haiti is the only country showing the highest values for lack of adaptive capacity. After Africa, Asia is the second largest hotspot which could be identified in Figure 9.11(c).

Vulnerability

The vulnerability map (Figure 9.12(c)) that is composed of an aggregated index summarizing susceptibility, lack of coping and lack of adaptive capacities shows that at a global scale Africa and South and South East Asia are hotspots of vulnerability. Table 9.5 gives an overview of the 10

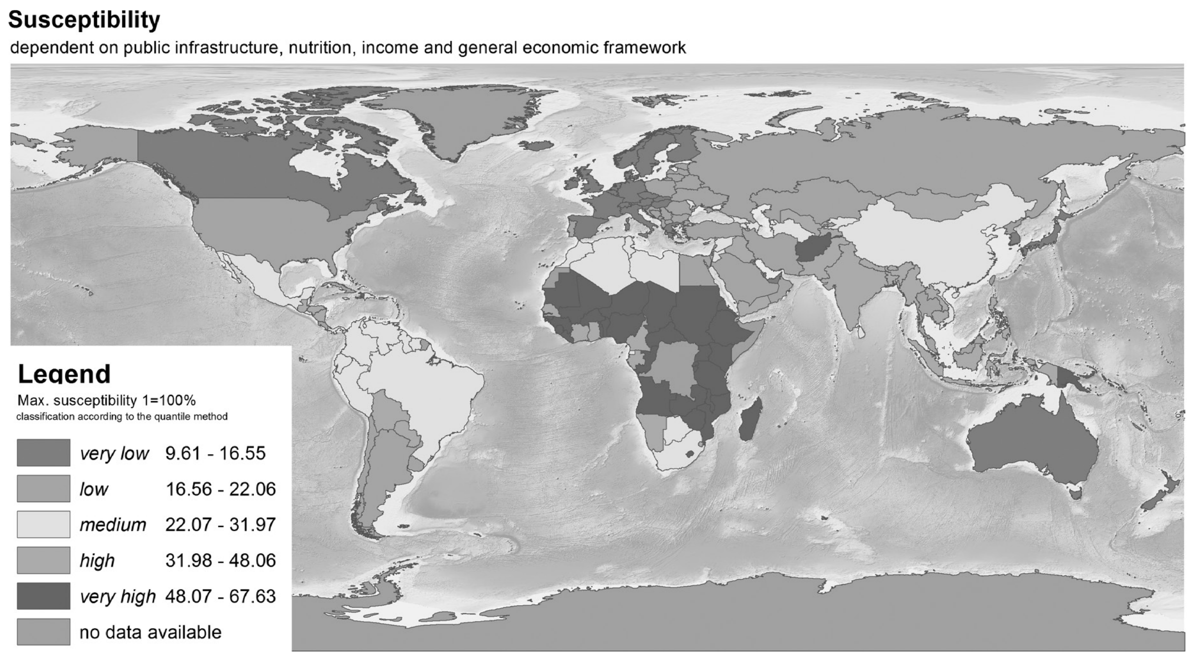

Figure 9.9 Susceptibility map

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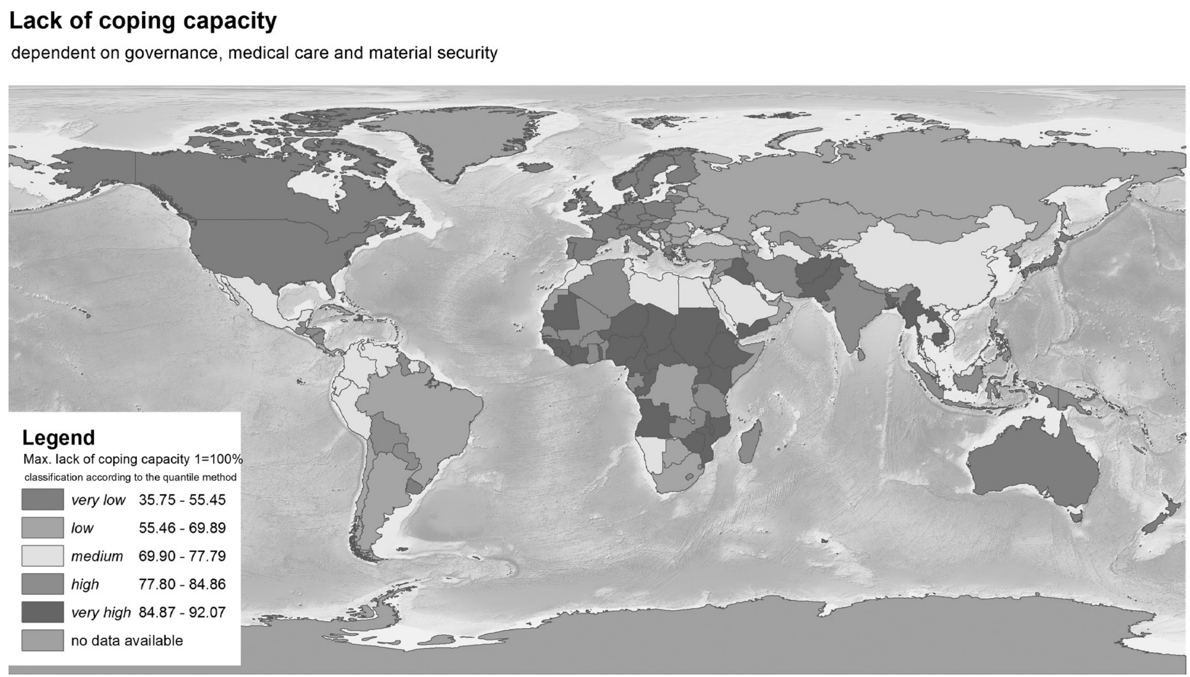

Figure 9.10 Lack of coping capacity map

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Table 9.4 The 10 countries with highest lack of adaptive capacity

Country (Top 10)	Lack of adaptive capacity
Afghanistan	74.26
Eritrea	72.68
Niger	71.93
Mali	69.84
Chad	67.74
Haiti	67.48
Mauretania	67.07
Sierra Leone	66.64
Pakistan	65.35
Guinea	64.91

Table 9.5 The 10 most vulnerable countries

Country (Top 10)	Vulnerability
Eritrea	75.35
Niger	75.17
Chad	74.74
Afghanistan	74.31
Haiti	73.53
Sierra Leone	72.20
Liberia	71.74
Mozambique	71.37
Guinea	71.04
Central African Republic	70.69

most vulnerable countries. The results also show that the most vulnerable countries, such as Eritrea, Niger, Chad, Afghanistan and Haiti – to name just a few – are also countries that are characterized by a relatively high level of poverty and severe problems in governance or are even failed states.

WorldRiskIndex

The WorldRiskIndex map (Figure 9.13(c)) shows the result of the formula presented in Figure 9.6, merging exposure to natural hazards and climate change with the vulnerability of countries and their population. Overall, there is a strong influence of exposure on the final risk level, just as it is a prerequisite for risk (multiplicative conjunction). For example, developed countries such as Chile and Japan have a relatively high risk level; however, this is mainly caused by their high level of exposure, whereas their vulnerability levels are rather low compared to developing countries. The results and different maps also show clearly that the

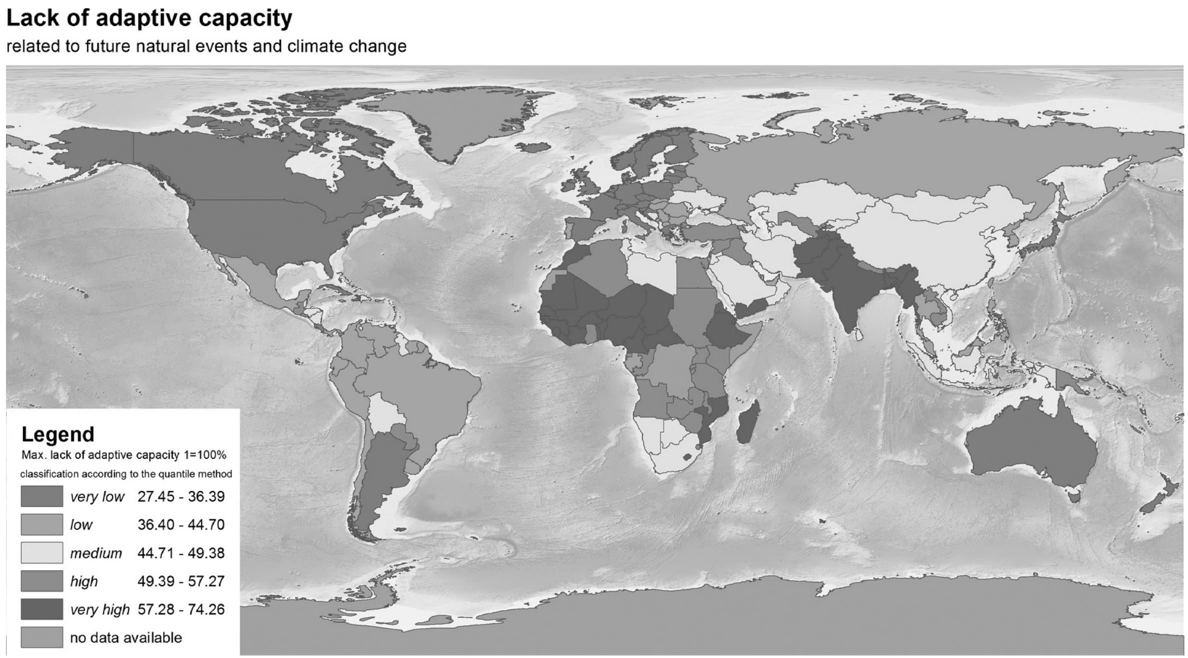

Figure 9.11 Lack of Adaptive Capacity Map

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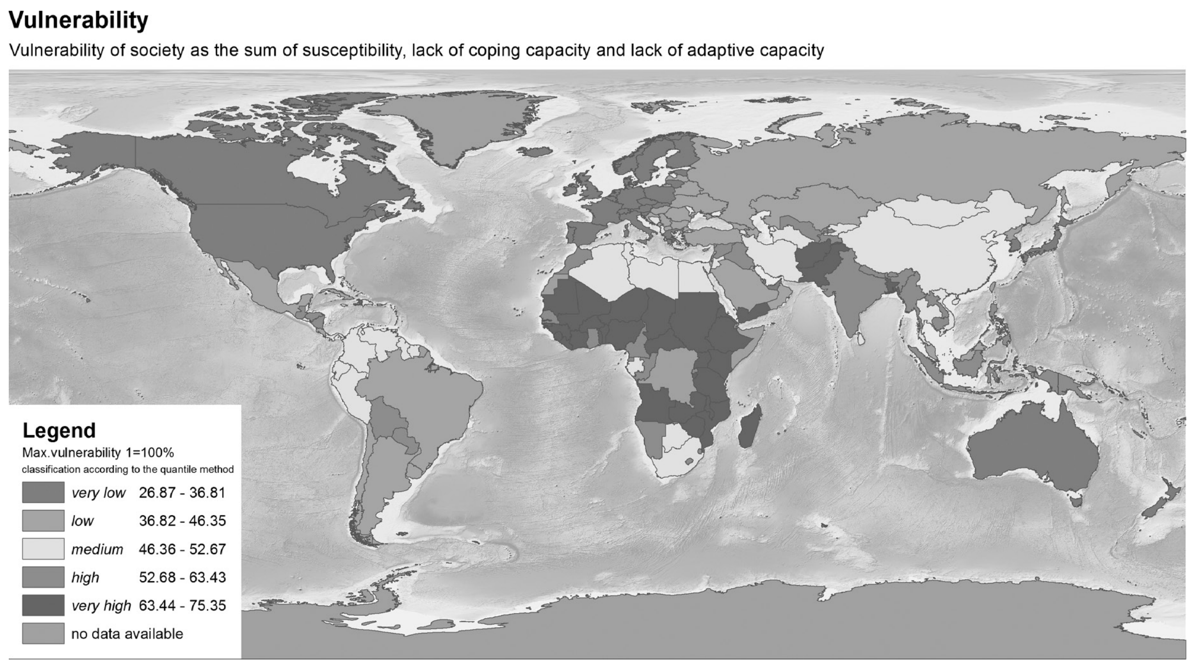

Figure 9.12 Vulnerability Map

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Table 9.6 Results for the WorldRiskIndex

Country (Top 10)	Exposure	Vulnerability	World Risk and Vulnerability Index
Vanuatu	63.66	57.04	36.31
Tonga	55.27	51.78	28.62
Philippines	52.46	53.35	27.98
Guatemala	36.30	57.16	20.75
Bangladesh	31.70	63.78	20.22
Solomon Islands	29.98	60.54	18.15
Costa Rica	42.61	40.80	17.38
Cambodia	27.65	62.07	17.17
Timor-Leste	25.73	66.59	17.13
El Salvador	32.60	51.81	16.89

vulnerability of a society or a country is not the same as its exposure to natural hazards; however vulnerability plays a central role in the determination of risk to natural hazards and climate change. Although Haiti and New Zealand both have a high level of exposure to natural hazards and climate change effects, such as sea-level rise, it is evident from the risk mapping that due to its low vulnerability, New Zealand ranks in a low risk profile, while Haiti is one of the countries most at risk due to both a high level of exposure to natural hazards and high vulnerability.

The top 10 countries for the World Risk Index are presented in Table 9.6. A comparison of the exposure and the vulnerability maps shows the different factors that determine a high or low level of risk. While Vanuatu and Tonga, for example, have high levels of risk due to both a high exposure to natural hazards and climate change as well as a high level of vulnerability, in contrast Cambodia and Timor-Leste have a relatively low exposure but a very high vulnerability and therefore face a high level of risk.

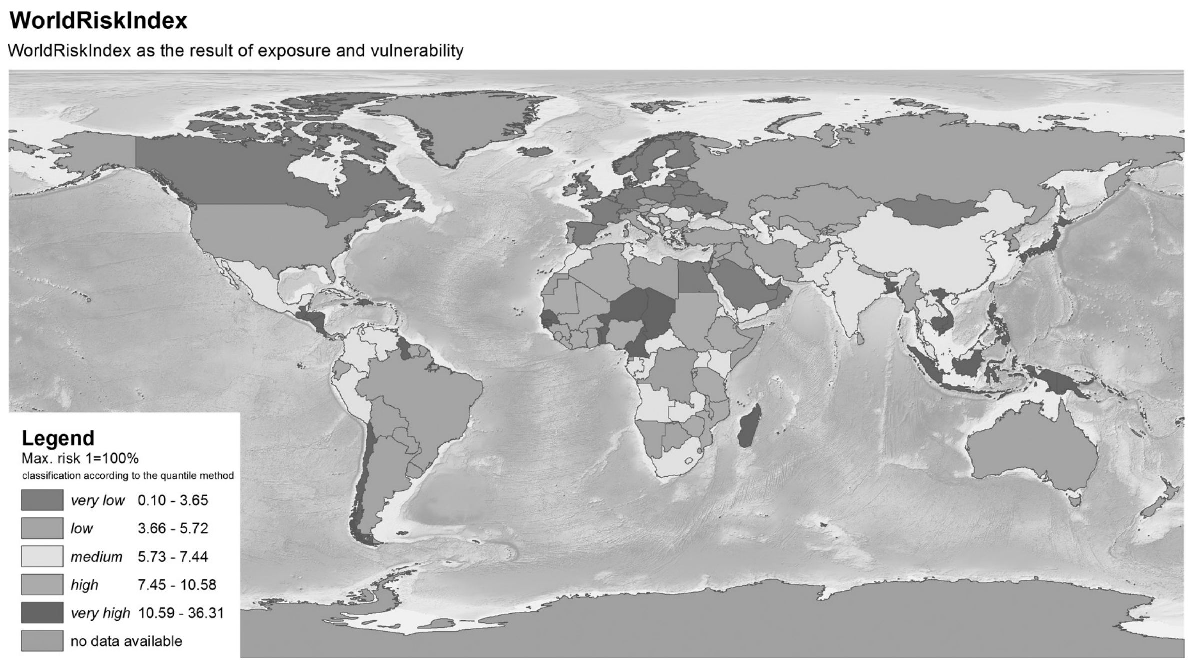

Figure 9.13 WorldRiskIndex Map

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EXCURSUS: Local assessment

The local assessment model was applied to Indonesia, where the definition of the indicators took into account the data available at the district level (Kabupaten). Calculating the exposure involved employing the same dataset as for the global index, using the administrative boundaries of the Kabupaten to determine the respective proportion of the exposed population.

For the development of indicators for susceptibility, coping capacity and adaptive capacity, information was obtained from the National Census, the National Socioeconomic Survey (SUSENAS*)* and the Village Potential Statistics, (PODES) at the Central Bureau of Statistics (BPS). At the end, 37 districts were considered for the assessment.

The results have been presented using a comparative example. Selected urban areas, such as the city of Padang in West Sumatra province as well as a predominantly agricultural district (a rural area) in the province of Central Java and Cilacap and the Gianyar in Bali were selected for comparing different levels of exposure, vulnerability and risk (see Table 9.7).

Table 9.7 Comparison of the various components of the local risk index for the Kabupaten Cilacap and Padang

Kabupaten	Cilacap	Padang	Gianyar
Exposure (min: 24.00, max: 59.90)	37.00	39.60	26.60
Susceptibility (min: 11.10, max: 47.90)	31.00	16.70	11.30
Lack of Coping Capacity (min: 31.80, max: 68.20)	50.10	52.90	31.80
Lack of Adaptive Capacity (min: 48.80, max: 70.70)	64.70	48.80	57.90
Vulnerability (min: 33.60, max: 62.30)	48.60	39.50	33.60
Risk (min: 14.50, max: 36.10)	18.00	15.60	9.00

The analysis shows that Padang and Cilacap do not differ significantly in the proportion of the exposed population (39.6 per cent vs. 37 per cent), whereas Ginayar is less exposed. The analysis of susceptibility for Gianyar, Padang and Cilacap also shows that both areas have lower susceptibility than Cilacap. This can be explained by the importance of regional income to the provincial capital, attracting young people for training or job searching.

Regarding coping capacities, Padang and Cilacap present a similar final value. Here, indicators for economic coverage reflect high economic activity in Padang, particularly due to income per capita; however, job security is higher for Cilacap, land ownership is almost the double, while the unemployment (inverse) is similar for both. Padang is characterized by a relatively good situation of social networks and respective institutions and a good security situation (absence of riots). Whereas Gianyar has better resources to cope, since its income is higher and the unemployment rate is relatively low.

Finally, the adaptive capacity is the highest for Padang, with a big difference in education attainment, and slightly higher values for school enrollment and economy diversification. The ecological footprint (at the province level), and the representation of women in the local governmental administration is also high. Based on the findings above, vulnerability is lowest for Gianyar followed by Padang and Cilacap. Combining vulnerability with exposure, the local risk index shows the highest value for Cilacap, followed by Padang and Gianyar. It can be clearly seen that although Cilacap and Padang have similar exposure values, the risk could be buffered by low vulnerability values, which can also be seen for Gianyar.

Conclusions

The WorldRiskIndex developed by the UNU-EHS presents an effort to assess vulnerability and risk in a more comprehensive way – considering exposure, susceptibility, coping and adaptive capacities. It is important to note that quantitative approaches, at the global or national scale, have a high potential for measuring exposure and susceptibility, as well as aspects of coping and adaptation using surrogate indicators and indicators that outline revealed vulnerability of past events. However, the ability of these global tools and datasets to capture local-specific coping and adaptation strategies is limited and, therefore, a second layer of a set of local indicators should allow for considering additional context-specific features and characteristics of vulnerability and adaptation, such as the access to information, government assistance for vulnerable groups or insurance protection – to name just a few. In this context, quantitative approaches and indicators can be combined at the local level with semi-quantitative and qualitative information – capturing, for example, issues of risk governance and the performance of disaster risk reduction. We also acknowledge the limitations of current data, knowledge and measurability (see also Pelling in this volume, Chapter 6). The coping and adaptation strategies to sea-rise level especially – which has not yet been experienced in most countries – are difficult to project.

The index provides a first overview and some good illustrative material for academic discussions as well as for the science-policy interface. The index and the different components should stimulate further discussions on how to reduce exposure and susceptibility and increase coping capacities, as well as improve adaptation strategies towards extreme events and natural hazards. The indicator and index concept proposed here encompasses both hazard-independent and hazard-dependent indicators, with a stronger emphasis on hazard-independent indicators, since these more easily permit the consideration of multiple hazards.

Furthermore the WorldRiskIndex is meant as a communication tool and does not intend to measure all the various facets of risk and vulnerability. It provides a first overview of some key aspects that can be measured currently and that encompass key factors of risk. It shows severe differences between the exposure to natural hazards and vulnerability. Also different aspects of capacities become clearer in their global distribution, for example in terms of coping as well as adaptive capacities.

Additional research is needed in the future to further enhance the capacities of countries and the international community to assess and measure risk.

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10

System of indicators of disaster risk and risk management for the Americas: Recent updating and application of the IDB-IDEA approach

Omar D. Cardona and Martha L. Carreño

Introduction

Disaster risk is associated not only with the occurrence of intense physical phenomena but also with the vulnerability conditions that favour or facilitate disaster when such phenomena occur. Vulnerability is intimately related to social processes in disaster prone areas and is usually related to the fragility, susceptibility or lack of resilience of the population when faced with different hazards. In other words, disasters are socio-environmental by nature and their materialization is the result of the social construction of risk. Therefore, their reduction must be part of decision-making processes. This is the case not only with post-disaster reconstruction but also with public policy formulation and development planning. As a result, institutional development must be strengthened and investment stimulated in vulnerability reduction in order to contribute to the sustainable development process in different countries.

Disaster risk management requires measurement of risk, and this risk measuring requires taking into account not only the expected physical damage, victims and economic equivalent loss but also social, organizational and institutional factors. The difficulty in achieving effective disaster risk management has been, in part, the result of the lack of a comprehensive conceptual framework of disaster risk that could facilitate a multidisciplinary evaluation and intervention (Cardona, 2004). Most existing indices and evaluation techniques do not adequately express risk and are not based on a holistic approach that invites intervention.

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

The Disaster Risk Management Indicators Program for Latin America and the Caribbean meets this need. The system of indicators proposed by IDEA for the Inter-American Development Bank (IDB) permits a systematic and quantitative benchmarking of each country during different periods between 1980 and 2010, as well as comparisons across countries. It also provides a more analytically rigorous and data driven approach to risk management decision-making. This system of indicators enables the depiction of disaster risk at the national level (but also at the sub-national and urban level to illustrate its application in those scales), allowing the identification of key issues by economic and social category. It also makes the creation of national risk management performance benchmarks possible in order to establish performance targets for improving management effectiveness.

The system of indicators, an outcome of the IDB-IDEA programme, provides a holistic approach to evaluation that is also flexible and compatible with other evaluation methods (Cardona, 2001, 2004 and 2011). As a result, it is likely to be increasingly used to measure risk and risk management conditions. The system's main advantage lies in its ability to disaggregate results and identify factors that should take priority in risk management actions, while measuring the effectiveness of those actions. The main objective is to facilitate the decision-making process. In other words, the concept underlying this methodology is one of controlling risk rather than obtaining a precise evaluation of it (physical truth).

This System of Indicators had three specific objectives: (1) improvement in the use and presentation of information on risk. This assists policymakers in identifying investment priorities to reduce risk (such as prevention and mitigation measures), and directs the post-disaster recovery process; (2) to provide a way to measure key elements of vulnerability for countries facing natural phenomena. It also provides a way to identify national risk management capacities, as well as comparative data for evaluating the effects of policies and investments on risk management; and (3) application of this methodology should promote the exchange of technical information for public policy formulation and risk management programmes throughout the region.

This System of Indicators was designed between 2003 and 2005 with the support of the Inter-American Development Bank (IDB) and developed to be useful not only for the countries but also for the Bank, facilitating the individual monitoring of each country and a comparison between the countries of the region. The first phase of the programme involved the methodological development, the formulation of the indicators and the evaluation of 12 countries from 1985 to 2000. Afterwards, two additional countries were evaluated with the support of the Policy Regional Dialogue on Natural Disasters. In 2008 a methodological review and the updating of the indicators for 12 countries was made. Indicators were updated to 2005 and for the most recent date (2007 or 2008) according to information availability for Argentina, Bolivia, Chile, Colombia, Ecuador, Jamaica, Mexico, Peru, Dominican Republic and Trinidad and Tobago. In addition, Barbados and Panama were included in the programme. In 2009–2010, the evaluations of Guatemala and El Salvador were updated, and Belize and Honduras were added to the programme. An evaluation and updating was made during 2011 and 2012 for Bahamas, Haiti, Guyana, Paraguay and Uruguay. A new evaluation including Venezuela and Brazil will be available during 2014.

Four components, or composite indicators, have been designed to represent the main elements of vulnerability and show each country's progress in managing risk. They are described in the following sections. Programme reports, technical details and the application results for the countries in the Americas can be consulted at the following web page: http://idea.bid.manizales.unal.edu.co (Cardona et al., 2003a and b, 2004a and b; Carreño et al., 2005; IDEA 2005, Cardona 2005, 2008, 2010).

The Disaster Deficit Index (DDI)

The DDI measures country risk from a macroeconomic and financial perspective when faced with possible catastrophic events. This requires an estimation of critical impacts during a given period of exposure, as well as the country's financial capacity for dealing with the situation. This index measures the economic loss that a particular country could suffer when a catastrophic event takes place, and the implications in terms of resources needed to address the situation. Construction of the DDI requires undertaking a forecast based on historical and scientific evidence, as well as measuring the value of infrastructure and other goods and services that are likely to be affected. See Cardona (2005, 2008, 2010), Cardona et al., (2008a and b, 2010) for more details about this methodology.

The DDI captures the relationship between the demand for contingent resources to cover the losses, $L_R{}^P$, caused by the Maximum Considered Event (MCE), and the public sector's economic resilience, $R_E{}^P$, (that is, the availability of internal and external funds for restoring affected inventories). Thus, DDI is calculated using the equation 1, as follows:

$$DDI = \frac{MCE\ loss}{Economic\ Resilience}, \quad DDI = \frac{L_R{}^P}{R_E{}^P} \tag{1}$$

$$\text{where} \quad L_R{}^P = \varphi \boldsymbol{L_R} \tag{2}$$

${L_R}^P$ represents the maximum direct economic impact in probabilistic terms on public and private stocks that are governments' responsibility. The value of public-sector capital inventory losses is a fraction φ of the loss of all affected goods, L_R, which is associated with an MCE of intensity I_R, and whose annual exceedance rate (or return period, R) is defined in the same way for all countries. This total loss, L_R, can be estimated as follows:

$$L_R = EV(I_R F_S)K \tag{3}$$

where, E is the economic value of all the property exposed; $V(\ )$ is the vulnerability function, which relates the intensity of the event with the fraction of the value that is lost if an event of such intensity takes place; I_R is the intensity of the event associated with the selected return period; F_S is a factor that corrects intensities to account for local site effects; and K is a factor that corrects for uncertainty in the vulnerability function. Detailed information about the loss estimation can be found in Ordaz and Santa-Cruz (2003).

The economic resilience, ${R_E}^P$ (the denominator of the index), is defined in equation 4:

$${R_E}^P = \sum_{i=1}^{n} {F_i}^P \tag{4}$$

where F_i^P represents the possible internal and external resources that were available to the government, in its role as a promoter of recovery and as owner of affected goods, when the evaluation was undertaken. The resources taken into account include: the approximate insurance and re-assurance payments that the country would receive for goods and infrastructure insured by government; the reserve funds for disasters that the country has available during the evaluation year; the funds that may be received as aid and donations, public or private, national or international; the possible value of new taxes that the country could collect in case of disasters; the margin for budgetary reallocations of the country that usually corresponds to the margin of discretional expenses available to government; the feasible value of external credit that the country could obtain from multilateral organisms and in the external capital market; and the internal credit the country may obtain from commercial and, at times, its Central Bank, when this is legal, signifying immediate liquidity.

A DDI greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the DDI, the greater the gap between losses and the country's ability to face them. If constrictions for additional debt exist, this situation implies an impossibility for recovery. Details about this methodology can be seen in Cardona (2005, 2009), Cardona et al. (2008a, 2008b, 2010).

A complementary indicator, DDI′, has been developed to illustrate the portion of a country's annual Capital Expenditure, E_C^P, which corresponds to the expected annual loss, L_y^P, or the pure risk premium. That is, DDI′ shows the percentage of the annual investment budget that would be needed to pay for future disasters.

$$DDI' = \frac{Expected\ annual\ loss}{Capital\ expenditures}, \quad DDI' = \frac{L_y^P}{E_C^P} \tag{5}$$

The pure premium value is equivalent to the annual average investment or saving that a country would have to make in order to approximately cover losses associated with major future disasters. The DDI′ was also estimated with respect to the amount of sustainable resources due to inter-temporal surplus.

Figures 10.1 and 10.2 show the results for the DDI_{500} (with a MCE with 500 years of return period) and DDI′ for countries of Latin America and the Caribbean (LAC) for 2008.

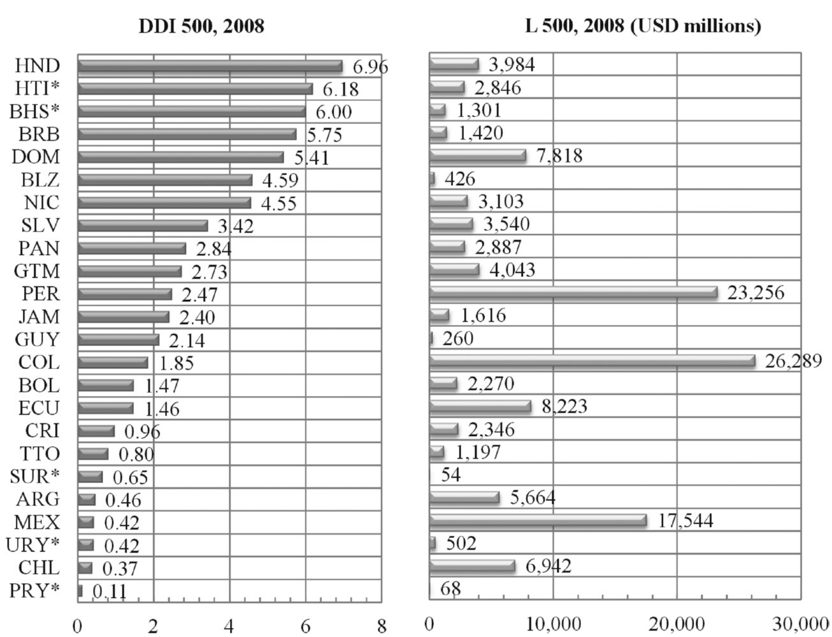

Figure 10.1 DDI and Probable Maximum Loss (500 years return period) for some countries of the Latin American and Caribbean Region in 2008. Countries that have a "*" are based on values for 2010. These countries correspond to the last evaluations and more recent information available.

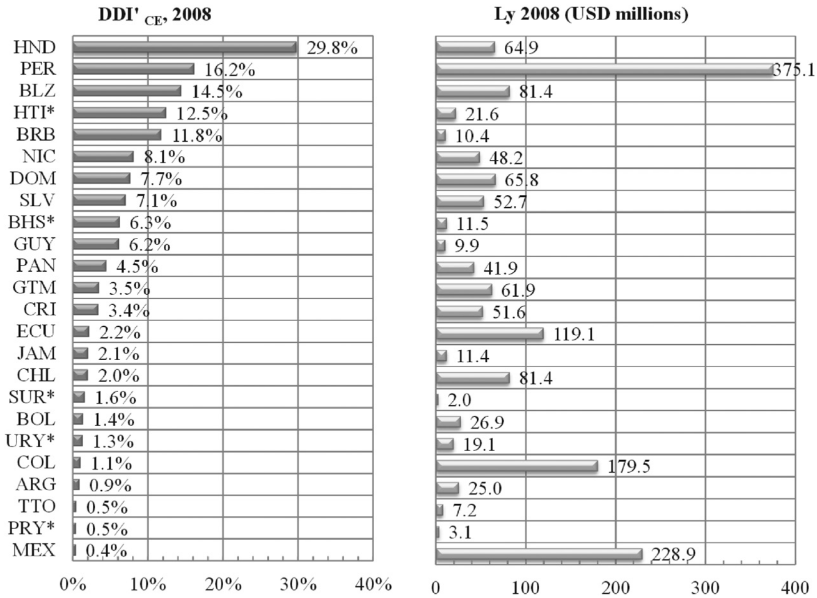

Figure 10.2 DDI' based on capital expenditure and the Average Annual Loss for 24 countries of the Latin America the Caribbean region in 2008. Countries that have a "*" are based on values for 2010. These countries correspond to the last evaluations and more recent information available.

These indicators provide a simple way of measuring a country's fiscal exposure and potential deficit (or contingency liabilities) in case of an extreme disaster. They allow national decision-makers to measure the budgetary implications of such an event and highlight the importance of including this type of information in financial and budgetary processes (Freeman et al., 2002). These results substantiate the need to identify and propose effective policies and actions such as, for example, using insurance and reinsurance (transfer mechanisms) to protect government resources or to establish reserves based on adequate loss estimation criteria. Other such actions include contracting contingency credits and, in particular, the need to invest in structural (retrofitting) and non-structural prevention and mitigation to reduce potential damage and losses as well as the potential economic impact of disasters.

The Local Disaster Index (LDI)

The LDI identifies the social and environmental risks resulting from more recurrent lower level events (which are often chronic at the local and sub-national levels). These events have a disproportionate impact on more socially and economically vulnerable populations, and have highly damaging impacts on national development. This index represents the propensity of a country to experience small-scale disasters and their cumulative impact on local development. The index attempts to represent the spatial variability and dispersion of risk in a country resulting from small and recurrent events. This approach is concerned with the national significance of recurrent small-scale events that rarely enter international, or even national, disaster databases but which pose a serious and cumulative development problem for local areas and, more than likely, also for the country as a whole. These events may be the result of socio-natural processes associated with environmental deterioration (Lavell, 2003a and b) and are persistent or chronic in nature. They include landslides, avalanches, flooding, forest fires, and droughts as well as small earthquakes, hurricanes and volcanic eruptions (Marulanda et al., 2011).

The LDI is equal to the sum of three local disaster sub-indices that are calculated based on data from the DesInventar database (made by the Network of Social Studies in Disaster Prevention of Latin America, La RED in Spanish) for number of deaths K, number of people affected A and losses L in each municipality, taking into account four wide groups of events: landslides and debris flows, seismo-tectonic, floods and storms, and other events. LDI is obtained from equation 6:

$$LDI = LDI_K + LDI_A + LDI_L \tag{6}$$

Figure 10.3 illustrates schematically how LDI is obtained for a country based on the information for events in each municipality.

The local disaster subindicators for each type of variable (K, A, L) are obtained from equation 7 according to the new modified formulation (Marulanda and Cardona 2006; Marulanda et al., 2008a and b),

$$LDI_{(K,A,L)} = \left(1 - \sum_{e=1}^{E} \left(\frac{PI_e}{100}\right)^2\right) \lambda\Big|_{(K,A,L)} \tag{7}$$

λ is a scaling coefficient and PIe, as expressed in equation 8, corresponds to the Persistence Index of effects (K, A, L) caused by each type of event e,

$$PI_{e(K,A,L)} = 100 \sum_{m=1}^{M} \frac{LC_{em}}{LC_m} \Big|_{(K,A,L)} \tag{8}$$

where

$$LC_{m\,(K,A,L)} = \sum_{e=1}^{E} LC_{em\,(K,A,L)} \tag{9}$$

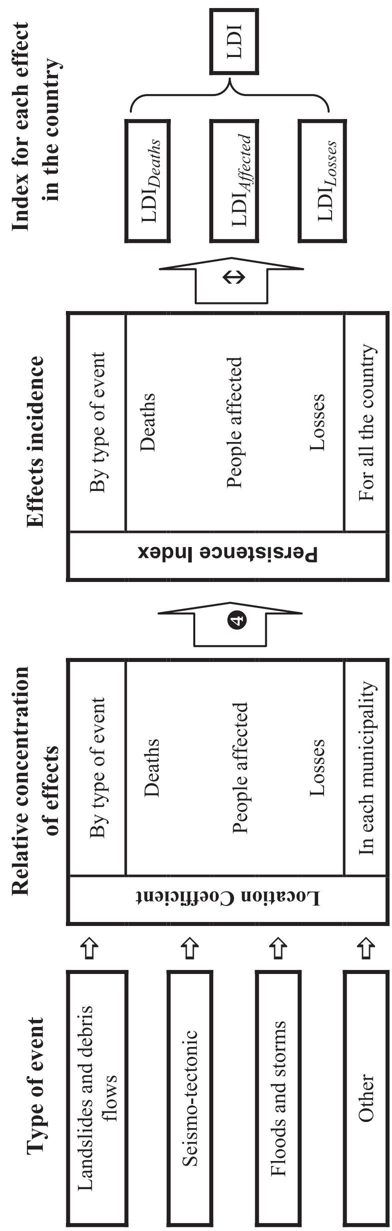

Figure 10.3 Diagram for the calculation of the LDI

LC_{em} corresponds to a Location Coefficient of effects x (K, A, L) caused by each type of event e in each municipality m, as is established in equation 10,

$$LC_{em(K,A,L)} = \frac{x_{em} x_{eC}}{x_m x_C} \eta \Big|_{(K,A,L)} \tag{10}$$

where the values of variable x corresponding to K, A or L, are:
x_{em} the value x caused by event e in municipality m;
x_m sum totals for x caused by all types of events considered in municipality m;
x_{eC} the value of x for event e throughout the country;
x_C the total sum of x throughout the country and
η is the relation between all types of events E and the number of municipalities in country M, where some effects have been registered.

These coefficients account for the relative weight of the effects caused by different types of events in the municipalities with respect to the country as a whole. Therefore, the Persistence Indices capture simultaneously for a given period (one year, five years etc.) the incidence – or relative concentration – and the homogeneity of local level effects for each type of event with respect to other municipalities and types of events in the country.

The LDI captures simultaneously the incidence and uniformity of the distribution of local disaster effects; i.e. it accounts for the relative weight and persistence of the disaster effects at county scale. The total LDI is obtained by the sum of three LDIs that are calculated based on the information available in the DesInventar database, regarding deaths, affected people and economic losses in each county of the country. If the relative value of the index is high, the uniformity of the magnitude and distribution of the effects of various hazards among counties is greater. A low LDI value means low spatial distribution of the effects among the counties where events have occurred. The range of each LDI is from 0 to 100 and the total LDI is the sum of the three components. A low LDI value (0–20) means high concentration of small disasters in few counties and a low spatial distribution of their effects between the counties where they had taken place. Medium LDI values (20–50) means small disaster concentration and distribution of their effects are intermediate; high LDI values (greater than 50) indicate that the majority of counties suffer small disasters and their effects are similar in all affected counties. High values reflect that vulnerability and hazards are generalized in the territory. The LDI takes into account only the small and moderate events; extreme events are excluded from the database through statistical

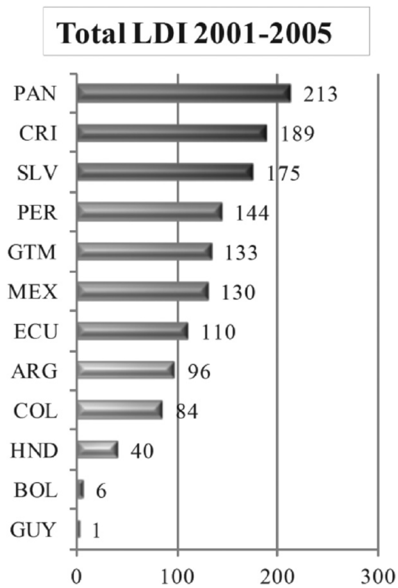

Figure 10.4 Total LDI 2001–2005 for some countries of the LAC region

identification of outliers (Marulanda and Cardona, 2006; Marulanda et al., 2008a and b).

In a complementary way, an LDI′ that measures the concentration of aggregate losses at county level has been formulated. Its value is between 0.0 and 1.0. A high LDI′ value means that high economic loss concentration due to small disasters has occurred in few counties. For example, an LDI′ equal to 0.66 and 0.83 means that approximately 10 per cent of counties of the country concentrate approximately 35 per cent and 97 per cent of the losses respectively. More details about the calculation method can be found in Cardona (2005), Marulanda et al. (2008a and b, 2011)

Figure 10.4 shows an example of results of the LDI for countries of Latin America and the Caribbean region in the period 1996 to 2000.

Prevalent Vulnerability Index (PVI)

The PVI depicts predominant vulnerability conditions by measuring exposure in prone areas, socio-economic fragility and lack of resilience. These items provide a measure of direct as well as indirect and intangible impacts of hazard events. The index is a composite indicator that provides a comparative measure of a country's pattern or situation. Inherent vulnerability conditions underscore the relationship between risk and development (UNDP, 2004). Vulnerability, and therefore risk, are the result of inadequate economic growth, and deficiencies, which may be corrected by means of adequate development processes. Although the indicators proposed are recognized as useful for measuring development (Holzmann and Jorgensen, 2000; Holzmann, 2001), their use here is intended to capture favorable conditions for direct physical impacts (exposure and susceptibility, ES), as well as indirect and, at times, intangible impacts (socio-economic fragility, (SF), and lack of resilience, (LR)) of potential physical events (Masure, 2003; Davis, 2003). The PVI, as shown in equation 11 is an average of these three types of composite indicators:

$$PVI = PVI_{ES} + PVI_{SF} + PVI_{LR} \tag{11}$$

The sub-indices for prevalent vulnerability conditions for each type of situation (*ES*, *SF*, *LR*) are obtained from equation 12

$$PVI^{t}_{c(ES,SF,LR)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Bigg|_{(ES,SF,LR)} \tag{12}$$

where, w_i is the weight assigned to each indicator, corresponding to each normalized indicator as expressed in equations 13 and 14. These represent the conditions of vulnerability for each situation (*ES*, *FS*, *FR*) respectively,

$$I^{t}_{ic} = \frac{x^{t}_{ic} - \min(x^{t}_{i})}{rank\,(x^{t}_{i})}, \quad \text{for (ES, SF)} \tag{13}$$

and

$$I^{t}_{ic} = \frac{\max(x^{t}_{i}) - x^{t}_{ic}}{rank\,(x^{t}_{i})}, \quad \text{for (LR)} \tag{14}$$

x^{t}_{ic} is the original data for the variable for country c during time period t, and
x^{t}_{i} is the variable considered jointly for all countries.
x^{t}_{M} it is the maximum value defined for the variable at t period
x^{t}_{m} it is the minimum value defined for the variable at t period
(x^{t}_{i}) rank it is the difference between the maximum and minimum value $(x^{t}_{M} - x^{t}_{m})$ at t period.

The weighting technique used to obtain the PVI was the Analytic Hierarchy Process (AHP), a widely used technique for multi-attribute decision-making proposed by Saaty (1980, 1987).

The indicators used for describing exposure, prevalent socio-economic conditions and lack of resilience have been estimated in a consistent manner (directly or in inversely, accordingly), recognizing that their influence explains why adverse economic, social and environmental impacts take place following a dangerous event (Cardona and Barbat, 2000; Cardona, 2004). Each one is made up of a set of indicators that expresses situations, causes, susceptibilities, weaknesses or relative absences affecting the country, region or locality under study, and which would benefit from risk reduction actions. The indicators were identified based on figures, indices, existing rates or proportions derived from reliable databases available worldwide or in each country. Figure 10.5 presents the structure of the PVI as a composite index; the component indicators used for exposure and susceptibility, social vulnerability and lack of resilience are listed.

In general, PVI reflects susceptibility due to the degree of physical exposure of goods and people, PVI_{ES}, which favour the direct impact in case of hazard events. In the same way, it reflects conditions of socio-economic vulnerability that favour the indirect and intangible impact, PVI_{SF}. Also, it reflects a lack of capacity for absorbing consequences, for efficient response and recovering, PVI_{LR}. Reduction of such factors, as the objective of the human sustainable development process and explicit policies for risk reduction, is one of the aspects that should be emphasized. More information about the indicators used can be find in Masure (2003); Lavell (2003a and b); Cannon (2003); Davis (2003); Wisner (2003); Benson (2003); Briguglio (2003). Details about the calculation method are in Cardona (2005).

Figure 10.6 shows the obtained results of the total PVI for 1995, 2000, 2005 and 2007. Figure 10.7 shows the results for 2007 as a ranking of the evaluated countries.

The Risk Management Index (RMI)

The RMI brings together a group of indicators that measures a country's risk management performance. These indicators reflect the organizational, development, capacity and institutional actions taken to reduce vulnerability and losses, to prepare for crises and to recover efficiently from disasters. This index was designed to assess risk management *performance*. It provides a qualitative measure of management based on predefined *targets* or *benchmarks* that risk management efforts should

Description	Indicator	Weight
Population growth, average annual rate (%)	**ES1**	*w1*
Urban growth, avg. annual rate (%)	**ES2**	*w2*
Population density, people/5 Km^2	**ES3**	*w3*
Poverty-population below US$ 1 per day PPP	**ES4**	*w4*
Capital stock, million US$ /1000 km^2	**ES5**	*w5*
Imports and exports of goods and services, % GDP	**ES6**	*w6*
Gross domestic fixed investment, % of GDP	**ES7**	*w7*
Arable land and permanent crops, % land area	**ES8**	*w8*

→ PVI_{ES}

Description	Indicator	Weight
Human Poverty Index, HPI-1	**SF1**	*w1*
Dependents as proportion of working-age population	**SF2**	*w2*
Social disparity, concentration of income measured using Gini index	**SF3**	*w3*
Unemployment, as % of total labour force	**SF4**	*w4*
Inflation, food prices, annual %	**SF5**	*w5*
Dependency of GDP growth of agriculture, annual %	**SF6**	*w6*
Debt servicing, % of GDP	**SF7**	*w7*
Human-induced Soil Degradation *	**SF8**	*w8*

→ PVI_{SF} → PVI

Description	Indicator	Weight
Human Development Index, HDI [Inv]	**LR1**	*w1*
Gender-related Development Index, GDI [Inv]	**LR2**	*w2*
Social expenditure on pensions, health and education, % of GDP [Inv]	**LR3**	*w3*
Governance Index (Kaufmann) ¥ [Inv]	**LR4**	*w4*
Insurance of infrastructure and housing, % of GD [Inv]	**LR5**	*w5*
Television sets per 1,000 people [Inv]	**LR6**	*w6*
Hospital beds per 1,000 people [Inv]	**LR7**	*w7*
Environmental Sustainability Index, ESI [Inv]	**LR8**	*w8*

→ PVI_{LR}

Figure 10.5 Diagram for the estimation of PVI_{ES}, PVI_{SF}, PVI_{LR} and the total PVI (IDEA, 2005)
* For example the Global Assessment of Human-induced Soil Degradation (GLASOD) (Oldeman et al., 1990)
¥ Scaling of six indicators that consider some dimensions of governance: The Voice and Accountability; Political Stability; Absence of Violence; Government Effectiveness; Regulatory Quality; Rule of Law; and Control of Corruption (Kaufmann et al., 2003).

aim to achieve. The design of the RMI involved establishing a scale of achievement levels (Davis, 2003; Masure, 2003) or determining the "distance" between current conditions and an objective threshold or conditions in a reference country (Munda, 2003).

The RMI was constructed by quantifying four public policies, each of which has six indicators. The policies include: the identification of risk, risk reduction, disaster management, and governance and financial protection. Risk identification (RI) is a measure of individual perceptions, how those perceptions are understood by society as a whole and the objective assessment of risk. Risk reduction (RR) involves prevention and

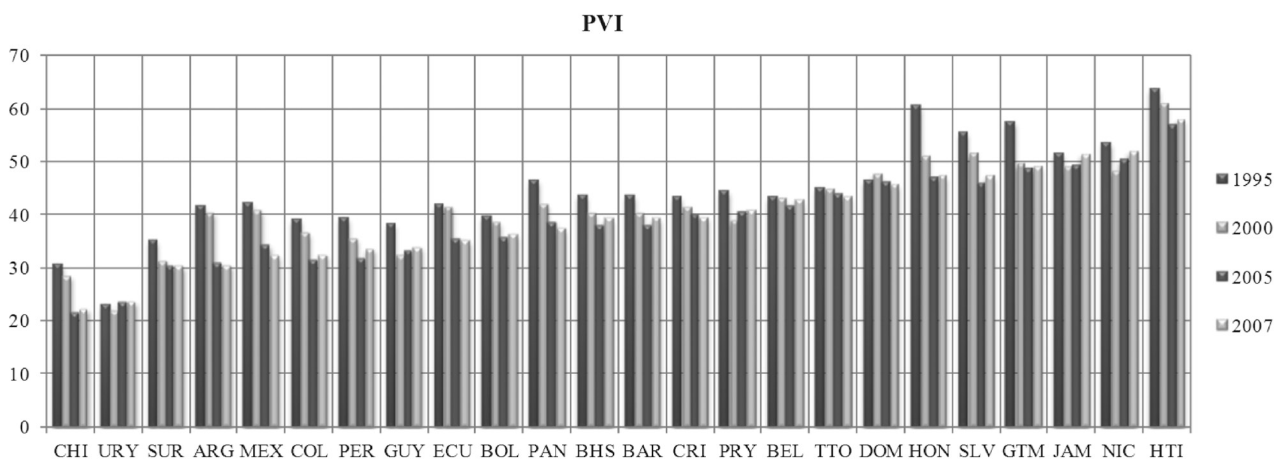

Figure 10.6 PVI for some countries of the Latin America and Caribbean region

PVI, 2007

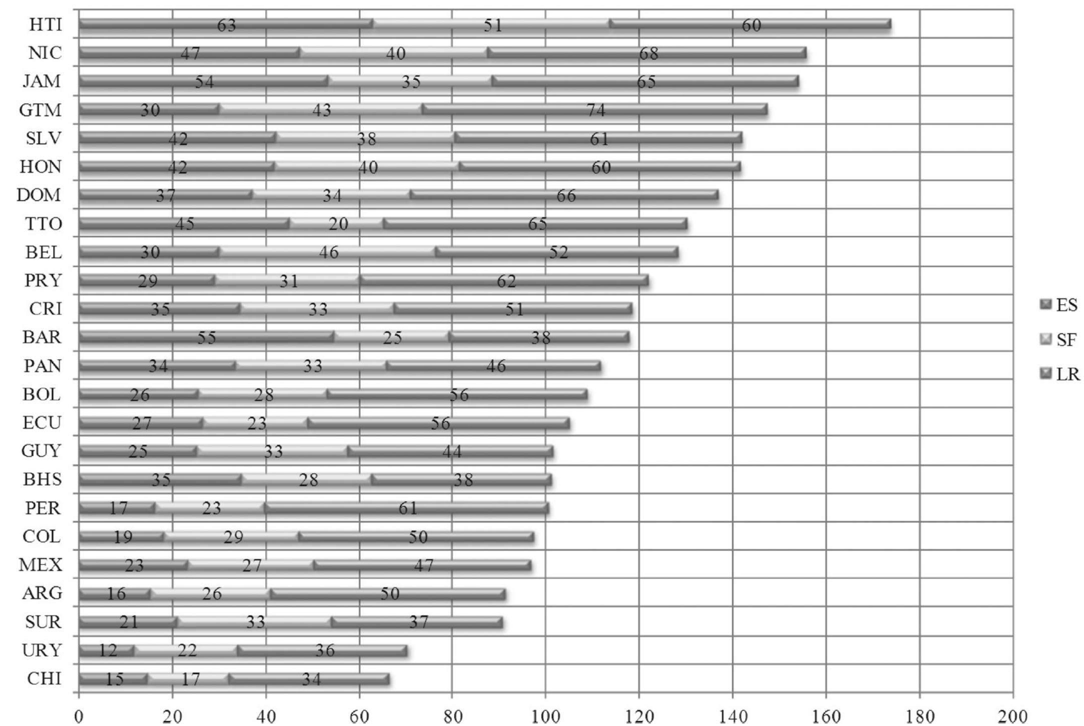

Figure 10.7 PVI of 2007 for some countries of LAC region

mitigation measures. Disaster management (DM) involves measures of response and recovery. And, finally, governance and financial protection (FP) measures the degree of institutionalization and risk transfer. The RMI, as indicated in equation 15, is defined as the average of the four composite indices:

$$RMI = (RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP}) / 4 \tag{15}$$

The indicators for each type of public policy (*RI*, *RR*, *DM*, *FP*) are obtained through equation 16,

$$RMI^{t}_{c(RI,RR,DM,FP)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Big|_{(RI,RR,DM,FP)} \tag{16}$$

where, w_i is the weight assigned to each indicator, RMI^{t}_{ic}. corresponding to each indicator for the territorial unity in consideration c and the time period t – normalized or obtained by the defuzzification of the linguistic values. Each indicator was estimated based on five performance levels (*low, incipient, significant, outstanding* and *optimal*) that correspond to a range from 1 (low) to 5 (optimal). These represent the risk management performance levels defined by each public policy respectively. Such linguistic values, according to the proposal of Cardona (2001) are the same as a fuzzy set that have a membership function of the bell or sigmoidal (at the extremes) type, given parametrically by the equations 17 and 18.

$$bell(x;a,b,c) = \frac{1}{1 + \left| \frac{x-c}{a} \right|^{2b}} \tag{17}$$

where the parameter b is usually positive.

$$sigmoidal(x;a,c) = \frac{1}{1 + \exp\left[-a(x-c)\right]} \tag{18}$$

where a controls the slope at the crossing point, 0.5 of membership, $x = c$.

These weights have been assigned using Analytic Hierarchy Process (AHP); see Saaty and Vargas (1991). Figure 10.8 shows the structure of the RMI as a composite index.

Indicator	Description	Weight		
RI1	Systematic disaster and loss inventory	w_{RI1}		
RI2	Hazard monitoring and forecasting	w_{RI2}		
RI3	Hazard evaluation and mapping	w_{RI3}	RMI_{RI}	
RI4	Vulnerability and risk assessment	w_{RI4}		
RI5	Public information and community participation	w_{RI5}		
RI6	Training and education on risk management	w_{RI6}		
RR1	Risk consideration in land use and urban planning	w_{RR1}		
RR2	Hydrographical basin intervention and environmental protection	w_{RR2}		
RR3	Implementation of hazard-event control and protection techniques	w_{RR3}	RMI_{RR}	
RR4	Housing improvement and human settlement relocation from prone areas	w_{RR4}		
RR5	Updating and enforcement of safety standards and construction codes	w_{RR5}		
RR6	Reinforcement and retrofiting of public and private assets	w_{RR6}		DRMi
DM1	Organization and coordination of emergency operations	w_{DM1}		
DM2	Emergency response planning and implementation of warning systems	w_{DM2}		
DM3	Endowment of equipments, tools and infrastructure	w_{DM3}	RMI_{DM}	
DM4	Simulation, updating and test of interinstitutional response	w_{DM4}		
DM5	Community preparedness and training	w_{DM5}		
DM6	Rehabilitation and reconstruction planning	w_{DM6}		
FP1	Interinstitutional, multisectoral and decentralizing organization	w_{FP1}		
FP2	Reserve funds for institutional strengthening	w_{FP2}		
FP3	Budget allocation and mobilization	w_{FP3}	RMI_{PF}	
FP4	Implementation of social safety nets and funds response	w_{FP4}		
FP5	Insurance coverage and loss transfer strategies of public assets	w_{FP5}		
FP6	Housing and private sector insurance and reinsurance coverage	w_{FP6}		

Figure 10.8 Component indicators of the DRMi (IDEA, 2005; Carreño et al., 2007)

This methodological approach permits the use of each reference level simultaneously as a "performance target" and allows for comparison and identification of results or achievements. Government efforts at formulating, implementing, and evaluating policies should bear these performance targets in mind (Carreño et al., 2004; 2005).

It is important to recognize and understand the collective risk to design prevention and mitigation measures. The design of prevention and mitigation measures depends on the individual and social risk awareness and the methodological approaches to assess risk. It then becomes necessary to measure risk and portray it by means of models, maps, and indices capable of providing accurate information for society as a whole and, in particular, for decision-makers. Methodologically, RMI_{RI} includes the evaluation of hazards, the characteristics of vulnerability in the face of these hazards and estimates of the potential impacts during a particular period of exposure. The measurement of risk seen as a basis for intervention is (only) relevant when the population recognizes and understands that risk.

The major aim of risk management is to reduce risk (RMI_{RR}). Reducing risk generally requires the implementation of structural and non-structural prevention and mitigation measures. It implies a process of anticipating potential sources of risk, putting into practice procedures and other measures to either avoid hazard, when it is possible, or reducing the economic, social and environmental impacts through corrective and prospective interventions of existing and future vulnerability conditions.

The goal of disaster management (RMI_{DM}) is to provide appropriate response and recovery efforts following a disaster. It is a function of the degree of preparedness of the responsible institutions as well as the community as a whole. The goal is to respond efficiently and appropriately when risk has become disaster. Effectiveness implies that the institutions (and other actors) involved have adequate organizational abilities, as well as the capacity and plans in place to address the consequences of disasters.

Adequate governance and financial protection (RMI_{FP}) are fundamental for sustainability, economic growth and development. They are also basic to risk management, which requires coordination among social actors as well as effective institutional actions and social participation. Governance also depends on an adequate allocation and use of financial resources to manage and implement appropriate retention and transfer strategies for dealing with disaster losses.

Figure 10.9 displays the results of the application of the RMI in countries of LAC region from 1990 to 2008, each for five years, and Figure 10.10 displays the ranking of the countries for 2008. More details about this methodology and its application can be found in Cardona (2005, 2008, 2010), Carreño (2006), Carreño et al. (2004, 2007).

Conclusions and future analysis

The programme of indicators laid heavy emphasis on *developing a language of risk* that various kinds of decision-makers understand. The disaster deficit, local disaster and prevalent vulnerability indices (DDI, LDI and PVI) are risk proxies that measure different factors that affect overall risk at the national and sub-national levels. By depicting existing risk conditions, the indicators highlight the need for intervention.

Creating a measurement system based on composite indicators is a major conceptual and technical challenge, which is made even more so when the aim is to produce indicators that are transparent, robust, representative, replicable, comparable and easy to understand. All methodologies have limitations that reflect the complexity of what is to be

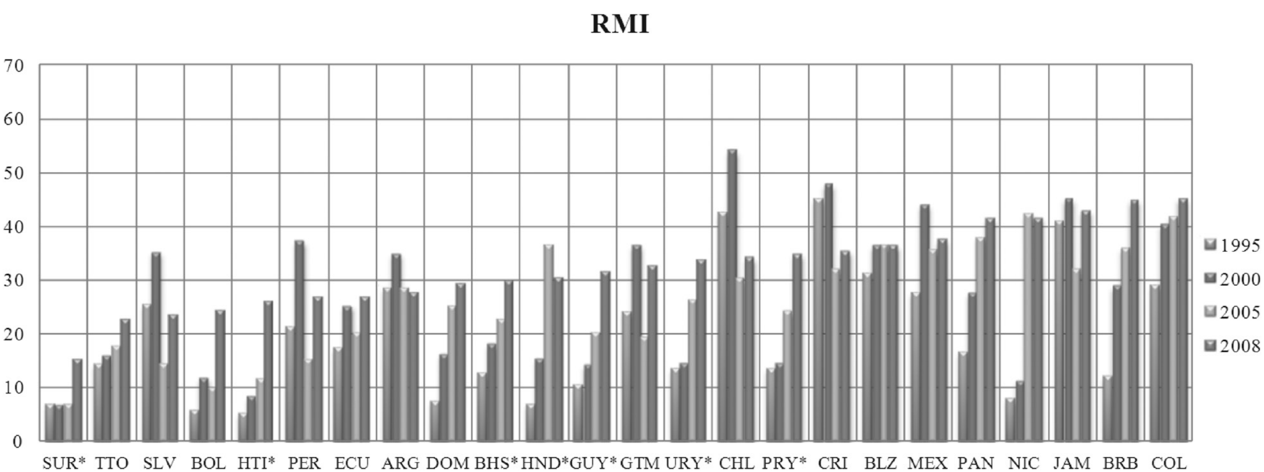

Figure 10.9 DRMi for some countries of the LAC region. Countries that have a "*" are based on values for 2010. These countries correspond to the last evaluations and more recent information available.

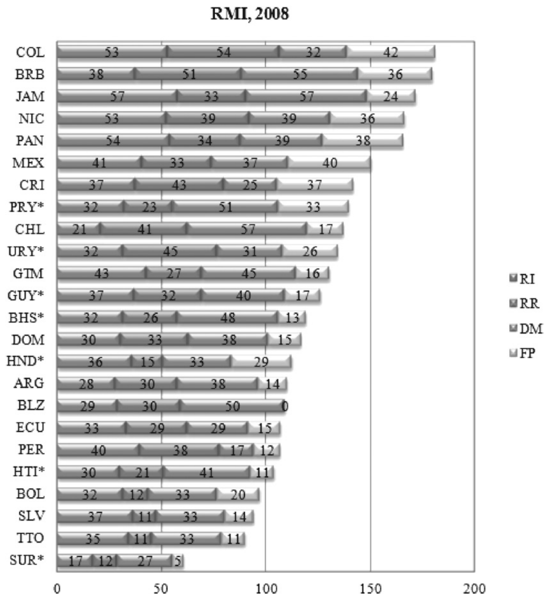

Figure 10.10 DRMi for 2008. Countries that have a "*" are based on values for 2010. These countries correspond to the last evaluations and more recent information available.

measured and what can be achieved. As a result, for example, the lack of data may make it necessary to accept approaches and criteria that are less exact or comprehensive than what would have been desired. These trade-offs are unavoidable when dealing with risk and may even be considered desirable.

This study indicates that the countries of the region face significant risks that have yet to be fully recognized or taken into account by individuals, decision-makers and society as a whole. These indicators are a first step in correctly measuring risk so that it can be given the priority that it deserves in the development process. Once risk has been identified and measured, activities can then be implemented to reduce and control it. The first step in addressing risk is to recognize it as a significant socio-economic and environmental problem. The RMI is also novel and far more wide-reaching in its scope than other similar attempts in the past. In some ways this is the most sensitive and interesting indicator of all. It is certainly the one that can show the fastest rate of change given improvements in political will or deterioration of governance. This index has the advantage of being composed of measures that more or less directly map sets of specific decisions/actions onto sets of desirable outcomes.

The indicators of risk and risk management described here have permitted an evaluation of 24 Latin American and Caribbean countries based on integrated criteria. The results show that it is possible to describe risk and risk management using coarse grain measures and classify countries according to a relative scale. An evaluation of individual countries allowed us to compare individual performance indicators for the period 1980–2008. The reports of the programme also estimated the indicators at the sub-national and urban level. This profile is a first step towards creating a "common operating picture" of disaster risk reduction for the region. That is, it represents a common knowledge base that can be accessed, viewed, and understood by all of the different policymakers responsible for disaster risk reduction in the region. Any group that is not included or that fails to comprehend the level and frequency of risk will likely fail to engage actively in the risk reduction process. Consequently, the construction of an effective common knowledge base for the system of decision-makers responsible for disaster risk reduction is fundamental to achieving change in practice.

Undoubtedly, the construction of the indicators is methodologically complex for run-of-the-mill professionals while the demands for information are relatively onerous in some cases, given access and identification problems. Certain variables or types of information are not readily available and require research as opposed to rote collection where such information exists as a normal part of data systematization at the national or international levels. Doubts exist as to the veracity and accuracy of some items of information, although overall the procedures used to "test" the information assure a very reasonable level of accuracy and veracity. In the same way, weighting procedures and decisions could be questioned at times, but again, overall, the decisions taken seem to be well justified and lead to adequate levels of accuracy. The use of official employees of risk management institutions at the national level in order to undertake the qualitative analyses is open to revision given the clear bias, in some cases, in favour of positive qualifications. The alternative, using scientists, informed independent persons and academics would resolve certain problems but may create others. Thus, maybe a cross-check double entry approach is best where both types of sector are taken into consideration.

To date the system of indicators has been opened up to scrutiny and discussion by international advisors, academics, risk professionals and a limited number of national technical and professional staff but too few policymakers as such. In the short term it would thus be very wise to organize a series of national dialogues where the derived indicator results and implications are presented to a selected number of national level policy and decision-makers. This would allow a testing of relevance and pertinence and offer conclusions with regard to future work on the programme. It is very important to take into account the set of "next steps" that might be taken to improve the reliability and validity of the data collected and the analyses undertaken. In the future, sustainability for the programme and promoting its applicability at the decision-maker level require, among other things:

- dissemination of the guidelines to easy analysis and indicator calculation;
- transformation of indices into political indicators;
- the diffusion and acceptance of the indicators and the method by national decision-makers in analysed countries and in others and;
- An agreement as to procedures for future collection of information and analysis.

Finally, perhaps the most important contribution of the programme was to initiate a systematic procedure for measuring and documenting disaster risk across the 24 nations engaged in this project. Once initiated, however, the programme itself becomes a process in which the participants learn by engaging in data collection, analysis and interpretation of findings. Some of the methods, adopted because no other measures existed, may now be re-examined and redesigned as cumulative data show new possibilities for refining the measures, or as data collection methods yield new possibilities for more complete and comprehensive documentation of risk and risk reduction practices.

Acknowledgments

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11

Multi-risk and vulnerability assessment of Europe's regions

Stefan Greiving

Background

The reduction of disaster risk from multiple hazard sources is an explicitly stated aim in several international agendas, for example in the Agenda 21 (from the UN Conference on Environment and Development 1992), the Johannesburg Plan (adopted at the 2002 World Summit on Sustainable Development) or the Hyogo Framework for Action 2005–2015: Building Resilience of Nations and Communities to Disasters (UN-ISDR, 2005) and the Special Report "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" (SREX Report) (IPCC, 2012). Strategies and actions to "control, reduce and transfer risks" based on (multi-)risk assessments and analyses can be subsumed under the term "risk management" (UN-ISDR, 2009). Developing guidelines for hazard and risk mapping is propagated as a key objective by the 2009 EC Communication "A Community approach on the prevention of natural and man-made disasters" (European Commission, 2009b). The communication also indicates the diversity of methodological approaches and seeks for a better comparability of hazard/risk information across the EU. This is mainly what the first part of this chapter is about.

The second part deals with vulnerability to climate change. In the EU Territorial Agenda (BMVBS, 2007a: 7) it is stipulated under Priority 5 that:

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

> joint transregional and integrated approaches and strategies should be further developed in order to face natural hazards, reduce and mitigate greenhouse gas emissions and adapt to climate change. Further work is required to develop and intensify territorial cohesion policy, particularly with respect to the consequences of territorially differentiated adaptation strategies.

However, territorially differentiated adaptation strategies call for an evidence basis, which is presented in the second part of this chapter: a pan-European vulnerability assessment as a basis for identifying regional typologies of climate change exposure, sensitivity, impact and vulnerability that was undertaken by the ESPON Climate project. On this basis, tailor-made adaptation options can be derived that are able to cope with regionally specific patterns of climate change.

As this chapter deals with disaster risk as well as vulnerability to climate change, it has to be recognized that the understanding of the key term "vulnerability" differs between the disaster risk and the climate change community. The UN-ISDR's definition of vulnerability – "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" – clearly stresses that vulnerability is a context- and hazard-dependant factor which contributes to risk (ISDR, 2009). A risk assessment is mainly based on past events, informed by statistics and consists of the elements shown in Figure 11.1.

Integrative approaches for assessing hazards in their spatial context ("hazards of place") have been developed by geographers since the 1970s

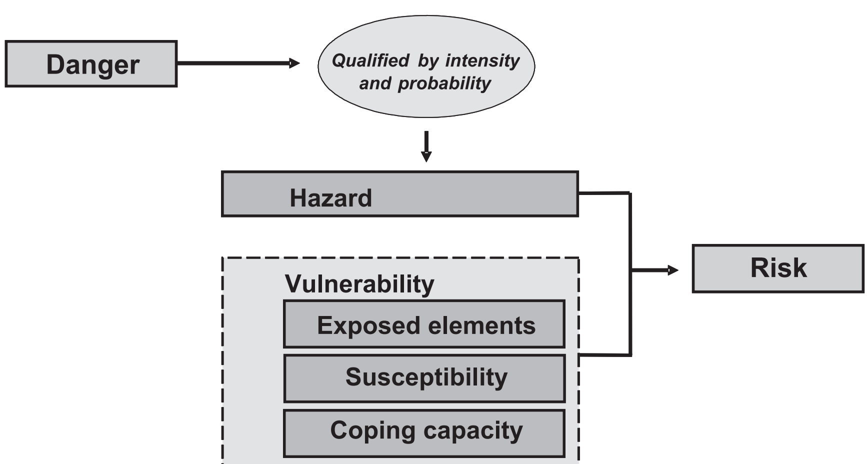


Figure 11.1 Elements of risk
Source: Author.

(Hewitt and Burton, 1971; Cutter and Solecki, 1989). Further methodological elaborations on this subject have rarely been attempted, as Cutter (1996) points out. Especially in Europe, a multihazard approach has not been used in spatial planning for many years. Although there is a tradition of spatial planning research in the context of single hazards (coastal flooding, river flooding, earthquakes, nuclear power plants), a synthetic consideration of spatially relevant hazards has only recently been addressed by a few authors (Egli, 1996; Burby, 1998; Godschalk et al., 1999, Greiving, 2002; Fleischhauer, 2004; Greiving et al., 2006). One reason for this recent change of perception is the realization that risk potential is increasing and that it is not sufficient to restrict risk policies only to the response phase of the emergency management cycle. Thus the mitigation of hazards is essential for promoting sustainable development, but appropriate spatial planning tools still have to be developed. Consequently, a methodology for a spatial risk assessment has to take into account the following criteria in order to meet the required goals: (1) a multihazard perspective, (2) a spatial perspective and (3) an integration of risk components (hazards and vulnerability) throughout the disaster management cycle (see also European Commission, 2009b).

In contrast to the disaster risk community, the climate change community defines vulnerability as the final outcome of the assessment:

> Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC, 2007)

A climate change vulnerability assessment is about changes in climatic stimuli which, together with the sensitivity of the exposed elements, assess the impact of climate change. The assessment is informed by projections about possible future climatic conditions. The vulnerability as final outcome is then the product of the impact and the capacity of a system to adapt to these changes, as shown by Figure 11.2.

In the following, similarities as well as differences in the methodological framework of Europe's regions will be discussed as well as the results in terms of patterns of risk and vulnerability.

A multi-risk assessment of Europe's regions

The approach was developed at the Institute of Spatial Planning, University of Dortmund (IRPUD) and first applied at the regional level, assessing

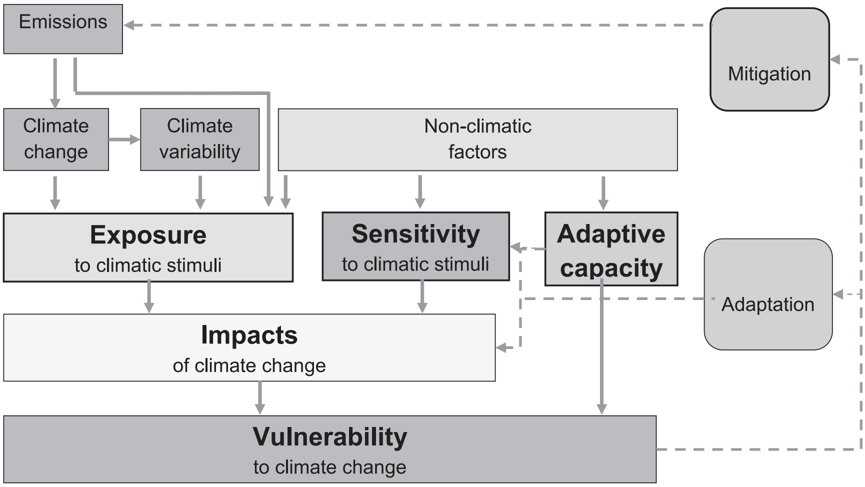


Figure 11.2 Climate Change Vulnerability Assessment
Source: Own figure based on Füssel & Klein (2006).

the integrated risk potentials of the approximately 1,500 NUTS-3 regions of the enlarged European Union (EU-27+2) (Schmidt-Thomé, 2006). In principle, however, the methodology itself can be applied at any geographical level and for any hazard and risk-related purpose (see Batista et al., 2004). Nonetheless, scales are always a challenge for risk assessments (Fekete et al., 2010) in that the chosen indicators are often scale-dependent.

This risk assessment approach tries to determine the total risk of a sub-national region. This means aggregating all relevant risks (from earthquakes, floods, etc.) to assess the integrated risk potential. The approach includes both natural and technological hazards but excludes risks with no real spatial underpinning (for example, epidemics). Hence it is an integrated risk assessment of spatially relevant hazards.

Structure and methodology

The Integrated Risk Assessment of Multihazards comprises four elements:

- Hazard maps:
  For each spatially relevant hazard a separate hazard map is produced showing in which regions and with which intensity this hazard occurs.

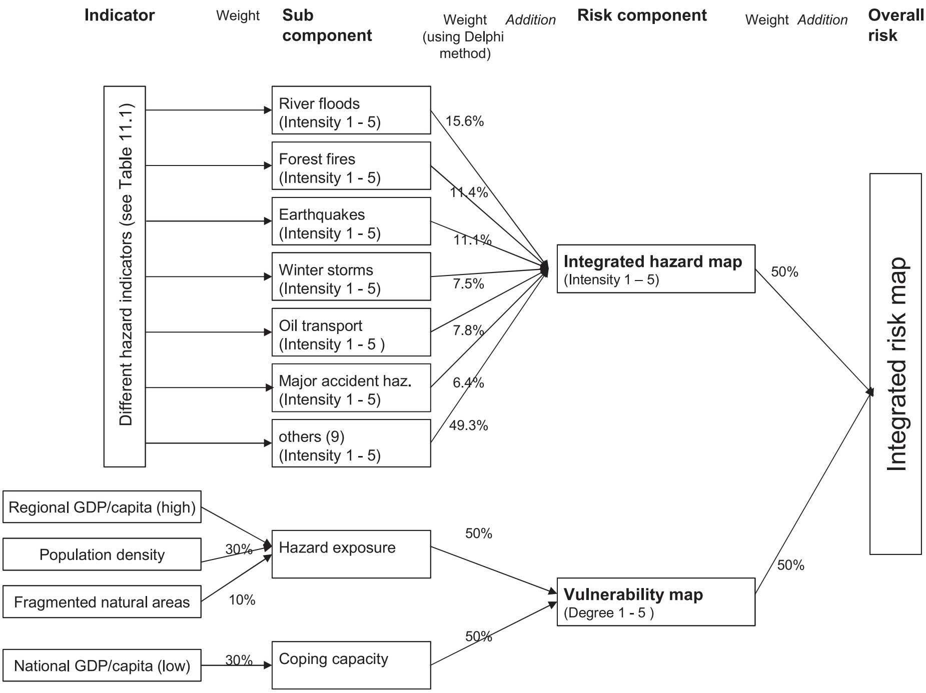


Figure 11.3 Calculation of the Integrated Risk Index (IRI)
Source: Author.

- Integrated hazard map:
  The information on all individual hazards is integrated in one map showing the combined overall hazards potential for each region.
- Vulnerability map:
  Information on the hazard exposure, as well as coping capacity in regard to potential hazards, is combined to create a map showing the overall vulnerability of each region.
- Integrated risk map:
  The information from the integrated hazard map and the integrated vulnerability map are combined, producing a map that shows the integrated risk to each region.

Figure 11.3 explains how risk was calculated.

Hazard maps

Hazard maps show where and with what intensity individual hazards occur. These maps do not yet contain any information on regional vulnerability. Thus they are merely hazard maps and not risk maps. The intensity of a hazard is determined on the basis of data on, for example, a hazard's frequency and magnitude of occurrence. These differ due to the specific characteristics of each hazard, making it impossible to define or derive a single classification that is valid for all types of hazard. Therefore the intensity of each hazard is classified separately on an ordinal scale using five relative hazard intensity classes (see Figure 11.4). This relative scale provides a way around the seemingly insurmountable differences in assessing risks between the various scientific disciplines involved, the main obstacle to integrated risk assessment. In addition, this relative scale allows the use of different hazard-related data regarding several spatially relevant hazards. Table 11.1 gives an example of indicators that have been used in the EU-27+2 study (Schmidt-Thomé, 2006). The table also indicates the relative importance of each hazard, generated from the experts' opinion, based on the Delphi method.

Integrated hazard maps

In a next step the individual hazard maps are aggregated into one integrated hazard map by adding together all single hazard intensities.[1] Mathematically, this is possible and easy to do because the intensities of all hazards are classified using five ordinal classes. For seven common hazards the range of values therefore lies between 15 and 75 (15 hazards) which have to be converted to an overall hazard intensity of 1 to 5 (see Figure 11.4). More problematic is the question of whether all hazards should be aggregated with equal or differing weights. Such weighting of hazards implies normative decisions, which of course have a crucial impact on the results of the integrated hazard values. Different weighting schemes can be justified, depending, for example, on recent disaster experiences and thus on a perception of heightened hazard. It is therefore proposed that the researchers involved and/or major stakeholders of the regions for which the risk assessment is conducted engage in a so-called Delphi process to assign different weights to the different hazards. The Delphi method, developed by Helmer (1966) has become widely accepted by a broad range of institutions (see Turoff and Linstone, 1975; Cooke, 1991). The Delphi Method is based on a structured process for collecting and synthesizing knowledge from a group of experts through iterative and anonymous investigation of opinions by means of questionnaires accompanied by controlled opinion feedback. After several rounds of assigning weights, the individual scores are finally aggregated to achieve collective weights for all hazards (see Table 11.1). On this basis the integration of all hazards and the production of an integrated hazard map can be achieved. For that purpose, the single range of hazard intensity (1–5) is multiplied by the Delphi weighting of a certain hazard.

Vulnerability maps

Another major component of a risk assessment is assessing a region's vulnerability to hazards. Regional vulnerability is determined by evaluating hazard exposure and coping capacity (see Figure 11.1). For both hazard exposure and coping capacity a set of indicators was selected. These indicators are used to measure vulnerability at the European level and they are not necessarily applicable on a regional scale or in developing countries. The following set of indicators was used in the hazards project:

Hazard exposure: The indicators for hazard exposure of an area's infrastructure, industrial facilities, production capacity and residential buildings are measured by the regional GDP per capita and the area's population density stands for the probable injury to people. Finally, the fragmentation of natural areas is used as an indicator for ecological vulnerability.

Coping capacity: In contrast to hazard exposure, coping capacity reflects the response potential of an area's population. While the vulnerability of an area is defined by its population density (the maximum number of people affected by a disaster), the coping capacity is measured by the national GDP/capita, since in disaster situations the whole nation is willing to deal or cope with the consequences. Thus coping capacity reflects the financial, socio-cultural and institutional potential of an area's inhabitants to prepare against and respond to hazards adequately.

As depicted in Figure 11.2, these components of vulnerability need to be aggregated to create an integrated vulnerability index. Instead of weighting all components equally, the three main components are each weighted at 30 per cent and the fragmented natural areas at 10 per cent, following a plausibility test of different weightings, made by the ESPON project team. However, this weighting process involves a normative decision and may therefore be open to other opinions. Each vulnerability component is classified using five ordinal classes, thus facilitating the integration of the economic and social vulnerability to one vulnerability index.

Integrated risk maps

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

For the task of combining vulnerability and hazard potential a 5×5 matrix has been used (see Figure 11.4). The values of a region's hazard

Overall hazard intensity \ Degree of vulnerability	1	2	3	4	5
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10

Figure 11.4 Integrated risk matrix
Source: Schmidt-Thomé (2005), p. 85.

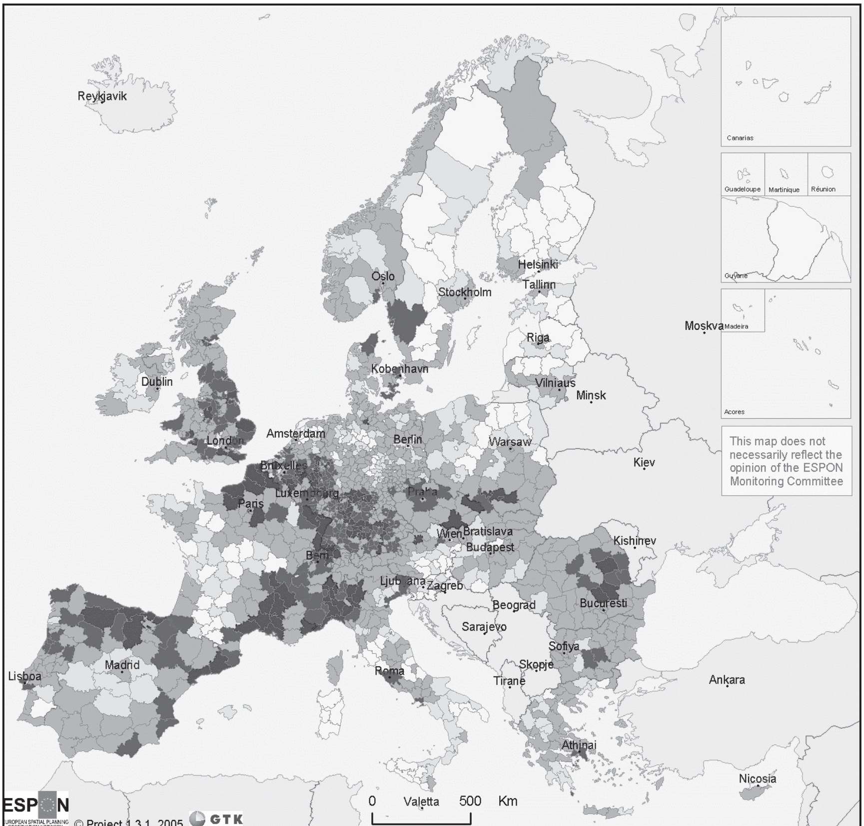
intensity and degree of vulnerability are added together to produce the region's integrated risk value. This aggregation procedure yields nine risk classes. The matrix shows that regions in one risk class might have the same overall risk value, but the composition of their risks may be different. For example, risk class six may be reached due to high vulnerability or due to high hazard intensity, or because of medium values for both items. Only after determining the risk class for each region under study can an integrated risk map be produced.

Results

In the following section, key results of the EU 27+2 application are presented. The aggregated hazard map shown in Figure 11.5(c) was generated from the 15 single-hazard maps.

The aggregated hazard map indicates that the greatest hazard potentials are found in parts of Southern, Western, Central and Eastern Europe. Some hotspots are located outside of this area, such as in central Italy and parts of southern Scandinavia. Only a few large areas have a very low aggregated hazard, mainly in Scandinavia, the Baltic States and south-central France. The map shows that the central parts of Europe tend to be more affected by hazards than the peripheral regions. The pattern is different when comparing urban with rural regions. Figure 11.6(c) indicates the vulnerability of different parts of the EU 27+2.

The integrated vulnerability map shows several patterns over the EU 27+2 area. Vulnerability tends to increase from west to east because of a



Hazard classification

- 0.00-0.1 fractile
- 0.10-0.25 fractile
- 0.25-0.75 fractile
- 0.75-0.90 fractile
- 0.90-1.00 fractile
- Non ESPON space

This preliminary map shows the aggregated hazard typology based on the single hazard indicators. The 15 hazard indicators are:
Large flood events 1987-2002
Seismic activity (peak ground acceleration)
Known volcanic eruptions
Occurence of winter and tropical storms
Occurence of storm surges
Occurence of tsunamis
Occurance of landslides
Occurance of avalanches
Occurrence of large droughts
Occurence of forest fires
Extreme temperatures
Number of chemical plants
Location of nuclear power plants
Volume of oil production and transport related activities
Air traffic hazard

Every indicator gives the value from 1 to 5. For the class "No data" value is 0.
All the indicator weights are based on expert opinion (Delphi method questionary).
The sum of 15 different weighted indicators are classified on base of fractiles.

Figure 11.5 Aggregated hazard map of Europe (NUTS 3)
Source: Schmidt-Thomé, 2005: 75.

Please see page 670 for a colour version of this figure.

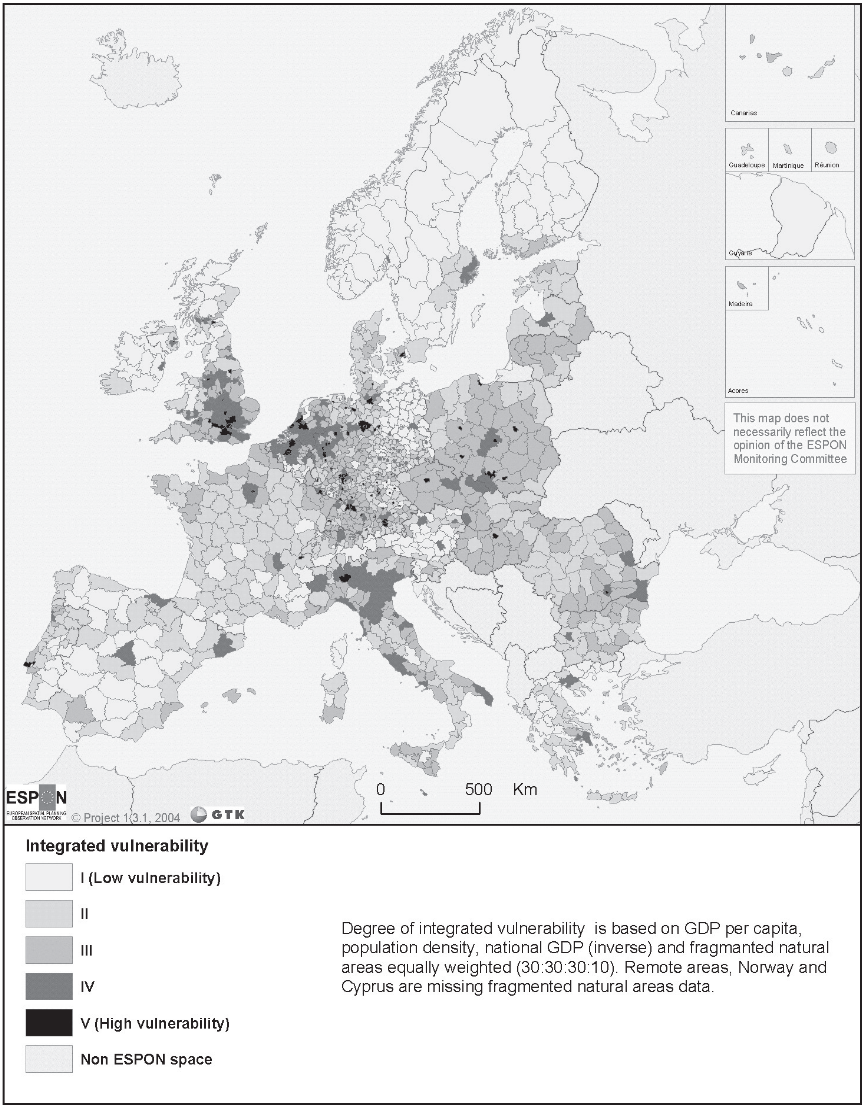


Figure 11.6 Degree of integrated vulnerability in Europe (NUTS 3)
Source: Schmidt-Thomé, 2005: 85

Please see page 671 for a colour version of this figure.

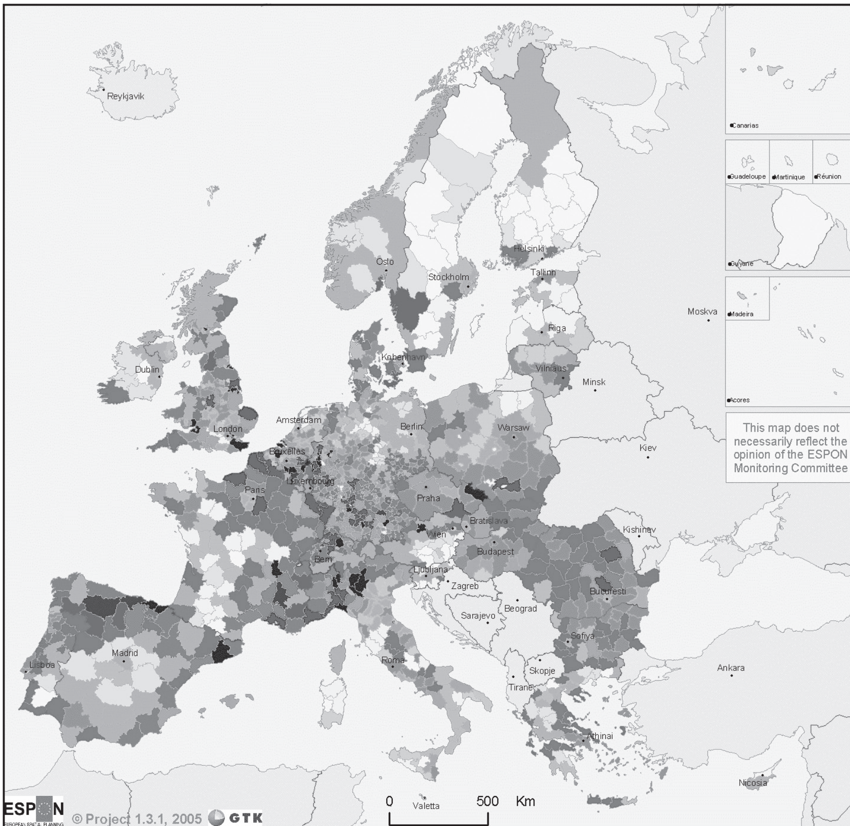
lower coping capacity, as based on the lower GDP/capita. Less fragmented areas have a lower vulnerability because the natural environment in larger undisturbed areas can recover faster than that in smaller areas. Densely populated areas with a high GDP per capita show the highest vulnerability, as the total number of people and assets per square kilometre poses a risk of higher vulnerability and greater total damage in case of a disaster. The variance in vulnerability between Western and Eastern European countries is because of lower coping capacity in the latter. In consequence, the influence of the existing differences in population density and GDP per capita on the integrated vulnerability in Western European countries is much greater than in Eastern Europe. However, inside the single member states the more populated central urban areas are more vulnerable due to their higher income in combination with higher population density. Figure 11.7(c) shows an aggregated risk map based on the aggregated hazard map (50 per cent) and the integrated vulnerability map (50 per cent).

The aggregated risk map shows a similar pattern to the aggregated hazard map. The so-called pentagon area (which covers southern UK, Benelux, the north-east of France and western Germany – the economic heart of the European Union) displays the highest agglomeration of high risk, while the largest parts with low risk are found in Northern Europe's peripheral regions. In general, urban areas seem to be more at risk than rural areas due to the influence of the vulnerability component on the overall risk. This tendency is particularly visible if each member state is analysed separately. In so doing, the influence of the national GDP/capita (which leads, for example, to a higher vulnerability in eastern Europe) can be excluded.

Extending the focus to climate change vulnerability in Europe's regions

The following section is about vulnerability to climate change. The United Nations Framework Convention on Climate Change provides the following definition: "Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

The EU White Paper "Adapting to Climate Change: Towards a European Framework for Action" (European Commission, 2009a: 4) explicitly relates to spatial planning and territorial development, respectively:



Typology of the regions

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

Figure 11.7 Aggregated hazard risk in Europe (NUTS 3)
Source: Schmidt-Thomé (2005), p. 88

Please see page 672 for a colour version of this figure.

> Extreme climate events cause huge economic and social impacts. Infrastructure (buildings, transport, energy and water supply) is affected, posing a specific threat to densely populated areas. The situation could be exacerbated by the rise in sea level. A more strategic and long-term approach to spatial planning will be necessary, both on land and on marine areas, including in transport, regional development, industry, tourism and energy policies.

The presented results of the ESPON Climate project are uniquely based on a clear *territorial* perspective. Most of the existing vulnerability studies have a clear *sectoral* focus, addressing very specific potential impacts of climate change on single elements of a particular sector (see for example, Zebisch et al., 2005; Carter, 2007), while the 2008 EEA report on an indicator-based assessment looks at sectors and thus cannot provide an integrated (regional) view (EEA, 2008). Other studies like the *Stern Review* focus only on a limited group of sectors (Stern, 2006). Furthermore, most studies lack a clear territorial pan-European focus. Specialized research is sensible and necessary, but the findings of specialized studies are not easily transferable between sectors or between regions. Due to methodological differences, findings may not even be comparable.

This is particularly troublesome in an international policy context like the European Union that calls for an integrative approach when the consequences of climate change on the competiveness of Europe as a whole, or on the territorial cohesion of European regions, need to be determined. For example, how much support may northern Finland vis-à-vis the Algarve require to adapt to climate change impacts? Thus one must go beyond mere local, regional, national and sectoral analyses and adopt a territorially comprehensive and thematically integrated approach. For that purpose, a new typology of regions has to be developed, characterized by similarities regarding climatic stimuli as well as their sensitivity and adaptive capacity. The chosen interdisciplinary, comprehensive and pan-European approach is based on the conviction that different types of regions are differently vulnerable and require different, tailor-made mitigation and adaptation measures to cope with climate change. Conversely, climate change may not only lead to negative impacts but also hold various opportunities.

Structure and methodology of the climate change vulnerability assessment

Exposure to climatic stimuli represents the nature and degree to which a system is exposed to climatic variations. The exposure of a system to climatic stimuli depends on the level of global climate change and, due to spatial heterogeneity of anthropogenic climate change, on the system's location (Füssel and Klein, 2006: 313). Thus, the assessment is very much dependent on projections to gain evidence on the spatiotemporal distribution and variability of developments. For the ESPON climate project these projections are based on the Intergovernmental Panel on Climate Change (IPCC) scenarios published in 2000 and employed within the fourth IPCC assessment report in 2007. Figure 11.8 illustrates the methodological concept in detail.

The exposure analysis made use of existing projections on climate change and climate variability from the CCLM climate model, whose results have been used, among others, by the 4th IPCC assessment report on climate change (Greiving et al., 2011). A cluster analysis was performed to yield climate change exposure regions, i.e. regions that are exposed in a similar way to climate change. Thus each of these regional clusters has a distinct profile of relevant climate stimuli changes, based on the estimated development trends of eight climate variables from the CCLM model between the time periods 1961–1990 to 2071–2100 under the A1B scenario (averaged model runs). It has been carried out for those cells that contain values for all indicators (i.e. land cells, 2,271 cells in total). A cluster analysis reduces the dimensions of a dataset by allocating the objects into groups in such a way that the objects within these groups are more similar to each other than to objects in different groups. The cluster mechanisms can be distinguished in hierarchical, partitioning and density-based methods (Handl et al., 2005). In our analysis the first two methods have been combined.

In addition to direct climatic stimuli, two important triggered effects of changes in temperature and precipitation patterns were considered for the impact assessment: sea-level rise and river flooding. What matters here are changes in areas prone to coastal storm surges and prone to river floods (in regard to the 100-year event). The data for river floods came from the LISFLODD model (recalculation for A1B scenario using all Ensemble models) and those for sea-level rise from the DIVA project.

Subsequently, a sensitivity assessment was conducted that determines each region's sensitivity to possible climate changes. These regional sensitivities differ according to each region's physical, environmental, social, economic and cultural characteristics. For each of these sensitivity dimensions several sensitivity indicators have been used.

Exposure and sensitivity are then combined to determine the potential impacts of climate change. Obviously some regions would be affected more severely, either because they are more exposed to climatic changes or because they are more sensitive to these changes. Thus, for determining the potential impact both exposure and sensitivity values of a region have to be aggregated and transformed into a system of five classes. The

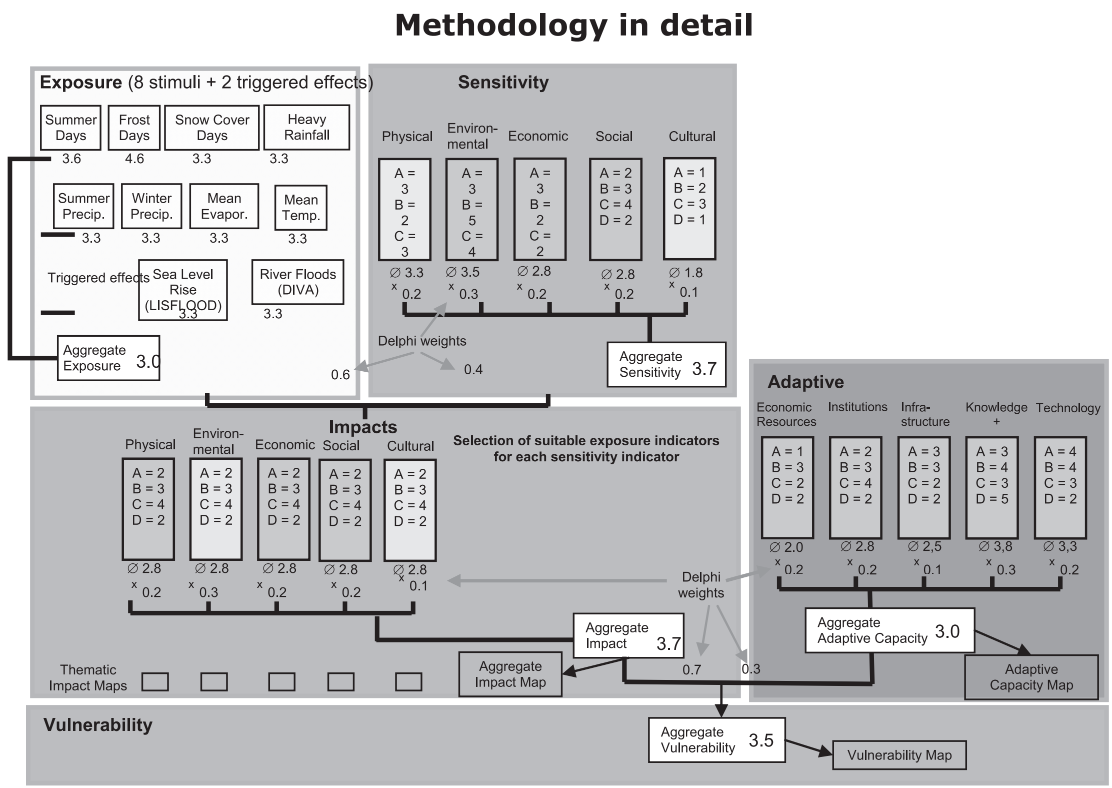


Figure 11.8 Climate change vulnerability assessment in detail
Source: Greiving et al. (2011).

two scores are then juxtaposed in a data matrix that will yield an impact score for each region.

A third major component of the project's research design is adaptive capacity in regard to climate change, i.e. the economic, socio-cultural, institutional and technological ability of a region to adapt to the impacts of a changing regional climate. High adaptive capacity counterbalances sensitivity, thus reducing vulnerability. Indicators for the various aspects of adaptive capacity will be assessed and combined in a similar procedure as that for climate change sensitivity. A combined adaptive capacity measure can be developed as a generic determinant for each region. Adaptive capacity is structured into awareness, ability and action (Schröder et al., 2005).

Thus, to arrive at the overall vulnerability of a region to climate change, only the impacts and the adaptive capacity to climate change will be combined. Hence a region with a high climate change impact may still be moderately vulnerable if it is well prepared for the anticipated climate changes.

Results

The ESPON Climate project is still a work in progress. Thus, only preliminary results can be shown here. A main research question was about new typologies for regions that are characterized by similar patterns in exposure, sensitivity, adaptive capacity and vulnerability. A first typology of climate change regions was developed by means of cluster analysis.

The analysis of European patterns of climate change has led to a typology of climate change regions derived from a cluster analysis. Based on the exposure indicators, five types of region, according to their climate change profile, have been identified. The most prominent climate change characteristics in each of these regions are summarized in Table 11.1. This table shows that every chosen stimulus is important for describing the main characteristics of at least one type of region.

A strong increase in annual mean temperature is observable for three clusters: namely, Northern Europe, South-Central Europe and the Mediterranean region. Strong decreases in the number of frost days predominantly characterize the clusters of Northern-Central Europe, Northern Europe and South-Central Europe, whereas strong increases in the annual mean number of summer days is projected for the clusters of South-Central Europe and the Mediterranean region. For change in precipitation in winter months, the Northern Europe cluster shows particularly strong increases, while for summer months the most significant changes in terms of strong decrease can be observed in South-Central Europe and the

Table 11.1 Different types of regions characterized by climate change based on cluster analysis

Cluster/Stimuli	Northern-Central Europe	North-Western Europe	Northern Europe	South-Central Europe	Mediterranean region
Change in annual mean temperature	+	+	++	++	++
Decrease in number of frost days	––	–	––	––	–
Change in annual mean number of summer days	+	+	○	++	++
Relative change in annual mean precipitation in winter months	+	+	++	○	–
Relative change in annual mean precipitation in summer months	–	–	○	––	––
Change in annual mean number of days with heavy rainfall	○	+	+	○	–
Relative change in annual mean evaporation	+	○	+	○	–
Change in annual mean number of days with snow cover CDSC	–	○	––	○	○

Key:
++ Strong increase
+ Increase
○ insignificant stimulus for the characterisation of the cluster
– Decrease
–– Strong decrease
Source: Greiving et al. (2011).

Mediterranean region clusters. The variables heavy rainfall and evaporation do not show very strong changes for any of the clusters, but days of snow cover are projected to decrease strongly in the Northern-Central Europe cluster.

The resulting spatial patterns divide the ESPON territory into five regions. The results seem plausible as the main topographic characteristics are well covered (such as Alps, Carpathians, Balkan, Pyrenees, Apennines) and underline the validity of the derived typology at least from a pan-European perspective (see Figure 11.9(c)).

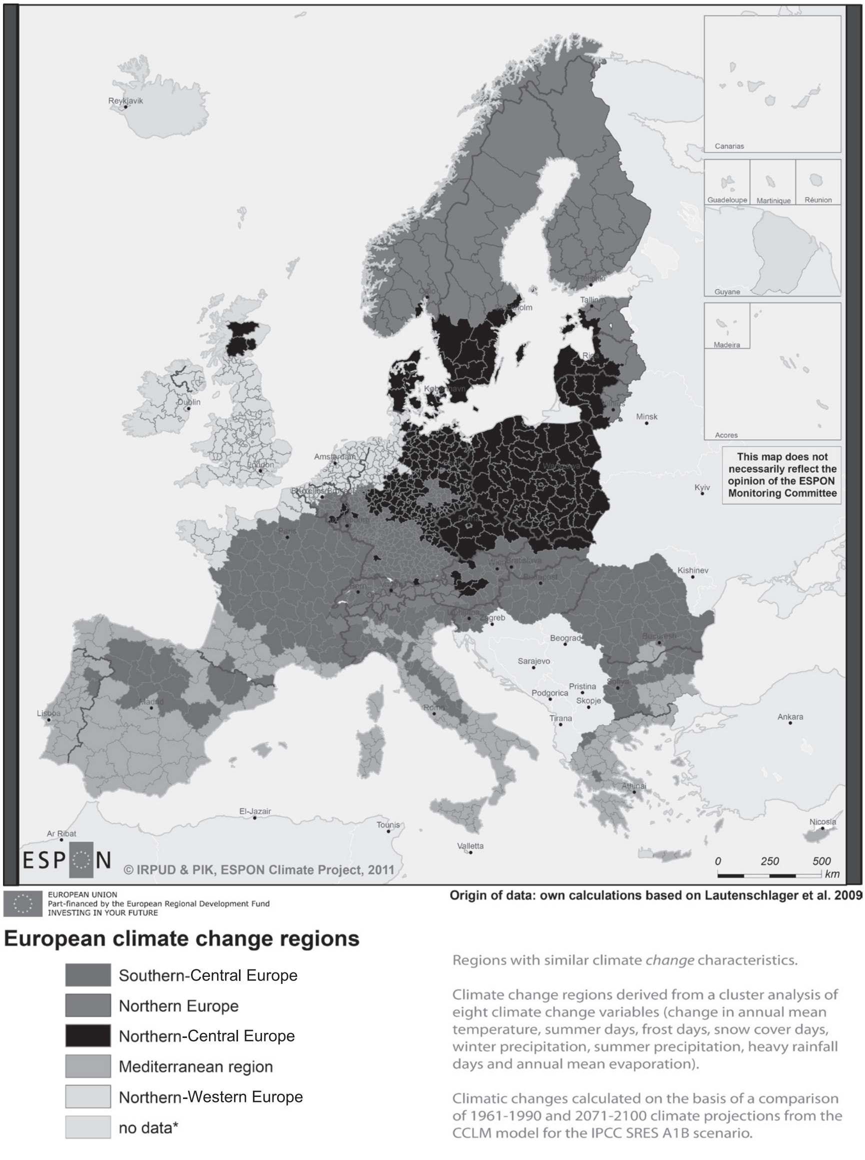


Figure 11.9 Map of the climate change typology
Source: Greiving et al. (2011).

Please see page 673 for a colour version of this figure.

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

- Physical sensitivity;
- Social sensitivity;
- Economic sensitivity;
- Environmental sensitivity;
- Cultural sensitivity.

The IPCC (2007) defines impact as "consequences of climate change on natural and human systems". The pattern of impacts of climate change on Europe's regions should be seen as evidence for adaptation needs: the more the potential impacts increase, the more important is adaptation in order to avoid negative consequences on the economy, population, physical assets, cultural heritage and the environment.

The aggregate potential impact (which encompasses the above mentioned five dimensions) on Europe's regions differs considerably: hot spots are mostly in the south of Europe – i.e. the big agglomeration areas and summer tourist resorts at the coastline. However, other specific types of region (mountains) are particularly impacted but partly for other reasons (sea-level rise, economic dependency from summer and or winter tourism). There seems to be a medium increase in some areas in northern Scandinavia. This results mainly from the sensitivity of the environment and flood prone infrastructure. All in all, two of the five existing biogeographical regions (EEA 2011) which relate to the recent climate come clearly out of this map: North-Western Europe and the Mediterranean region.

Adaptive capacity is defined as the "ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and technologies" (IPCC, 2007). The ESPON Climate project studied adaptive capacity by distinguishing between awareness, ability and action (Schröter et al., 2005). All in all, the Northern European countries have higher capacity than most of the Southern European countries. Also, Eastern European countries have lower capacity than Western or Northern European countries.

The potential vulnerability of Europe's regions to climate change (shown in Figure 11.10(c)) indicates a clear south–north gradient because the considerable adaptive capacity of Scandinavia and Western European countries lowers the potential impact. Those countries which may expect a medium to high increase in impact seem to be less able to adapt compared to those for which the severity of the problem is less visible. This observation is also shown by other recent studies on the status of national adaptation strategies (Swart et al., 2009; Greiving and Fleischhauer, 2010). This scenario for the future may contradict territorial cohesion – one of the main policy goals of the European Union (EC, 2010) – since climate change is a likely trigger for deepening the existing socio-economic imbalances between the core of Europe and its southern and south-eastern periphery.

Function and target group

Application to a Europe-wide assessment, using NUTS 3 regions in the EU 27+2 as the spatial analytic unit, provides information at a fine resolution for the EU as well as for planning authorities at provincial and local levels, but at present, the European Commission is the main target group for the information that has been generated. Risk management as well as adaptation to climate change should be made an integral and explicit part of EU policy. This calls for better coordination of policy measures at all spatial scales. Based on such assessments of Europe's regions, the EC's Structural Funds could be used for risk management, using criteria relevant to risk and vulnerability to identify regions that are eligible for funding, something that is precisely an objective of European adaptation policy (see also European Commission, 2009a). Additionally, planning authorities at the provincial and local levels might use the information in the assessment to compare their specific situation with other regions.

Open questions and limitations

While this aggregation procedure has the advantage of being transparent and easy to perform, it does not take into account the interrelations between hazards (exacerbating or ameliorating effects). Unfortunately, very little scientific work has been done so far on the effects of such cascading effects. For the climate change community, the same applies to cross-sectoral issues and, more importantly, to adaptation policies (see Greiving and Fleischhauer, 2010).

Developing an integrated risk index based on relative hazard intensities can be seen as a way beyond scientific approaches from the several involved disciplines, based on different risk assessment methodologies of single hazards. However, some methodological problems still remain, particularly the weighting problem, future parameter changes and the limits of measurability. The definition of risk used determines how risk policy is carried out. Moreover, defining risk is an expression of power and underlines the normative impetus of any risk assessment. Slovic (1999) therefore argues that whoever controls the definition of risk, and therefore the weighting of the different parameters when assessing it, controls risk policy.

Here, the Delphi method was used to weigh hazards and vulnerability indicators on a regional level in both projects. Although the panel which represents policymakers from all EU member states is dealing with uncertainty, each event also generates knowledge and is an impulse for reconsideration in the light of that knowledge. Thus, the weighting results generated by the Delphi method may be seen as snapshots that would need regular updating in order to take into account extreme events as well as new knowledge about the future climate situation.

Changes of parameters that shape risk in the future: The index presented in this chapter and used in the ESPON hazards project is based only on past data. Of course, the ESPON Climate vulnerability assessment is based on projections about the future climate. However, data considering sensitivity as well as adaptive capacity represent the current situation, although they contribute to an assessment for the time period 2071–2100. To acknowledge future changes, a dynamic component, aiming at monitoring certain parameters (changes in population density and GDP/capita and changes in hazard intensity) has to be integrated when monitoring spatially relevant trends. Thus, scenarios have to be created for identifying possible future conditions.

Problem of data quality: When the methodology is applied, data for specific hazards often differ widely. For some hazards, only the number of historic events will be available while for others detailed loss data will be available. The methodology indicates that hazard intensities have little comparability. On a practical level, however, the methodology also shows a way out of this problem by transferring all data on hazard intensities into a relative scale. An ideal set of data would consist of reliable information about probable annual losses (PAL for frequent hazardous events) and probable maximum losses (PML for very unlikely events) (see Cardona in this volume).

Limits of measurability: In the fields of coping capacity and adaptive capacity, the search for appropriate indicators and data will soon reveal the limits of measurability. As the methodology has shown, some aspects can be quantified, while others that might also be important for assessing coping as well as adaptive capacities cannot be measured quantitatively. These include social cohesion and organizational structures.

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

Problem of scale: Existing intra-regional differences in disaster risk as well as climate change vulnerability are disregarded by pan-European assessments. This is mainly due to the normalization of data: the existing differences are quite small compared with the differences across the whole continent. This clearly shows the scale-dependency of any risk and vulnerability assessment.

Outlook

As climate change impacts on European regions, climate change and related disasters pose multi-dimensional, multi-causal and multi-layered risks to regions and their populations. Global risk trends indicate that hazard is changing due to climate change, urbanization and environmental degradation (ISDR, 2009: 53). The Fourth IPCC Assessment Report (IPCC, 2007: 361) concluded that vulnerability of settlements tends to be a function mainly of three factors: location (coastal and riverine areas most at risk), economy (those dependent on weather-related sectors at most risk) and size (larger settlements at greater aggregate risk but having more resources for impact prevention and adaptation). This statement was empirically proved by the pan-European vulnerability assessment of the ESPON Climate project which is clearly visible when looking at the final vulnerability map: coastal as well as mountain regions were identified as hot spots but also areas in the south and east of Europe which are dependent on weather-related sectors like tourism and agriculture (see figure 11.10(c)). However, the ESPON Hazards risk assessment came to similar conclusions for disaster risks.

Thus, present information allows assessing disaster risk as well as climate change vulnerability. The maps shown here indicate that vulnerability factors and assessments are key components when determining action for risk reduction and climate change adaptation. It should also be remembered that poorly governed cities are also more vulnerable than well-managed ones (ISDR, 2009: 9). Thus, more attention should be paid to institutional vulnerability (see for example, ECLAC/IDB, 2000). Political and institutional vulnerability, understood as institutional weakness as a whole, and more specifically any weaknesses in the democratic system,

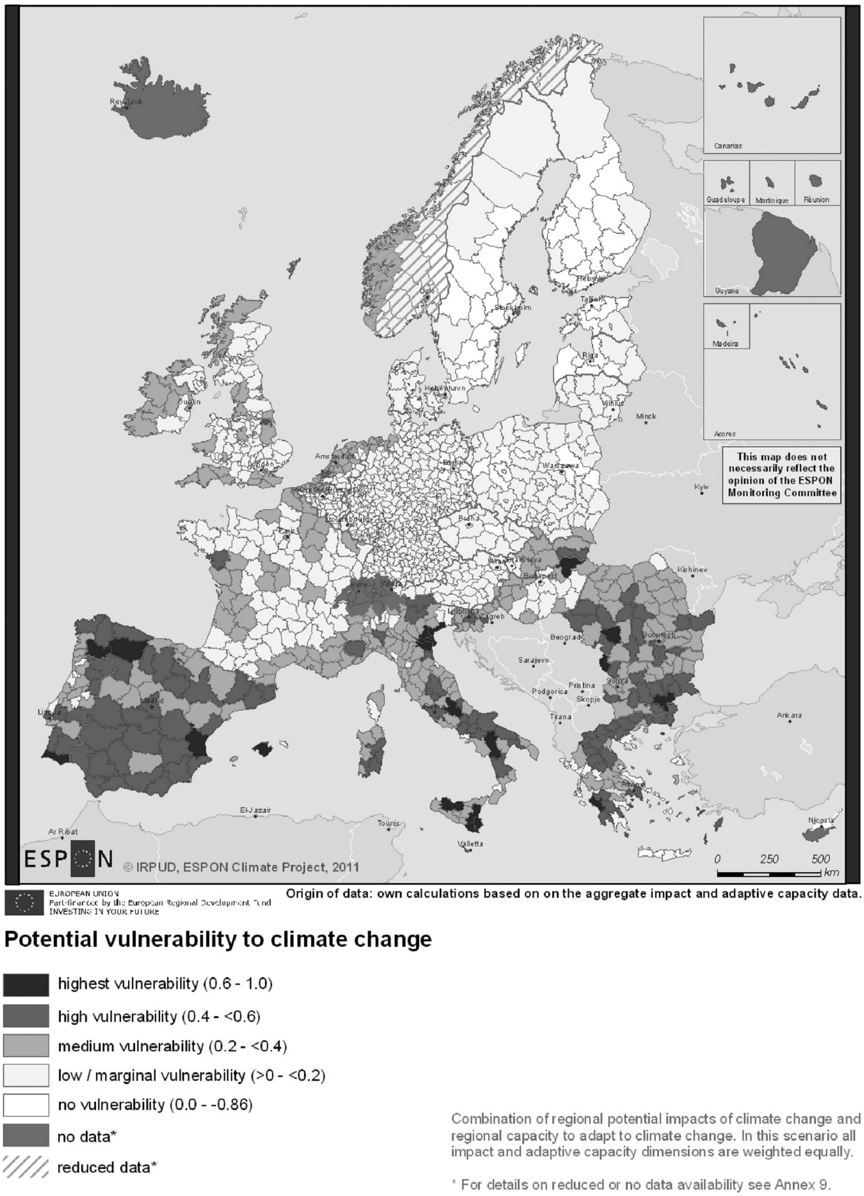


Figure 11.10 Potential vulnerability of European regions to climate change
Source: Greiving et al. (2011).

Please see page 674 for a colour version of this figure.

have often been seen as one of the major causes of vulnerability where natural phenomena are concerned. The inability of traditional government systems to involve all relevant stakeholders from the beginning in decision-making and to communicate any risks has negative consequences for the efficiency of public policies, the legitimacy of government action and participation by citizens and the private sector in national efforts. There is a close relationship between the need to reduce vulnerability and the increase in the organizational and participatory capacity of communities, the private sector and government. In this context, the emerging concept of risk governance should be highlighted (IRGC, 2005).

The growth of urban population, demographic shifts to more storm-prone locations and the growth of wealth have collectively made cities more vulnerable to climate extremes. Another impact affecting cities is responsible for higher mean summer temperatures and the extension of the length of the warm (summer) season, cumulating in heat waves that pose threats mainly to densely built-up city centres (so-called heat island effect). This phenomenon, which can be observed in various European regions, mainly in the south, implies economic risks related to unexpected consumption of energy to run air-conditioning units. To conclude, the aggregated risk map which came out of ESPON Hazards, as well as the aggregated vulnerability map from ESPON Climate, show similar spatial patterns: high risk and vulnerability is characteristic of agglomeration areas.

Multidimensionality and multi-causal chain reactions are a characteristic dimension of global climate change but also relevant for disaster risk. The interlocking nature of natural hazards and climate change is now generally recognized; the ESPON climate project considered changes in sea levels, storm surges and river flooding as indirect effects of climate change. However, all these phenomena are an integral part of a larger constellation of disaster risk, risks related to food (consumption) and energy insecurity, financial and economic instability, environmental degradation, disease and epidemics, conflict and extreme poverty (ISDR, 2009) and have been confirmed by both ESPON projects. Therefore, vulnerability can be seen as a systemic variable, describing the degree to which a system is susceptible to, and unable to cope with, any kind of threat.

Note

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

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12

The evolution of the Social Vulnerability Index (SoVI)

Susan L. Cutter and Daniel P. Morath

Introduction

The empirical exploration of vulnerability has emerged almost totally within the past decade. Despite the abundance of work (discussed comprehensively in previous chapters) in the development of conceptual frameworks of vulnerability, systematic measurement of who and what are vulnerable has lagged behind the conceptual framing. Some of the reticence is due to issues of spatial scale (the unit we use to measure such entities as a city, a neighborhood, a census unit). Some is also due to the lack of data and inconsistencies and disagreements about the best methodological approach for such measurement. This chapter provides an overview of one approach to measure vulnerability empirically, the Social Vulnerability Index (SoVI). It also provides examples of its practical application for hazard assessment and disaster planning.

Conceptualizing vulnerability: The background

Scale is an important consideration in measuring risk and vulnerability (Birkmann 2006, 2007). The use of national-level indicators permits broad scale analyses to identify natural disaster hotspots – intersections of risk and vulnerable populations (Dilley et al., 2005; Dilley, 2006). Similarly, recent work on the national-level Disaster Risk Index (Peduzzi et al., 2009) monitors risk using population exposure, vulnerability and hazards

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

in order to map and compare countries. Such efforts are useful from an international policy perspective. However the definitions and drivers of vulnerability and indicators to measure them vary between industrialized and less-industrialized nations, especially where development pressures are inextricably linked to risk and vulnerability from local to global scales (Blaikie et al., 1994; Cardona, 2004). This development-oriented paradigm of risk and vulnerability provides another framework for vulnerability assessment – one that takes a more holistic approach to risk management (Carreño et al. 2007). Nevertheless, these national efforts lack context-specific accounting for fundamental differences between nations or sub-regions in their risk, exposure or vulnerability.

Combining themes from both the risk-hazard and political ecology perspectives of vulnerability research, Cutter (1996) proposed the Hazards of Place (HOP) model of vulnerability (Figure 12.1). The HOP model, built on Hewitt and Burton's concept of the hazardousness of place (1971), reaffirms that like damaging events, vulnerability is equally place-based and context-specific. The HOP model's contribution is its confluence of biophysical vulnerability and social vulnerability in the production of vulnerability at specific locales. Biophysical vulnerability is a function of hazard potential filtered through a geographic context (for example, elevation, distance), while social vulnerability is also produced from the hazard potential and filtered through a socio-economic context, or social fabric (for example, urban/rural; age distributions). Additionally, the model develops the potential feedback of place vulnerability in its reduction or enhancement of risk and mitigation that interact to produce the hazard potential in the first place. Although simplistic and exploratory in its presentation, the HOP model may be applied to multiple hazard events as they occur across many regions, over different time periods and at different spatial scales. The HOP model and its context-specific local orientation stand in stark contrast to the national-level indicators mentioned above, providing more of a place-based bottom-up approach to measuring vulnerability.

As a proof-of-concept, Cutter et al. (2000) operationalized the Hazards of Place (HOP) model to conduct a local-scale, empirical assessment of all-hazards vulnerability for the coastal county of Georgetown, South Carolina. In the case study, the representation of biophysical vulnerability used the geometry of hazard exposure zones (for example, flood plains, surge inundation zones, seismic zones) and historical hazard frequency. Social vulnerability was characterized using eight socio-economic indicators chosen deductively from the primary dimensions of social vulnerability found in the extant theoretical literature and the battery of contextual disaster case studies. These variables included: total population and total housing units (proxies of people, structures at risk); number of females, number of non-white residents, number of people under age

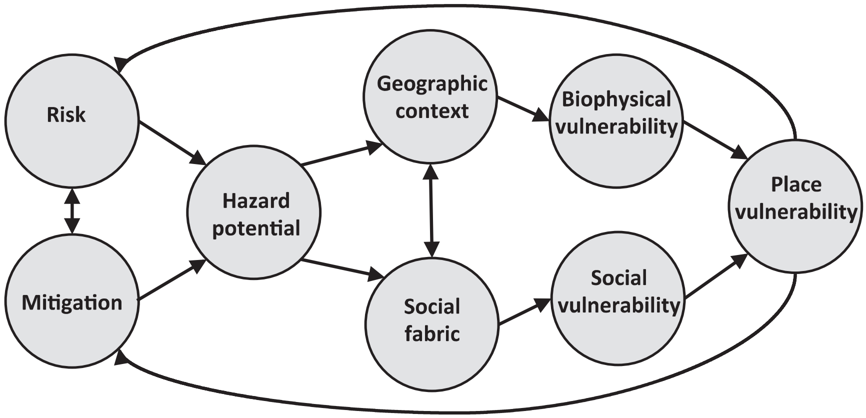

Figure 12.1 The Hazards of Place Model of Vulnerability (Cutter, 1996). Risk and mitigation interact to produce hazard potential, which is filtered through (1) sociospatial context (social fabric) to create social vulnerability and (2) geographic context to produce biophysical vulnerability. The interaction between biophysical and social vulnerability yields place vulnerability. Note the feedback of place vulnerability to risk and mitigation.

18 and number of people and over age 65 (proxies of differential access to resources); mean house value (proxy for wealth or poverty); and number of mobile homes (proxy for structural vulnerability). Combining these theoretical components of place revealed the vulnerability of people living inside hazard zones. The methodology developed for this research is an important benchmark for empirically measuring biophysical and social vulnerability in geographic terms, with a mapped visual representation. In this way, the specific drivers of community vulnerability were compared spatially within the study region. The case study demonstrated that the areas with greatest biophysical risk do not always spatially intersect the most socio-economically sensitive populations. The stratification of social space reflects a difference in potential social costs of hazards across the region and explains why portions of a county or community experience a hazard differently, despite their equal exposure. These findings are confirmed by other case studies from the disaster vulnerability literature. In post-Katrina New Orleans, for example, Finch et al. (2010) demonstrate that the underlying social vulnerability influenced the impact and rate of recovery; the latter also varies widely across flood-inundated neighborhoods as a result of socio-economic disparities. Similarly, Peacock and Girard (1997) illustrate the disproportionate losses, uneven insurance settlement and stunted recovery among minority communities affected by Hurricane Andrew.

The Georgetown case study provided a much-needed methodology for downscaling place vulnerability. However, the use of so few variables to capture social vulnerability was problematic as it did not account for some of the local nuances of marginalized and sensitive populations, such as female-headed households, ethnicity, occupation or education. This concern provided the impetus for developing a place-based, scale dependent, inductive approach for measuring social vulnerability, the Social Vulnerability Index (SoVI) (Cutter et al., 2003).

Development and construction

Throughout the hazards and disasters literature, there is a rich tradition of research focused on those particular social factors that affect a community's ability to prepare for, respond to and recover from disasters. Among the key indicators are social attributes such as socio-economic status, race and ethnicity, gender, age, employment and employment sector, housing tenure and special needs populations. These indicators are summarized by the Heinz Center (2000, 2002); Mason (2006); Mileti (1999); Morrow (1999); and the National Research Council (2006). Informed by the theoretical dimensions and empirical case studies discussed in the extant literature, Cutter et al. (2003) first deductively culled an exhaustive collection of 250 socio-economic and built-environment candidate variables describing social vulnerability from the 1990 Decennial Census. This long list of variables was reduced using a combination of statistical methods to decrease multicollinearity within the dataset, and resulted in a subset of 42 independent county-level variables for the entire United States. These were then normalized as either percentages, per capita or density measures (Cutter et al., 2003). In the construction of vulnerability measures, it is important to recall that social vulnerability is produced at the intersection of characteristics of sensitive population groups. It is not just the proportion of the residents that represents these large categories that is essential (elderly or minority ethnicity, for example) but also how age, ethnicity, gender and socio-economic status interact to produce socially vulnerable populations.

To capture the intersectionality of vulnerability dimensions among US counties, Cutter et al. (2003) implemented a composite index approach, using readily available US Census data. The construction of the index was based on the statistical procedure of principal components analysis (PCA). Using this approach, the initial set of 42 variables was further condensed to a smaller set of multidimensional components, in keeping with the multidimensional nature of vulnerability. To simplify the latent structure of the dimensions, and produce more independence between them, a varimax rotation was applied. Using the Kaiser Criterion for the extraction of factors (eigenvalues > 1), 11 independent components were produced, accounting for 76.4 per cent of the variance among all counties.

To describe the multidimensional components of vulnerability produced by the PCA, the individual variable loadings were examined. Using expert judgement combined with knowledge of the study region, the factors were named and a determination was made regarding the tendency of the composite factor to increase or decrease overall social vulnerability. To produce a measure of overall social vulnerability in each county, the component scores were summed, taking this cardinality into account. For example, where the factor indicated a potential to increase vulnerability (poverty, unemployment, minority status), the factor score was added. Alternatively, if the factor tended to decrease vulnerability (wealth, high housing value) the factor score was subtracted. In those rare instances where the factor both increased and decreased vulnerability (such as elderly loading positively and children loading negatively), an absolute value was used. As no a priori assumptions were made regarding the relative importance of each factor in defining a county's vulnerability, the additive model applied equal weighting in the absence of any theoretical or methodological justification for one component being *more representative* of vulnerability than another.

SoVI is a comparative assessment of the relative levels of vulnerability between places. High positive values indicate counties with elevated social vulnerability, while high negative values indicate lower social vulnerability. To visually interpret social vulnerability in the United States, Cutter et al. (2003) mapped the overall SoVI score based on standard deviations (Figure 12.2). Mapping vulnerability in this way illustrates the degree to which some places are more vulnerable than others, highlighting counties at the extremes of the distribution (i.e. high and low social vulnerability). The visualization of the SoVI scores highlights the comparative nature of the metric. Given the particular interest in outlying values, namely to identify those places with highest and lowest social vulnerability, classification by standard deviation provides an objective method for mapping the outliers based on the distribution of the data for each iteration of SoVI. It is important to note that this sum of scores represents a relative measure and cannot and should not be interpreted on an absolute scale. For example, you *can* deduce from the SoVI score that Place A, which has a SoVI score of 10, is more vulnerable than Place B, which has a SoVI score of 1. You *cannot* deduce, however, that Place A is 10 times more vulnerable than Place B.

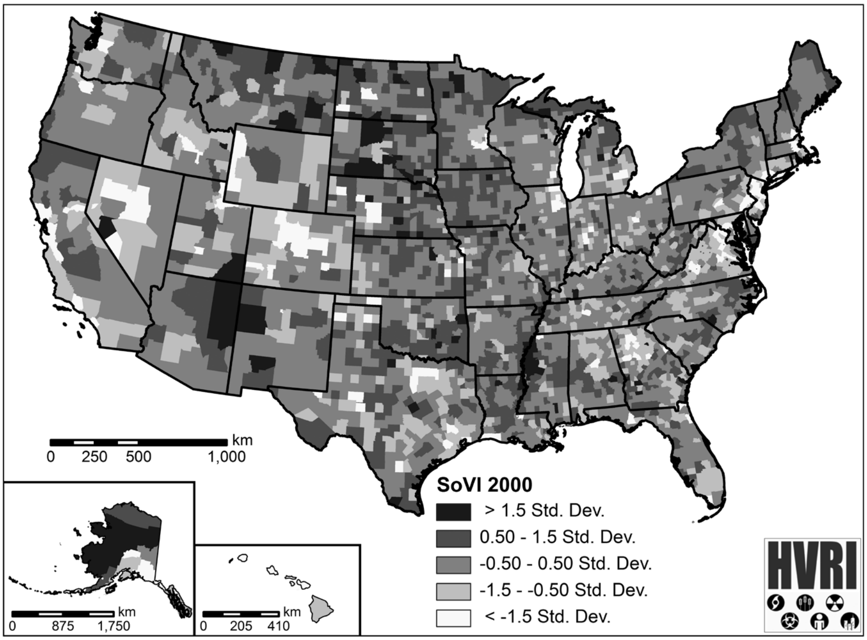

Figure 12.2 SoVI scores for US counties, 2000. This updates the original construction (Cutter et al., 2003) using the same procedures but more recent data (2000). Data available from http://www.sovius.org

Please see page 675 for a colour version of this figure.

Stability and sensitivity of SoVI

Two important advancements were made after the initial development of SoVI (Cutter et al., 2003). The first was a temporal stability assessment of how well SoVI performed over an extended time period in capturing the historic variability in social vulnerability. Following the same procedures and collecting the same 42 variables from US censuses starting in 1960 and through to 2000, Cutter and Finch (2008) found that SoVI consistently explained between 73 per cent and 78 per cent of the variance in the data, with the number of components ranging from 9 to 12 (the original had 11 components explaining 76 per cent of the variation). While there was some variability in the individual components from decade to decade, several components consistently contributed to increased social vulnerability over the 50-year period – socio-economic status, density of development (urban/rural), age and gender. Generally, the spatial pattern of vulnerability became more geographically dispersed over time, with concentrations of social vulnerability related to known historical social movements and migrations. Although the national trend illustrated a steady reduction in social vulnerability across the United States, there are significant regional drifts depicting a consistent increase among selected groups of counties, each exhibiting a different set of driving factors, illustrating the place-specific nature of vulnerability. In this same paper Cutter and Finch (2008) forecast SoVI to 2010, using a linear extrapolation from the historic censuses.

Demonstrating the geographic differences in the driving factors of social vulnerability for different regions of the United States, Table 12.1 compares the factor scores of four counties in census year 2000. Here, the SoVI score is derived by summing the cardinally adjusted factor scores across the row. For example, in Apache County, Arizona, the SoVI score ranks in the 99th percentile, indicating high social vulnerability. In examining the individual factors, a clear contributor to the high SoVI score is Factor 8, characterized by a large Native American population and high unemployment incidence. In another area of elevated social vulnerability in Orleans Parish, Louisiana (96th percentile), race and gender (Factor 5) play a key role in increasing the SoVI score. In contrast to Apache County, however, the particular racial or ethnic group minority is the large African-American population. Employment (Factor 7) also plays an important role in the elevated vulnerability of Orleans Parish, as shown by the prevalence of females in the labour force, female-headed households and lower-wage service occupations. However, wealth indicators (Factor 4) reduce the overall vulnerability score in Orleans Parish. In Sarasota County, Florida, an area of moderate-high social vulnerability, the primary driving factor of the SoVI score is age, particularly populations over the age of 65 and those collecting social security benefits (Factor 2), followed by gender (Factor 6). However, in combination with negative scores from a number of factors, particularly socio-economic class, rural/special needs and wealth (Factors 1, 3 and 4), the overall SoVI score for Sarasota is reduced. The final example, Orange County, California presents an area of very low relative social vulnerability (1st percentile). Here, the primary driver of the low SoVI score is wealth (Factor 4), and lack of minority female-headed households (indicated by the negative for Factor 5). As these examples illustrate, the components of vulnerability are consistent across the country. However, the ways in which they manifest themselves and are interpreted vary by the local context. The analysis of the driving factors within SoVI enables such distinctions to be made.

A more formal sensitivity analysis of SoVI examined how methodological changes in variable composition and construction, along with

Table 12.1 Comparison of SoVI driving factors across the USA (2000). The data correspond to the updated SoVI map in Figure 12.2(c).

County, State	Major City	Nat'l Percentile	Factor Scores[1] 1	2	3	4	5	6	7	8	9	SoVI Score
Apache County, Arizona	Chinle	0.99	1.97	1.49	–0.59	0.47	0.11	0.63	–0.77	8.68	–0.18	11.81
Orleans Parish, Louisiana	New Orleans	0.96	1.00	0.65	0.32	–2.25	3.46	0.49	1.56	0.14	–0.42	4.95
Sarasota County, Florida	Sarasota	0.76	–1.02	3.34	–1.78	–1.19	–0.15	1.78	1.37	–0.47	0.55	2.43
Orange County, California	Anaheim	0.01	–0.71	1.05	–1.06	–4.41	–1.84	0.25	0.03	–0.15	0.27	–6.56

[1] Description of the Factors:
Factor 1: Socio-economic class and poverty. Characterized by % over age 25 without a diploma, % in poverty, per capita income (–), % of the population in the civilian labour force.
Factor 2: Age. Characterized by % over age 65, % under age 5, people per unit and % of households collecting social security benefits.
Factor 3: Rural and special needs. Characterized by % living on a rural farm, % employed in the primary sector, hospitals per capita and nursing home residents per capita.
Factor 4: High-density wealth. Characterized by housing density, average house value, average contract rent and % of households with income over $100,000.
Factor 5: Race and Gender. Characterized by females in the labour force, % black and % of female-headed households.
Factor 6: Females. Characterized by % of females.
Factor 7: Service workers. Characterized by % employed in the service industry.
Factor 8: Native American ethnicity and unemployment. Characterized by % Native American and % unemployed.
Factor 9: Migrants. Characterized by % of recent foreign migrants.

geographic context, affect the modelled output (Schmidtlein et al., 2008). While SoVI proved to be robust to changes in variable composition and scale, changes in quantitative construction with the PCA (including rotation, factor extraction, weighting in aggregation methods) and the interpretation of the factors affected the results of the algorithm. The sensitivity analysis highlighted the importance of expert knowledge and familiarity with the study area in validating the representation of social vulnerability. It also demonstrated the robustness of the algorithm to changes in scale (for example, downscaling to sub-county units) in producing a consistent percentage of variance explained.

Enhancements in the SoVI algorithm

SoVI's methodology has also been refined to consider built environment characteristics separately from the socio-economic factors that are inherently linked to vulnerability (Borden et al., 2007; Piegorsch et al., 2008). Given the significance of built environment variables especially in urban areas, and the difficulty in extracting many of the original built environment variables at a sub-county scale, subsequent iterations of SoVI used a smaller set of variables that only depicted social indicators, which were available down to the US Census block group scale (Table 12.2). Most notably, the distilled set of variables now excludes several of the built environment indicators used in the original construction of the index, including the number of commercial establishments per square mile and value of farm products per square mile. Additionally, other variables that were not consistently available at sub-county resolutions, such as birth rate and local government debt to revenue ratio, were removed. The modified variable set represents a comprehensive list of scalable, interrelated socio-demographic characteristics known to influence vulnerability.

Social vulnerability and hazard exposure

SoVI has been applied in a number of different contexts and analyses. A majority of SoVI's applications seeks to address the missing societal component in environmental hazard assessments. In its earliest contextual application, SoVI was combined with the US Geological Survey's physically based coastal vulnerability index to reveal overall coastal place vulnerability to erosion hazards for US coastal counties (Boruff et al., 2005). The results of the analysis indicate that place vulnerability along the coast is highly differentiated by a range of socio-economic and physical indicators. For some regions, such as the Gulf Coast, place vulnerability was

Table 12.2 Modified list of SoVI variables*

Variable Name	Description
MEDAGE	Median Age
QBLACK	% African American
QINDIAN	% Native American
QASIAN	% Asian and Hawaiian Islanders
QSPANISH	% Hispanic
QKIDS	% of population under 5 yrs of age
QPOP65O	% of population 65 and over
PPUNIT	Average number of people per household
QRENTER	% renter-occupied housing units
NRRESPC	Per capita residents in nursing homes
QFEMALE	% female population
QFHH	% female-headed households, no spouse present
HOSPTPC	Per capita number of community hospitals
HODENT	Number of housing units per square mile
PERCAP	Per capita income (in dollars)
MHSEVAL	Mean value of owner-occupied housing units
M_C_RENT	Mean contract rent
PHYSICN	Number persons per 100,000 population employed as healthcare practitioners and in technical occupations
MIGRA	% foreign-born citizens immigrating between 1990 and 2000
QCVLUN	% civilian unemployment
QRICH	% of households earning $100,000 or more
QPOVTY	% living below poverty level
QRFRM	% rural farm population
QMOHO	% of housing units that are mobile homes
QED12LES	% of population 25 years or older with no high school diploma
QCVLBR	% of population participating in the labour force
QFEMLBR	% females participating in the labour force
QAGRI	% employment in farming, fishing and forestry occupations
QTRAN	% employed in transportation, communications and other public utilities
QSERV	% employed in service industry
QURBAN	% urban population
QSSBEN	% of population collecting social security benefits

*These 32 variables are now used exclusively in the construction of SoVI

more a product of social characteristics. The opposite was true of the Pacific and Atlantic Coasts, where physical characteristics were more influential on vulnerability overall. Cutter et al. (2007) also applied SoVI in a coastal context, examining counties along the US hurricane coasts. The analysis compared temporal changes in demographic indicators of vulnerable populations in 1970 and 2000, and then related these changes in socio-economic structure to social vulnerability using SoVI. The results of this analysis showed a massive population out-migration from the northeast United States and the Great Lakes region towards coastal areas along the Sun Belt. Concurrent with this population shift was the influx of certain vulnerable demographic groups – elderly, Hispanics and mobile home occupants – which contributed to increased socio-economic sensitivity in coastal places. When coupled with an increasing trend in hazard events and disaster losses, the empirical evidence suggests that the US hurricane coasts have become vulnerable over the past 30 years.

Throughout the years, SoVI has provided a societal context for measuring vulnerability to a number of physical hazards. It has been applied to levee failures in the Sacramento-San Joaquin Delta area (Burton and Cutter, 2008), comparing variations in community vulnerability to tsunami hazards in the Pacific north-west (Wood et al., 2010), examining the spatial linkage between social vulnerability and estimated earthquake losses in Charleston, SC (Schmidtlein et al., 2011), regional evaluations of societal vulnerability to climate-sensitive hazards (Emrich and Cutter, 2011) and assessing the missing societal components in hurricane impact modelling (Burton, 2010). Additionally, Tate et al. (2010) incorporated SoVI as the social component for multihazard mapping analysis for the purpose of place-based hazard mitigation planning.

Applications

It has been nearly a decade since the initial publication of the Social Vulnerability Index. While there have been relatively few published critiques of inductive approaches (Brooks et al., 2005), there are issues with the complexity of the SoVI methodology that limit its utility for non-experts and practitioners (Schmidtlein et al., 2008). Despite this criticism, SoVI has found its way into many practical applications reaching beyond the academic spectrum, especially for preparedness and planning by hazards practitioners. For example, SoVI appears in hazard and risk assessments for South Carolina (SCEMD, 2008) and California (CalEMA, 2010) to aid in disaster mitigation planning. SoVI was also employed in hurricane risk research for Miami-Dade County, Florida (Chang, 2005). SoVI has also been applied to inform research and commentary on the social dimensions of Hurricane Katrina in terms of differential impacts and disaster recovery (Cutter and Emrich, 2006; Cutter et al., 2006; Finch et al., 2010). The algorithm has proven its utility for areas outside the United States as well, in describing the social vulnerability of Caribbean Island nations (Boruff and Cutter, 2007), in central Portugal (de Oliveira Mendes, 2009), and in Norway (Holand et al., 2011; Rød et al., 2010). There is also considerable interest in coupling SoVI with existing web-based products, such as NOAA's Digital Coast. For this application, the interest is in the visualization of the potential impacts of sea-level rise and coastal flooding on socially vulnerable communities (NOAA 2010).

To make SoVI more accessible to the emergency management community, a SoVI website was launched (www.sovius.org) which includes social vulnerability maps for the entire United States (by county), as well as for each individual state and Federal Emergency Management Agency (FEMA) region. The site also includes the overall SoVI score in tabular form along with the national percentile that the score represents. Finally, the site provides links to applications and publications using SoVI, in addition to a frequently asked questions (FAQ) section and a step-by-step procedure for calculating SoVI, labelled "The SoVI Recipe" so that others can replicate the algorithm.

Advanced GIS applications were developed to assist local emergency managers in producing a visualization of social vulnerability and its intersection with hazard exposure (Tate et al., 2010). In 2010, the Hazards and Vulnerability Research Institute (HVRI), in coordination with the South Carolina Emergency Management Division, launched a web-based hazards mapping application, the Integrated Hazards Assessment Tool (IHAT) (HVRI, 2010), which provides both hazard exposure and social vulnerability metrics (Tate et al., 2011). Presently developed only for South Carolina, the ability for users to rapidly produce hazard exposure and social vulnerability maps for inclusion in planning documents will facilitate improved understanding of vulnerability at the local and state levels, and help tailor mitigation efforts accordingly.

Lastly, the advocacy community has used the SoVI as a tool for understanding the inequalities in impacts of climate change for populations in the US south-east (Oxfam, 2009). This report, commissioned by Oxfam America, illustrates the disproportionate exposure of socially vulnerable populations to drought, flooding, hurricane winds and sea-level rise as a means for promoting climate change policy actions at local, state and national levels. The inclusion of an interactive web application (Oxfam, 2010) allows hazard practitioners and advocacy groups to visualize areas in the US south-east where physical risk and social vulnerability converge.

Future directions and conclusions

By many measures, the Social Vulnerability Index (SoVI) has achieved a modicum of success as an empirically based approach for measuring social vulnerability. The initial development of SoVI as an algorithm for spatially quantifying social vulnerability is marked by several contributions to empirically based vulnerability assessments. The factors identified in the statistical analysis are consistent with hazard vulnerability and disaster risk literature (Blaikie et al., 1994; Heinz Center, 2002; Peacock et al., 1997; Phillips et al., 2010), representing both the variability of social vulnerability and the diversity of the primary drivers in different places. This output affords a comparative spatial analysis, not only addressing which locations are vulnerable but who is vulnerable and why. The index can be successfully coupled with biophysical risk to further examine the complex interactions between the physical and social systems, improving hazard assessment and allowing selective targeting of hazard mitigation. Additionally, the methodology can be used on a subset of counties, or at the sub-county scale in a specific region to ascertain the similarities and differences in relative levels of social vulnerability (and its subsequent factors) in a more localized area. Since the SoVI score is place-based, and spatially reliant, each application of SoVI will reveal a different set of factors and dominant variables precisely for the particular study area and scale. As the SoVI indicators are shaped to reflect the social fabric of the United States, however, the relevance of particular variables tends to be limited to the industrialized world. To apply the SoVI algorithm in other geographic regions necessitates a contextual examination of factors that influence socio-economic disparity and diminished access to resources for that particular locale. In this way, candidate variables are chosen deductively to represent the predominant driving forces that perpetuate social vulnerability in particular places.

One glaring issue for future SoVI development is the implication of large changes in institutional data collection in the United States. Historically, SoVI data have been collected exclusively from the US decennial census. This has preserved the scalability and standardization of SoVI's input variables. However, the 2010 US census marked a shift in collection methodology, as the decennial long form (which collects information on income, housing, employment, household structure and education) is no longer being distributed. This change will undoubtedly affect the way in which researchers and advocacy groups in the United States measure socio-economic phenomena. An alternative is presented in the US Census Bureau's American Community Survey (ACS) five-year estimates, which use a rolling sample method to collect data across multiple years, including areas down to the block group scale. Several concerns exist, however, as the data will no longer represent an explicit snapshot but only signify a point in the five-year collection period. As a result, temporal analysis may not be possible using ACS data and comparisons with previous decennial census datasets are not recommended (Environmental Systems Research Institute, 2011). Furthermore, the sampling rate for the ACS product is significantly smaller in comparison to the 2000 decennial long form (approximately 1 in 40 compared to 1 in 6, respectively), raising questions on the accuracy of the data, especially for smaller enumeration units (Alexander, 2002; Environmental Systems Research Institute, 2011). Future research must acknowledge these issues and reconcile such problems as data accuracy to preserve the robustness of SoVI applications.

Another continuing conundrum in the evolution of the SoVI algorithm and approach is the lack of empirically based model validation. Here the concern is the selection of an appropriate post-disaster outcome measure with which SoVI could be verified quantitatively. Part of this issue lies in the selection of the appropriate outcome indicator. Should it be economic losses (an inverse relationship with social vulnerability), human losses such as deaths or some other indicator? Several researchers suggest that there is no singular concrete variable against which composite vulnerability measures can be validated (Saisana et al., 2005; National Research Council, 2006; Schmidtlein et al., 2008). At present, there has been little research effort focused on the quantitative validation of SoVI, and it is unclear as to whether or not such efforts would return useful information. Alternatively, it is possible to examine the pattern of social vulnerability and link to differential impacts using a combination of qualitative and quantitative measures, such as those disparate patterns of recovery in post-Katrina New Orleans illustrated by Finch et al. (2010).

SoVI is not an absolute measure of vulnerability (and should not be used as such); instead it captures the place- and scale-specific relative levels of social vulnerability. SoVI is best used in determining broad patterns in the spatial distribution of social vulnerability to hazards and in the discovery of underlying driving factors that produce vulnerable populations in local places, especially in developed countries. These pre-impact conditions can then be examined in more detail using a variety of other approaches and perspectives as discussed in this volume, or they can be viewed in the context of hazard-specific threats. From a policy perspective, SoVI provides a rationale for the allocation of differential resources and disaster preparedness strategies to marginalized communities that are most socially vulnerable prior to the event or in organizing tailored response efforts afterwards. At its core, SoVI is a quantitative assessment of the relative level of social vulnerability between places. The SoVI map reflects only one product of the index – the visualization of the results. The data produced in the algorithm can be used analytically to examine the dimensions that produce vulnerable populations in different places. In this regard, SoVI has enormous utility in facilitating further exploratory analyses on the locally based drivers of social vulnerability, and in the place-based targeting of intervention strategies for improved preparedness, response and mitigation based on the relative levels of social vulnerability in those local places.

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13

Disaster vulnerability assessment: The Tanzania experience

Robert B. Kiunsi and Manoris Victor Meshack

Background of the study: climate change, disaster occurrences and the need for vulnerability assessment in Tanzania

Tanzania is located in East Africa between longitudes 29º and 41º east, and latitudes 1º and 12º south. The country has an area of 945,000 km^2 and a population of 41 million people, of whom 26 per cent live in urban, and the rest in rural, areas. Administratively, Tanzania is divided into 21 regions, 113 districts and 7 agro-ecological zones (see Figure 13.1(c)) (National Bureau of Statistics, 2004; MWLD, 2003). The climate of Tanzania is influenced by two main factors of location: its latitude and its position at the eastern edge of the African continent. The country's mean annual temperature ranges from 21ºC in the highland areas to 29ºC at sea level. In all parts of the country, July is the coolest month of the year. The warmest month shows more variation. It can be either before or after the main rainy period. Annual rainfall in Tanzania ranges from 400 mm per annum, mainly in the central parts of the country, to 2,300 mm in the highlands and western parts of Lake Victoria. Tanzania has abundant natural resources including land, wildlife and water resources in terms of lakes and rivers. According to the United Republic of Tanzania (URT, 2008a), Tanzania is a rich country in terms of vegetation and wildlife as about 80 per cent of the country is still covered by natural or semi-natural vegetation. Wildlife protected areas cover about 28 per cent of the total land. The country has seven major lakes, among them

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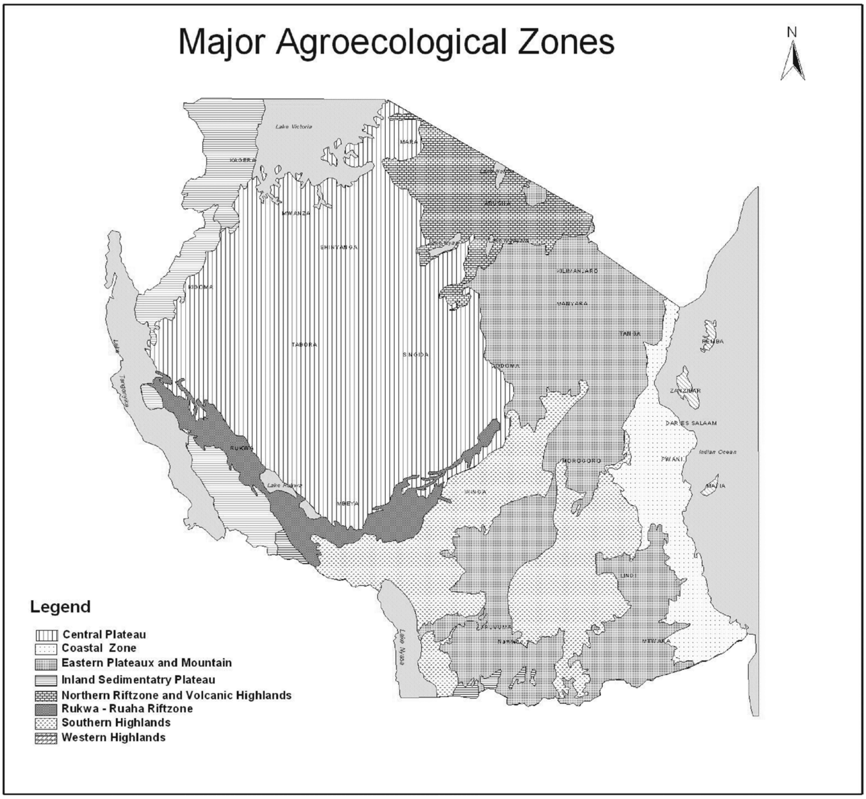

Figure 13.1 Agro-ecological zones of Tanzania
Source: Authors.

Please see page 676 for a colour version of this figure.

Lake Victoria and Lake Tanganyika, and 10 major river systems including River Rufiji and River Pangani. The surface river flow regime and moisture conditions in the country correspond to the general rainfall pattern. Rivers and lakes start rising in November/December and experience a maximum in March–April, with a recession period from May to October–November.

According to Initial National Communication (INC) and Habiba and Peter (2010), the National Adaption Programme of Action prepared by the Vice President's Office in 2003 and 2007 respectively climate change in Tanzania will lead to an increase in annual average temperature of 2ºC–4.5ºC. Furthermore, the reports indicate that bimodal rainfall areas will experience an increase in rainfall of 5–45 per cent, while the unimodal areas will have reduced rainfall of 5–15 per cent. Hulme et al. (2001)

provides information on climate change in the East African Region in which it is predicted that temperature will change by 0.2ºC–0.3ºC per decade and there will be an increase in precipitation of 2–20 per cent during the wet months and a decrease in rainfall by 5–10 per cent in the dry months. Available data indicates that climate change is already taking place in Tanzania. According to Habiba and Peter (2010), climatic data from 1960 to 2005 show that temperature in Tanzania has been increasing. For example, in the highlands of Arusha Region there has been an average increase in temperature of 1.1ºC. Similarly, the IPCC report (2007) reveals that large areas of the western part of the country have experienced a temperature increase of 1ºC to 2ºC for the period covering 1974–2005.

According to Hulme et al. (2001), Smith and Lazo (2001), URT (2007) and Mongi et al. (2010), climate change in Tanzania, as elsewhere in the world, will have a number of impacts including an increase in extreme weather events, such as droughts, heavy rainstorm events such as El Niño and heat waves. Other eventualities are a reduction in food security, sea water level rise and an increase in human diseases and pests. In terms of extreme weather events it is expected that frequency of drought occurrences and related consequences in the drylands of the country will increase. The World Food Programme (2010) report on comprehensive food security and vulnerability analysis showed that between 85 per cent and 94 per cent of households living in unimodal rainfall areas had been subjected to drought shocks in the previous year. According to the URT (2007), northern areas of the country including the Lake Victoria basin will experience an increase in rainfall. This might lead to increased frequency in flooding in the low-lying urban areas and in settlements along major river valleys. In terms of human health, an increase in rainfall and unusually high maximum temperatures might lead to an increase of malaria cases as unusually high maximum temperatures are usually correlated with a rise in the number of malaria cases. Flooding, especially in unplanned urban areas, might lead to an increase of water-related diseases including cholera. It is important to note that about 60 per cent of the urban dwellers in Tanzania live in unplanned settlements.

Climate change will negatively or positively impact on crop production in Tanzania. The National Adaptation Programme for Action (NAPA), for example, shows that the there will be a reduction of maize production by 33 per cent countrywide. At the same time coffee production is expected to increase by 18 per cent in bimodal rainfall areas and by 16 per cent in unimodal rainfall areas. It is predicted that the sea water level will rise by 0.10–0.90 metres along the eastern Africa coast. This will affect the low-lying areas along the coastal areas and islands.

The country is prone to both climate and non-climate-related hazards and has a long history of their disastrous impacts. Disasters commonly occur as result of epidemics, pests, flood, drought, fire, accidents, cyclones/strong winds, refugees, conflicts, landslides, explosions, earthquakes and technological hazards. Climate change issues are handled by the Division of the Environment (DoE), which is housed within the Vice President's Office. A National Climate Change Committee composed of senior government officials from different sectors and research institutions is in place. Its main function is to advise the DoE on climate change issues, mitigation and adaptation measures. The DoE works together with other ministries and research institutions and NGOs, but there is no formalized institutional arrangement for climate change management.

Disaster issues are handled by the Disaster Management Department located in the Prime Minister's Office. The institutional arrangement for disaster management is guided by the National Disaster Management Policy of 2004, the Disaster Relief Co-ordination Act, 1990 and National Operational guidelines of 2003. At the national level, the structure is composed of the Tanzania Disaster Relief Committee (TANDREC) and the Disaster Management Department. The main function of the committee is to oversee and coordinate government activities for disaster prevention, preparedness, mitigation and recovery. In order to manage disaster at various levels, disaster committees have been formed at sector ministries, regions, villages, districts and wards.

Due to the country's vast area and high diversity of geographic conditions determined by various physical, social and economic factors, each part of the country experiences different kinds of disasters. In recognition of these threats, the Tanzanian government has made various efforts to strengthen its capacity for disaster management (for example, preparedness, emergency and recovery plans) at different levels by introducing policies, legislation, institutions and operational guidelines, and by conducting continuous training. However, the government's efforts are severely hampered by the lack of reliable data on the vulnerabilities of communities that are exposed to these different types of disaster.

Recognizing that there is a great need to collect more data on vulnerabilities at various levels, the government has enlisted a number of institutions to conduct vulnerability assessments at various levels as discussed below.

Vulnerability assessments in Tanzania

As already discussed in this volume, vulnerability is a complex concept that has many definitions. However, it can be generalized that vulnerability assessments have three main aspects: the exposure to a hazard. The characteristics (sensitivity or susceptibility) and the response capacities of the elements at risk. The elements at risk can be people, their livelihood activities, social and economic infrastructure and the ecological services. Depending on its objectives, the assessment of vulnerability can be made at various levels of a society, i.e. at an individual level, a household, a community or nationally or regionally (Schneiderbauer and Ehrlich, 2006). In addition, vulnerability can be conducted from a social or biophysical perspective. According to Birkmann (2006), vulnerability assessment from a social perspective means focusing more on human beings and the necessary conditions for their survival and adaptation, while biophysical vulnerability focuses more on the susceptibility of environmental components to negative effects of climate change.

A number of vulnerability assessments have been carried out in Tanzania, including the following:

- Initial National Communication under the United Nations Framework Convention on Climate Change in 2003;
- Disaster vulnerability assessment, phase II in 2003;
- Comprehensive Food Security and Vulnerability Analysis in 2010;
- Rapid Vulnerability Assessment Report on Drought Affected Areas (made yearly whenever there is a drought in the country).

Disaster vulnerability assessment phase II was conducted by the Disaster Management Department, the Ardhi University (the former University College of Lands and Architectural Studies) and the University of Dar es Salaam, assisted by the Red Cross of Tanzania, and regional disaster focal officers in year 2003. The specific objectives of the study were to:

- determine the type, location and frequency of disasters at the household, village, district and national levels;
- identify the current capacity and coping systems (organizational arrangement) at household, village, district and national levels;
- identify direct and indirect causes of vulnerability to major hazards in Tanzania;
- develop a national vulnerability index;
- map out vulnerability of a given hazard at the national level;
- develop a national cross-case vulnerability analysis report.

Structure and methodology

The following section discusses the theoretical and conceptual framework of the study. Subsequent sections focus on the methodology for the data collection procedure and data analysis.

Vulnerability assessment

The term vulnerability is defined in various ways. For example, de Satge et al. (2002) defines it as "the characteristics that limit any individual, a household, a community, a city, a country or even an ecosystem's capacity to anticipate, manage, resist or recover from an impact of natural or other threat (often called 'hazard' or natural 'trigger')". UNDP (1992) defines vulnerability as "the degree of loss (for example from 0 to 100 per cent) resulting from a potentially damaging phenomenon". The Tanzanian vulnerability assessment study involved collecting and analysing data on four components: the hazards, elements at risk, characteristics of individuals or communities, and coping strategies or manageability.

Hazard is a natural or human-driven event that could lead to a particular level of loss, including mortality and injuries, damaged property and disruption of economic activity and the environment. A hazard becomes a disaster when it strikes certain elements that are at risk. These can be people, resources, services or infrastructures, which are exposed to specific threats. Elements at risk are attributed by location-specific characteristics that are ruled by physical, socio-economic and political factors and that render individuals or communities defenceless against hazards. Examples of such characteristics include poverty, low levels of education, limited access to power, lack of investment and living in dangerous locations. Thus, exposure is the degree to which people, livelihoods or property are likely to be struck or affected by a hazard (de Satge et al., 2002).

Manageability or coping strategies refer to how well households, communities and societies can anticipate, manage, resist or recover from the impact of a disaster. The degree of coping capacity is determined by the accumulation and quality of assets. These include, for example, physical capacities such as appropriate house construction techniques or socio-economic assets.

Risk in this study is defined as the probability of a hazard occurring, and the probability that the elements of risk will be affected by a hazard, resulting in a particular level of loss, including loss of life, persons injured, property damaged and economic activity disrupted.

Conceptual framework

The conceptual framework was based on the disaster crunch model of Wisner et al. (2004), and consists of three main components: (1) underlying causes, (2) dynamic pressures and (3) unsafe conditions (see also Chapter 1, Figure 1.8).

Underlying causes can be characterized as a set of deep-rooted factors within a society that form and maintain vulnerability: for example, limited access to power and resources.

Dynamic pressure is defined as a translating process that turns the effects of a negative cause into unsafe conditions. This process may be due to lack of basic services or their inadequate provision, or it may result from a series of macro-forces, such as lack of appropriate skills, local markets, education and investment.

Unsafe conditions refer to the vulnerability context, where people and property are structurally exposed to the risk of a potential disaster. Factors include the fragility of the physical environment, for example living in dangerous locations, together with an unstable economy with low-income levels.

This framework assumes that communities, for example those with limited access to power or resources (i.e. underlying causes), lacking appropriate skills and education (i.e. dynamic pressure), and with low incomes, are more vulnerable to hazards than communities not exposed to such conditions. The three main conditions that make individuals or communities vulnerable to hazards were assumed to be present in Tanzania. However, due to lack of consolidated data on the physical and socio-economic conditions of the different communities, the crunch model could not be adopted. Instead, the four main parameters (hazard occurrence, effects of the last disaster occurred, hazard manageability and coping strategies) were calculated on the basis of agro-ecological zones as a spatial classification of the country. Physiographic parameters, such as precipitation patterns, dependable growing seasons and average water-holding capacity of soil, characterize these zones. They can directly reflect the physical, and indirectly the socio-economic, conditions of the different communities in the country. This is due to the fact that more than 75 per cent of the population in Tanzania still live in rural areas and mainly depend on farming to sustain their livelihoods. This means (assuming that all other parameters are equal) that areas with reliable rainfall and good soils are likely to be economically and socially better off than areas exposed to drought and with poor soils.

Scale of the survey

The Tanzanian mainland accounts for a total of 8,811,087 households, according to a census conducted in 2002. By using a multistage sampling method, the sample size was determined to be 2,040 households at a 95 confidence interval, and a design effect of 1.3. The sample size at district level was 42 out of 113 districts, and at village level it was 84 villages. A

Table 13.1 Characteristics of agro-ecological zones

S/N	Zone	Altitude m/ sea level	Precipitation pattern	Dependable growing season in months	Physiographic
1	Coastal (C)	<100 to 500	Bimodal and monomodal	3 to 10	Combination of coastal lowlands, uplands, undulating and rolling plains
2	Eastern plateau and mountain blocks (E)	200 to 2,000	Predominantly monomodal	From <2 to 7	Many physiographic types, ranging from flat areas, undulating and rolling plains, hilly mountain, plateau to mountain blocks
3	Southern highlands (H)	1200 to 2,700	Monomodal	5 to 10	Composed of flat to undulating rolling plains and plateau, hilly areas and mountains
4	Northern rift valley and volcanic highlands (N)	900 to 2,500	Monomodal	<2 to 9.5	Ranges from flat to undulating plains, hilly plateau to volcanic mountains
5	Central plateau (P)	800 to 1,800	Monomodal	2 to 6	Composed of flat plains, undulating plains, plateau and some hills
6	Rukwa-Ruaha rift zone (R)	800 to 1,400	Monomodal	3 to 9	Composed of flat terrain, rocky terrain and complex terrain
7	Inland sedimentary plateau, Ufipa plateau and western highlands (SUW)	200 to 2,300	Monomodal	3 to 9	Composed of undulating plateau, strongly dissected hills, dissected hilly plateau and undulating rolling plains.

Source: de Pauw, 1984.

sampling protocol was prepared to minimize biases and to include both urban and rural areas, along with all agro-ecological zones.

Methodologies

The main methodologies used for this study included questionnaire-based interviews at household, village and district levels, checklists, geographical information system (GIS) and statistical analysis.

Interviews and data collection

Three sets of questionnaires were developed: one each for the household, village and district levels. Each set of questionnaires covered the key topics: hazard occurrence, effects of the most recent disaster, hazard manageability and coping strategies, including critical facilities. Due to the differences in information available at different levels for some of the research topics, level-specific questions were developed that differed in detail and in the choice of subtopics of the main areas. For example, at the household level, the question on manageability was meant to determine levels of awareness, while at the village and district levels it was meant to determine the level of preparedness.

The study was essentially based on the perceptions of the interviewees at the household and village levels, and on a mixture of recorded data and insights provided by district officers. This type of approach was used in order to be able to compare the different perceptions of hazards in the country.

The household data were then used to generalize hazard and disaster occurrence in the whole country, according to agro-ecological zones. This was possible because the number of cases was statistically large enough.

Data processing and analysis

The analysis of interview data determined the different types of hazards, their effects and coping strategies in order to calculate risk levels and the vulnerability index at the household, village, district and zonal levels. The data analysis was made by using statistical packages such as S-Plus, R, SAS and StatXact and GIS. Five main steps were followed when compiling and analysing data. After the first step of data cleaning, initial analysis was undertaken to determine hazard occurrence, effects and manageability at the three levels. Due to their large sample size, household data were used to obtain a broad picture of the spatial distribution of hazard occurrence in each agro-ecological zone. Subsequently, coping strategies for the three most commonly mentioned hazards were generated for each zone. This was done by matching and summarizing the coping strategies identified at the household, village and district levels. The unit for processing rankings was the percentage of respondents at each level. In the next step, a risk index was calculated for each disaster by fitting the response variables of the household questionnaire linked to the impacts of the last disaster (for example, loss of life, property and loss of income) into a statistical model.

The goal was to find the best and most parsimonious, fitting yet socially reasonable, model to describe the relationship between disaster impact (response variable) and a set of explanatory variables. Explanatory variables are characteristics or attributes of the sampling unit (for example, a household, village or district) that influence the outcome (response) variable. Explanatory variables are sometimes referred to as predictor variables, covariates or independent variables.

In situations where one is dealing with discrete variables as responses, models are selected from a class of generalized linear models. In this particular context, logit models were chosen due to the nature of the response variables.

The logit model is a regression model that is tailored to fit a categorical response variable. In its most widely used form, the categorical response variable is a simple dichotomy, with possible values like yes/no, 0/1, present/absent, etc.

In the model selection, the variables/factors thought to influence the outcome of a disaster were added and removed in a sequential manner until a model that described the data reasonably well was obtained. Among possible approaches for model selection, the stepwise selection method was employed because it combines other approaches like backward elimination and forward selection methods. In the construction phase of the model, variables that met the criterion by Hosmer and Lemeshow were considered (i.e. with p-value of at least 0.25 in an univariate logistic regression analysis) (Neter et al., 1996: 347). The last step was to calculate the vulnerability index by using the UNDP (1992) formula:

$$\text{Vulnerability} = \frac{\text{Hazard} * \text{Risk}}{\text{Manageability/copying strategies}}$$

Example for calculating the vulnerability index in Tanzania

This section gives a more detailed example of how the vulnerability index as previously outlined was calculated. Although the vulnerability index can be calculated for each research level, the example here focuses on calculating the index on the basis of agro-ecological zones for the hazards of drought, disease outbreak and pests.

Hazard occurrences at the household, village and district levels

A total of 15 types of hazard were identified, including drought, disease outbreak, floods, landslides, pests, refugees and HIV/AIDS. It should be noted that hazard occurrences at the household and village level were mostly based on perceptions, while hazard occurrences at the district level were mostly based on records. All values are indicated as a percentage of respondents. They do not add up to 100 because multiple responses were allowed. Before aggregating values for the four most common hazards, the results were compared across all research levels, as shown in Figure 13.2.

For all levels, the study revealed that the three most commonly occurring hazards were pests, drought and disease outbreaks. Pest scored the highest at both the household and village levels, followed by drought and disease outbreaks at the household level, and vice versa at the village level.

The study shows that there is a difference in the order of hazard occurrences at the district level when comparing lower levels: HIV/AIDS, together with disease outbreaks, are the most common hazards at district level, followed by pests, drought and strong winds.

The differences in the ranking of the major occurring hazards between the data collected at district level and at grassroots levels (i.e. household

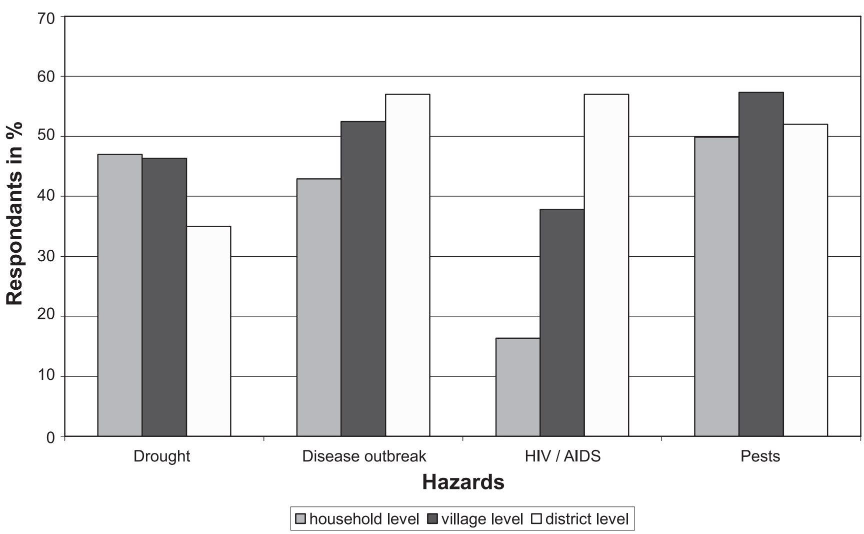

Figure 13.2 Four main hazards compared according to different levels
Source: Authors.

and village) is not surprising, because the household and village data were based on perceptions while the district data were mostly based on insights and records by the administration. Another reason why there are differences in the perceptions of interviewees at different levels is because they had to deal with different issues in their daily activities. At the village level, for example, the focus of people's perceptions was more on agricultural-related hazards, while at the district level, as the people questioned also live in the district capital, both agricultural and urban-related issues were significant. Furthermore, we had to take into account the different degree of openness of people when dealing with sensitive questions. For instance, at the household level, people were probably less open when responding to questions about HIV/AIDS than at the village or district level. This is probably because hazards due to HIV/AIDS are comparatively lower at the household level.

Hazard occurrences at the zonal level

In order to estimate the occurrences of hazards at the level of agro-ecological zones, only household data were used. Figure 13.3 shows the estimated occurrences of the four major hazards in each zone. Using drought as an example, its occurrence is highest in the northern rift valley

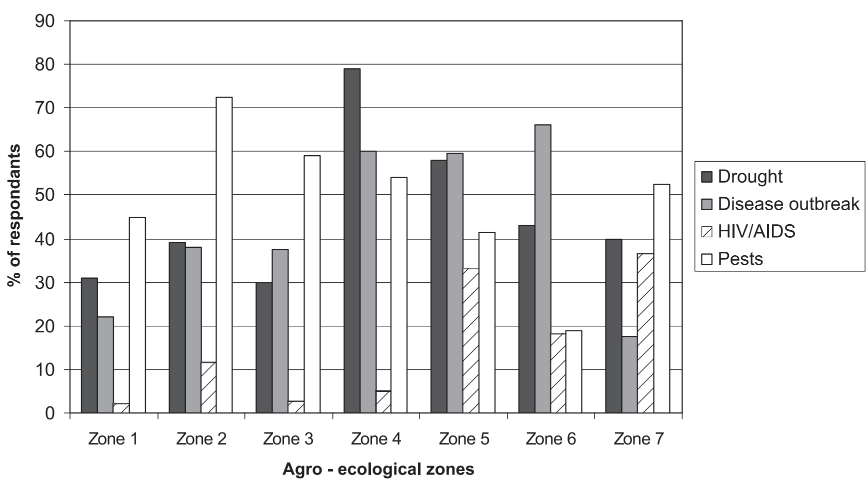

Figure 13.3 Hazard occurrence in different agro-ecological zones
Legend: Zone 1 = Coastal; 2 = Eastern plateau and mountain blocks; 3 = Southern highlands; 4 = Northern rift valley and volcanic highlands; 5 = Central plateau; 6 = Rukwa-Ruaha rift zone; 7 = Inland sedimentary; Ufipa plateau and western highlands.
Source: Authors.

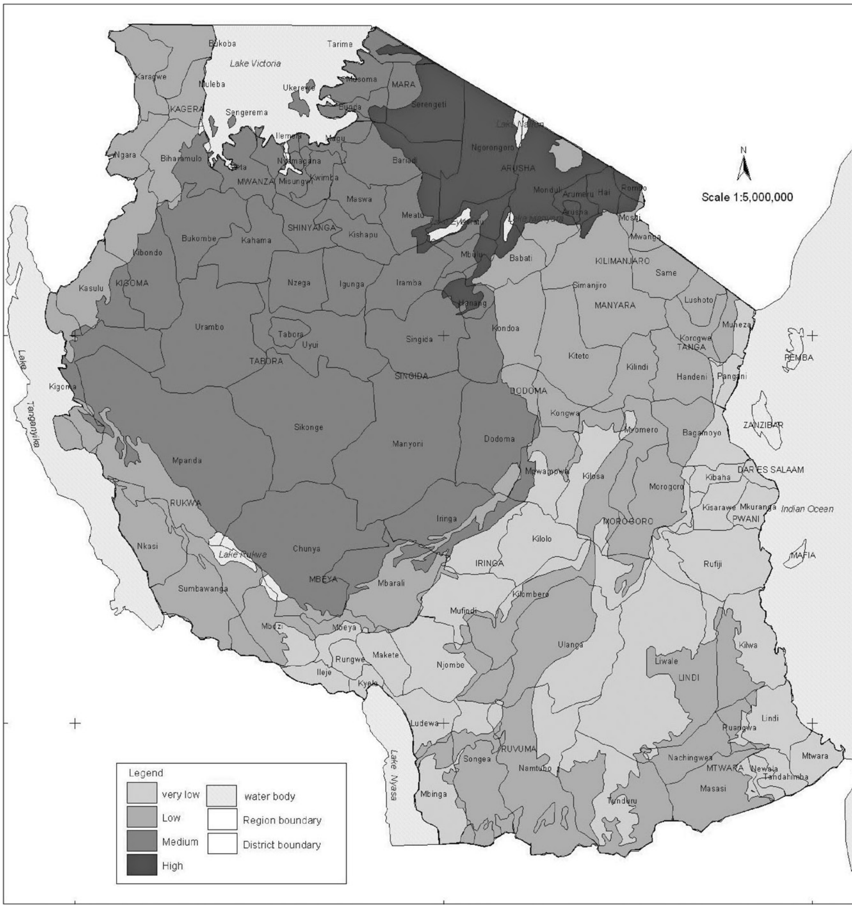

Figure 13.4 Drought occurrence in Tanzania
Source: Authors.

and volcanic highlands (79 per cent), followed by the central plateau (58 per cent), the Rukwa–Ruaha rift zone (43 per cent), the inland sedimentary, Ufipa plateau and western highlands (40 per cent), the eastern plateau and mountain blocks (39 per cent) and lastly the coastal zone. The estimated values for each zone were then used to produce hazard maps for the three most common hazards.

Figures 13.3 and 13.4 show the distribution of drought occurrence across all zones. The map classifies the zones as high (Zone 4 in Figure 13.3), medium (Zone 5) and low occurrence (Zones 2, 6, and 7) levels.

Manageability/coping strategies

A number of questions were asked to assess the level of hazard manageability and coping strategies at all levels for the most common hazard types outlined above. Figure 13.5 shows the results of questions about coping strategies and disaster awareness at the household level. The responses showed, for example, that the three main methods for coping with drought were selling assets (33 per cent), seeking employment elsewhere (29 per cent) and growing drought-resistant crops (22 per cent). With regard to coping with pests, 38 per cent of the respondents stated that they used pesticides. As for information on the last disaster that had occurred (disaster awareness), responses to questions revealed that the majority of the households (32 per cent) obtained information through public meetings, followed by radio (31 per cent), newspapers (12 per cent) and posters (7 per cent).

Other questions were posed about disaster communication, for example about the number of people listening to local radio programmes, like the *Jikinge Na Maafa* [protect yourself against hazards] programme.

At the village level, various questions were asked to get a sense of how authorities and civil institutions were managing disasters. The data revealed that, generally, the level of disaster management was still very low. However, 65 per cent of the villages had conducted awareness-raising activities on disaster management issues within the previous year. A

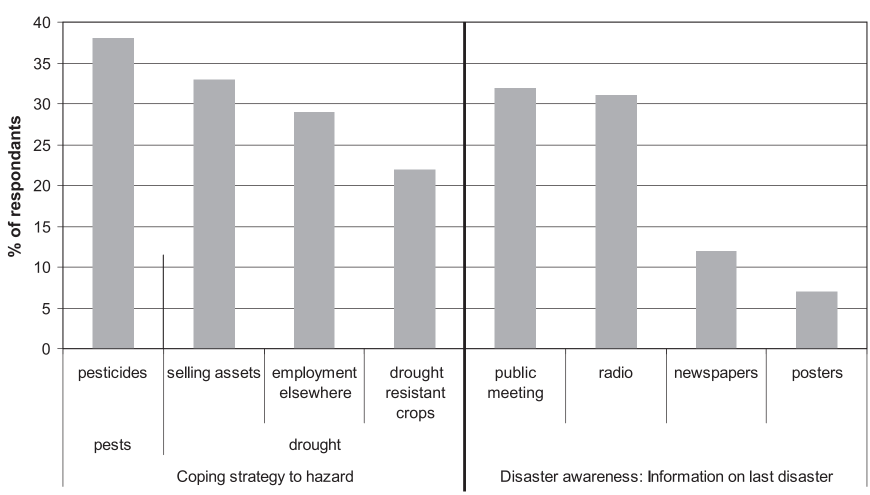

Figure 13.5 Coping strategy for drought and pests; disaster communication
Source: Authors.

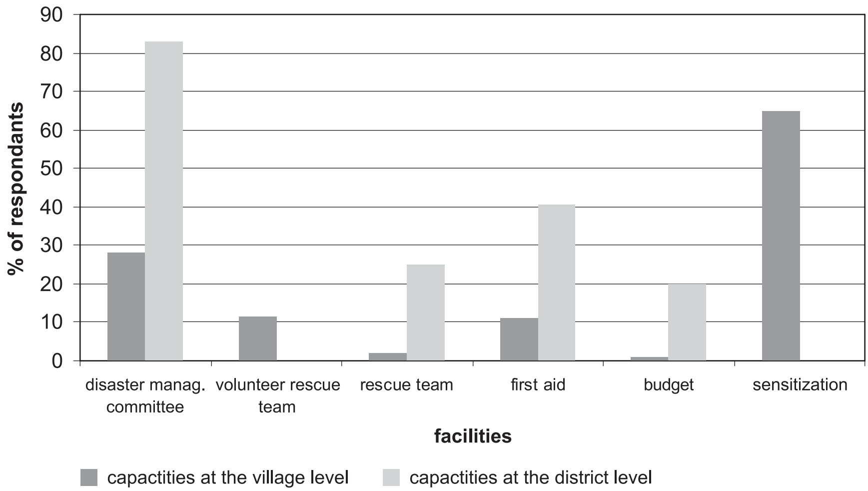

Figure 13.6 Institutional set-up for disaster manageability at the village and district level
Source: Authors.

comparison of disaster management facilities between the two levels showed better service provision at the district level. Other questions were posed about the existence of critical facilities, such as hospitals and clinics.

Generalized coping strategies at zone level

After determining the coping strategies for each hazard and research level, the next step was to calculate comparable values for the three most common hazards according to agro-ecological zones. In order to obtain a cross-level value for each agro-ecological zone, the coping strategy with the highest score at the household level, together with those at the village and district level (based on the percentage of respondents at each level), were added together and then divided by the total number of indicated coping measures. Equal weight was given to each facility found at the district level, irrespective of its capacity. In that way, an index showing the relative strength of coping measures at a zonal level was obtained. These indices summarize the coping strength in each zone for a particular hazard, and they were also used for comparison of strengths of coping measures across zones.

Table 13.2 shows the manageability index levels for drought in each zone. The coping strategies for drought ranged from 70 to 78, with the eastern plateau and mountain blocks (Zone 2) having the highest values, and the central plateau (Zone 5) the lowest values.

Table 13.2 Aggregated coping strategies for drought according to agro-ecological zones

		Zones						
	Manageability	1	2	3	4	5	6	7
Household level	Coping strategy – drought	43.86	50.62	37.63	73.27	43.11	29.41	30.38
Village level	Disaster committee	24.44	99.51	51.04	59.72	42.34	64.56	0
	Disaster budget	0	0	0	0	0	0	0
	Sensitization	72.6	61.6	98.71	99.21	29.64	100	90.82
District level	Health centres	100	100	100	100	100	100	100
	Clinics	100	100	100	100	100	100	100
	Dispensaries	100	100	100	100	100	100	100
	Emergency plan	100	100	100	100	100	100	100
	Hospitals	100	100	100	100	100	100	100
	Food plan	100	100	100	100	100	100	100
	Disaster equipment	100	100	100	100	100	100	100
	District disaster committee	100	100	100	50	75	100	75
	Disaster budget	60	0	0	16.67	16.67	0	25
	Drought manageability index	76.99	77.82	75.95	76.83	69.75	76.45	70.86

Source: Authors.

Impacts of the last disaster

Data on impacts of the last disaster were also obtained at all levels, although in this chapter only data based on the household survey are presented. Respondents were asked to describe the impacts of the last disaster on population and property. The main impact at the household level was identified as loss of livelihood/income (48 per cent), followed by property damage (42 per cent), illness or injury (35 per cent), loss of life (28 per cent) and displacement (8 per cent).

Risk levels based on the last disaster

On the basis of responses to questions about the last disaster, three models with respect to loss of life, property and income were constructed. Each of these models met the Hosmer and Lemeshow criteria (Neter et al., 1996: 347) (i.e. all explanatory variables with a p-value of at least 0.25 in a univariate logistic regression analysis were considered for further analysis). An example for calculating disaster risk (loss of life) obtained through the selected model (see data processing and analysis) is shown in Table 13.3; intermediate results have been omitted.

Concerning the impact variable "loss of property", hazards such as conflicts, disease outbreaks and floods contributed significantly to this

Table 13.3 Hazards and other factors associated with loss of life

Parameter	DF	Estimate	Standard Error	Chi-Square	Wald Pr > ChiSq
Intercept	1	–32.081	0.3536	823.064	>.0001
Posters	1	0.6578	0.2648	61.705	0.0130
Disease outbreaks	1	0.6395	0.2468	67.114	0.0096
HIV/AIDS	1	13.918	0.4286	105.430	0.0012
Disaster committees	1	0.8238	0.1628	256.149	<.0001
Sensitization	1	0.6132	0.2136	82.396	0.0041
Zone 1	1	–0.3347	0.6945	0.2322	**0.6299
Zone 2	1	0.0162	0.3218	0.0025	**0.9597
Zone 3	1	0.3683	0.2602	20.047	**0.1568
Zone 4	1	–13.701	0.3721	135.587	0.0002
Zone 5	1	0.7820	0.2634	88.114	0.0030
Zone 6	1	10.828	0.3056	125.564	0.0004
Disabled	1	0.2230	0.1047	45.345	0.0332
Distance form dispensary	1	0.2445	0.0605	163.162	<.0001

** Factors that are not significant to the loss of life (at 5% level of significance)
Source: Authors.

effect. Factors included the level of illiteracy at household level, as well as the degree of sensitization at village level. This effect seemed to be the same among agro-ecological zones. The model also revealed that people living in the central plateau and Rukwa–Ruaha rift zone (Zone 5 and 6) were at much higher risk of loss of life when hazards occur than those living in other zones.

In the case of the impact variable "loss of income", hazards with significant impact were drought and floods. Again, as was the case with the variable "loss of property", there seemed to be no differences for the "loss of income" variable across agro-ecological zones.

Using the same model as for calculating risks of loss of life, it can be seen that the hazards of disease outbreaks and HIV/AIDS had a significant impact. Contributing factors were the number of disabled persons in the household and distance (in kilometres) from the household to the nearest dispensary. Figure 13.7 shows the strong relationship between the loss of life and the distance (in kilometres) from the household to the nearest dispensary.

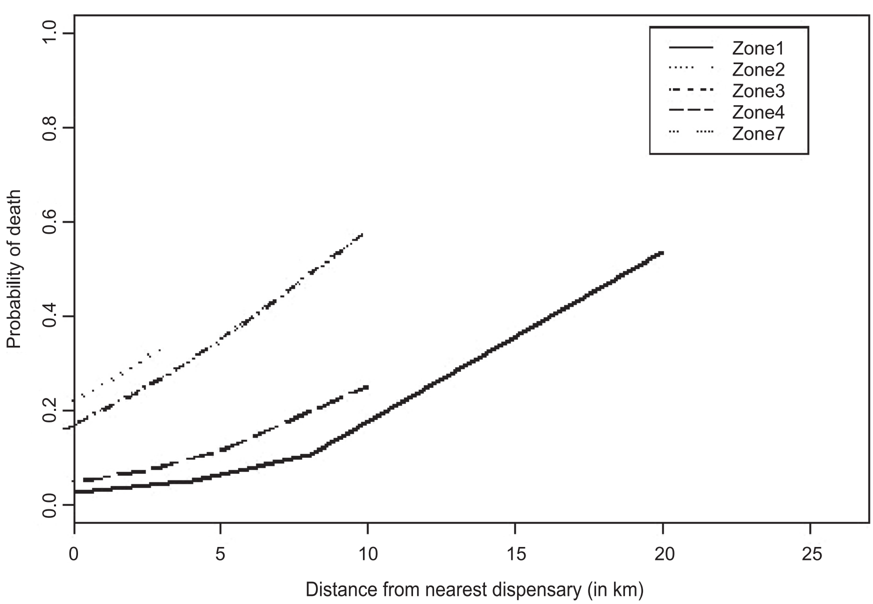

Figure 13.7 Interrelationships between distances from nearest dispensary and probability of death
Source: Authors.

Risks at the zonal level

Using the results of the fitted models displayed in Table 13.3, hazard risks for a particular effect – loss of life, loss of property and loss of income – were estimated for every individual in the study.

In order to derive risks based on three impact factors according to zones, the risk levels of individuals from the same zone were grouped and averaged. These were pooled together and weighted to obtain a single estimate across all effects. Loss of life was given the highest weight (0.7), and loss of property and loss of income were given equal weights (0.15). Table 13.4 summarizes these findings. The value for risk, indicated as probabilities, ranges from 0 to 1, with 0 being an ideal desirable situation and 1 the worst case scenario. The calculated values show, for example, that even though pests rank very high as a hazard, the effects were not significant.

Table 13.4 shows that the Rukwa–Ruaha rift area (Zone 6) had the highest risk level. This means that if a hazard occurs, the possibility of loss of life, property or income would be higher there than in the other zones. In the Rukwa–Ruaha rift area, loss of life had the highest mean value, and this was probably compounded by death due to high levels of disease outbreak.

Table 13.4 Ranking of zones according to hazard risk

	Mean Probabilities				
Zone	Loss of Income	Loss of Property	Loss of Life	Pooled Probabilities	Ranking
1	0.56	0.34	0.03	0.16	7
2	0.55	0.50	0.22	0.31	4.5
3	0.57	0.45	0.32	0.38	3
4	0.75	0.60	0.16	0.31	4.5
5	0.64	0.41	0.38	0.42	2
6	0.50	0.40	0.57	0.53	1
7	0.48	0.24	0.06	0.15	6

Legend:
Zone 1 = Coastal; 2 = Eastern plateau and mountain blocks; 3 = Southern highlands; 4 = Northern rift valley and volcanic high lands; 5 = Central plateau; 6 = Rukwa-Ruaha rift zone; 7 = Inland sedimentary, Ufipa plateau and western highlands.
Source: Authors.

The vulnerability index for agro-ecological zones

The vulnerability index was determined for drought, disease outbreaks and pests by using the UNDP (1992) calculation scheme.

The values for hazard occurrence and calculated manageability risk levels at the zonal level were merged to produce a vulnerability index for each zone, as indicated in Table 13.5. For example, the vulnerability index for drought in coastal areas (Zone 1) was calculated by multiplying the value for drought by the value for risk (see equation for calculating vulnerability in section on Methodologies), divided by manageability (Chapter 6; Table 13.2). Overall, the results showed that the vulnerability index for drought was highest in the central plateau (Zone 5), for disease outbreak in the Rukwa–Ruaha rift zone (Zone 6) and for pests highest in the eastern plateau and mountain blocks (Zone 2).

Discussion of the vulnerability index results

The index will be discussed using drought as an explanatory example.

According to the vulnerability index, the central plateau (Zone 5) was the most vulnerable (0.35), closely followed by the northern rift and volcanic highlands (Zone 4) (0.33) and the Rukwa–Ruaha rift zone (Zone 6).

Even though drought occurrence was highest in the northern rift and volcanic highlands (Zone 4), this zone's vulnerability was only the second highest because it had a relatively low risk factor compared to the central plateau (Zone 5), which implies higher drought manageability capacities. The Rukwa-Ruaha rift zone (Zone 6), which was the third most vulnerable area, had the highest risk factor compared with the other zones but had relatively low drought occurrence and the highest manageability capacities. The other zones had essentially low drought vulnerability because they had low drought occurrence and high manageability capacities.

Initial National Communication (INC)

This report was prepared by the Division of the Environment in the Vice President's Office (VPO) as one of the requirements for countries that ratified the UNFCCC. The main purpose of the report was to identify human-induced emissions and their removal by natural sinks. In addition the report was to provide policy and technological options for the minimization of greenhouse gases as well as a vulnerability assessment for climate change and requisite adaptation. The IPCC guidelines of 1991

Table 13.5 Vulnerability index parameters by zone

		Zones						
		1	2	3	4	5	6	7
Manageability of three major hazards	Drought	67.78	76.47	75.99	74.72	68.57	76.80	71.02
	Disease outbreak	71.56	69.62	68.75	65.09	64.74	74.06	62.24
	Pest	69.75	66.19	66.68	64.05	57.07	73.84	57.95
Hazard occurrence	Drought	31.06	38.94	30.00	78.91	57.69	43.04	40.21
	Disease outbreak	21.80	37.50	37.10	59.83	59.59	65.82	17.35
	Pest	44.69	72.60	58.71	53.91	41.80	18.99	52.55
Risk		0.16	0.31	0.38	0.31	0.42	0.53	0.15
Vulnerability Index	Drought	0.06	0.16	0.15	0.33	0.35	0.30	0.08
	Disease outbreak	0.05	0.17	0.21	0.28	0.39	0.47	0.04
	Pests	0.10	0.34	0.33	0.26	0.31	0.14	0.14
	General	0.07	0.22	0.23	0.29	0.35	0.30	0.09

Legend:
Zones 1 = Coastal; 2 = Eastern plateau and mountain blocks; 3 = Southern highlands; 4 = Northern rift valley and volcanic highlands; 5 = Central plateau; 6 = Rukwa-Ruaha rift zone; 7 = Inland sedimentary, Ufipa plateau and western highlands.
Source: Authors.

were used to create the GHG inventory in Tanzania, and the 1996 IPCC Global Warming Potential (GWP) with a 100-year time horizon was applied for calculating GWP index. The impacts for climate change and vulnerability are based on the 1997 US Country Studies report on assessment of vulnerability and adaptation response options for 49 countries, including Tanzania (Smith and Lazo, 2001). The INC contains, among other things, an inventory of anthropological greenhouse gas (GHG) emissions in Tanzania, including carbon dioxide, methane and nitrous oxide and climate change predictions. Furthermore, the report explains the impacts of climate change and vulnerability on the ecosystem and socio-economic systems in terms of water resources, crop production, grasslands and livestock, coastal resources and structures, forests, wildlife and biodiversity and public health. Strictly speaking, the INC was not a vulnerability assessment as such but is about the impact of climate change on the environment and on livelihoods.

Rapid Vulnerability Assessment (RVA) Report on Drought Affected Areas

The RVA report on drought affected areas is normally prepared by the Tanzania Food Security Team (FSIT) whenever there are indications of food insecurity in the country (URT, 2008b). The FSIT is mainly composed of personnel from the Disaster Management Department and the National Food Security Division in the Ministry of Agriculture, Food Security and Cooperatives. The objectives for the RVA include identifying the villages and wards that are food insecure, establishing the characteristics and coping strategies of food insecure households, determining the appropriate intervention measures and recommending short-, medium- and long-term strategies for reducing household food insecurity in affected areas. Overall, the data used in the RVA are based on food security indicators such as food availability, accessibility and stability and nutritional status. A variety of methods are used in collecting data, including questionnaires, focus group discussions and interviews. Data collection is done at regional, district and village levels and in the markets. The main purpose of collecting data in the markets is to get information on food supplies, prices and market dynamics. The 2008 RVA covered the nine regions of Shinyanga, Kilimanjaro, Morogoro, Mwanza, Singida, Lindi, Mbeya, Manyara and Arusha. The results indicate that shocks that affected households most were drought, floods, high food prices and crop pests. The failure of short rains in bimodal rainfall areas and the below average rainfall in unimodal areas led to reduced food and cash crop stock. This in turn led to reduced market supplies, resulting in increased food prices. For the year 2008 a total of 184,769 or 5 per cent of the total population in the affected areas were found to be food insecure, mostly in parts of Kikilmanjaro, Arusha, mayara, Singida, Mwanza, Lindi and Morogoro regions. The food insecure households that were identified by the RVA required a support of a total of 4,300 metric tons of food grains for a period of two months. The common coping strategies for food insecure households were generating funds through alterative activities such as petty trading, casual labour or getting financial support from relatives.

Comprehensive Food Security and Vulnerability Analysis (CFSVA)

The CFSVA provides a comprehensive food security and vulnerability analysis for the year 2009/10 (WFP, 2010). The main objective when preparing this report was to provide inputs to the government's strategic plans in order to help the decision-makers target resources in addressing poverty and food security in the country. The CFSVA was conducted by the World Food Programme, the National Bureau of Statistics, the Food Security Information team and the Ministry of Agriculture Livestock and Environment. A three-step methodology of literature review, primary data collection and primary data analysis and reporting was used in preparing the CFSVA. The study used three main sources, i.e. households, communities and traders, for its primary data. A specific questionnaire was prepared and used to collect data from each data source. A two-stage sampling strategy was used initially to identify rural areas and, subsequently, the enumeration areas in each region. Enumeration areas were identified by using Probability Proportional to Size (PPS). A total of 4,410 and 210 households were identified in Tanzania mainland and Zanzibar respectively. Data entry was done by using the Censuses and Surveys Processing Package (CSPRO), while data cleaning and analysis was primarily done by using the Statistical package for Social Science (SPSS).

The results for Tanzania mainland show that poor consumption households were most prevalent in Mtwara Region (20 per cent), Manyara Region (17.6 per cent) and Arusha Region (6.8 per cent). Regions that had borderline food consumption were Dodoma (37.8 per cent), Morogoro (33.8 per cent) and Manyara (42.9 per cent). Acceptable food consumption regions were found in the western and coastal areas of the country. The report identified several factors that contributed to food insecurity, including illiteracy of the head of the household, which negatively affected food consumption. Others that affected food consumption positively were cultivating four or more food crops, using chemical fertilizers and enjoying other assets of wealth. The three shocks found in mainland

Tanzania were drought (58.4 per cent), high food prices (53.40 per cent) and plant/animal pests (34.7 per cent). Many of the regions in dryland areas reported a higher frequency of drought: for example, Arusha Region (90.5 per cent), Manyara (80.0 per cent), Dodoma (85.2 per cent) and Mara, (85.7 per cent). The CFSVA shows the impacts of drought as income loss (90.8 per cent), asset loss (33.4 per cent) and food loss (78.9 per cent). The report indicates that 12.1 per cent of the households that were affected by the previous drought had not recovered during the survey period and 35.35 per cent had partially recovered.

Uses of vulnerability assessment reports in Tanzania

Vulnerability assessment reports for sustainable development planning, and disaster risk reduction in particular, are looked at first of all for determining policy and legal measures which can provide vulnerability information for development planning. Second, there is interest in how vulnerability assessment information may be applied in strategic and sectoral planning. The analysis of vulnerability information for policy and legal frameworks is confined to two policies and acts respectively. The two policies are Environmental Management Policy (URT, 1997) and National Disaster Management Policy (URT, 2004a) and the two acts are the Environmental Management Act (URT, 2004b) and the Disaster Relief Co-ordination Act, of 1990. These policies and acts have been chosen because they relate directly to climate change and disaster management issues. For national strategic planning, the analysis is confined to Tanzania Development Vision 2025 (URT, 2000) and the National Strategy for Growth and Reduction of Poverty II (NSGRP II) (2010), both broad and inclusive strategies. Briefly, Tanzania Development Vision 2025 aims at achieving high-quality livelihoods, good governance and the rule of law, and a strong and competitive economy by the year 2025, while NSGRP II, like its predecessor NSGRP I, aims at accelerating economic growth, reducing poverty, improving living standards and social welfare through good governance and accountability. NSGRP II is also used as an implementation vehicle for Tanzania Development Visions 2025 as well as Millennium Development Goals. For sectoral planning, land use planning practice has been employed to determine the extent to which vulnerability assessment information is being used.

At the policy level, the National Environmental Policy of 1997 does not make direct reference to climate change issues, climate change impacts or mitigation adaptation but provides general statements on sustainable development and environmental development. The Environmental Management Act's (EMA) section 75, however, does stipulate measures to be taken for climate change mitigation and adaptation. The National Disaster Management Policy of 2004 was based on the old concept of the disaster management cycle. The policy does not contain any elements on disaster risk reduction in which vulnerability assessment is included. The Disaster Relief Co-ordination Act of 1990, which was enacted for overseeing and coordinating the overall relief operations at the national level, is commonly acknowledged to be outdated for handling disaster issues as it is not based on disaster risk reduction principles. The act does not have any provisions for vulnerability assessments and their applications in the country. At the strategic planning level, Vision 2025 takes into account both disaster and environmental issues, advocating the control of land degradation and climate change as a necessary condition for attaining a strong and competitive economy. On disaster issues it advocates capacity building for anticipating and responding to external changes including disasters. Similarly, NSGRP II takes into account both environmental and disaster issues. Goal 4 of the NSGRPII is about ensuring food and nutrition security, environmental sustainability and climate change adaptation and mitigation measures that address climate change issues. In fact one of the targets of Goal 4 is to strengthen early warning systems, responses to natural disasters and institutional frameworks. DRR issues, and in particular the use of vulnerability assessment information in urban planning practice, including for example during the formation of the urban planning teams, in which the specialists in disaster management are not included, are not taken into account. Similarly DRR issues are not taken into account during formulation of the planning concepts, data collection and analysis, plan preparation and approval. Above all the urban planning guidelines of 2007, which is one of the main tools used in planning, do not take into account both climate change and DRR issues (Kiunsi et al., 2009).

Conclusions

Even though Tanzania is endowed with many natural resources, the main livelihood activities of majority of its people, i.e. rain-fed agriculture and livestock keeping, are still directly dependent on climate dynamics, especially rainfall. These activities are potentially becoming under greater threat from climate change and variability that is taking place in the country. Climate changes will impact or are already impacting on water resources, food crop production, livestock keeping, natural and semi-natural vegetation and coastal resources. Climate change will also lead to an increase in climate-related disasters including drought and flooding. In terms of administration, climate change and disaster issues are handled by two separate institutions. Due to the need for climate change mitigation and adaptation and also due to the need for including DRR in development planning, a number of vulnerability assessments are have been conducted under guidance of the two institutions. The Division of Environment has focused its assessments on climate change impacts and disaster management and the Ministry of Agriculture has focused on drought and its impacts and vulnerability of the local population. In Tanzania it appears that climate change, impact, mitigation and adaption are taken into account more than DDR issues. However, at the sectoral level – for example in urban planning – neither climate change nor DRR issues are being taken into account.

Acknowledgements

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14

Assessment of vulnerability to natural hazards and climate change in mountain environments

Stefan Schneiderbauer, Marc Zebisch, Steve Kass and Lydia Pedoth

Introduction

In recent years the focus of research dealing with responses to climate change has shifted from mitigation to adaptation (Schipper and Burton, 2009). While mitigation concentrates on the source of climate change, adaptation addresses its actual and potential consequences. Possible options for adaptations are numerous and selection of the most appropriate and more effective actions needs to take into account a variety of issues, such as the uncertainty of climate scenario outputs, the acceptance of the adaptation actions by those populations involved, the potentially negative side effects, etc. Decisions on adaptation actions and their timely implementation in appropriate locations and at suitable scales of time and space require the establishment of a supportive knowledge base (European Commission, 2009). This includes enhancing the understanding of the territorial distribution of vulnerability to climate change (Harvey et al., 2009). This chapter attempts to contribute to the growth of such a supportive knowledge base as well as providing a better understanding of and communication about vulnerability features, particularly in mountain regions and, specifically, the Alps.

Mountain regions represent hot spots of vulnerability relating to climate change and certain natural hazards, particularly those triggered by the force of gravity. This is: (1) due to their exposure to recent climate warming, and (2) due to the high degree of specialization of their ecosystems. For example, the temperature increase in the Alps has been

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

twice the global average during the last century, particularly threatening to alter hydrological conditions and processes (European Environment Agency, 2009). In reference to the overall vulnerability of a coupled human/natural system, the Alps represent an interesting case for the following reasons:

- They are relatively densely populated compared to other mountain regions, with a concentration of assets and infrastructure in the valley bottoms threatened by natural hazards.
- They are generally highly developed with a strong economy – both facts that strengthen their capacity to deal with and adapt to the threats of natural hazards and climate change.
- In a large number of areas they are strongly dependent on income from tourism, based on the natural attractiveness of the environment (including glaciers) and their supply of sport activities, namely skiing.

In addition, the Alps have received special attention concerning their exposure and sensitivity to climate threats during recent years. A number of studies and projects have been generated that focus either on a limited Alpine region (Pröbstl et al., 2008; Kromb-Kolb et al., 2001) or on a particular sector of concern (OECD, 2007; Zierl and Bugmann, 2005).

However, the methodology introduced here aims to support a holistic appraisal of mountain regions within the context of climate change and mountain-specific natural hazards. It allows for the consideration of various economic sectors or cross-sectoral topics of concern, which permits the integration of societal capacity to cope with and adapt to climate changes as well as the transferability of the overall methodology to non-mountain regions. Our approach has been developed within two projects dealing with the evaluation of Alpine regions' vulnerability to climate change.[1] The location of these regions is shown in Figure 14.1.

The appraisal of the vulnerability has been put into practice for a number of test case regions, each covering a NUTS 3 region in the Alpine Arc, or a certain part of it. One of these model regions lies within the Province of Bolzano (South Tyrol), providing a major study example for this chapter. The outcomes had to contribute to transnational analysis, focusing on commonalities, particularities and hot spots of vulnerability to climate change over the Alpine Arc. This called for a certain degree of methodological and procedural standardization of the vulnerability assessment and its components within the various model regions.

Climate change in the Alps

The Alpine region has undergone an exceptionally high temperature increase of around +2°C between the late nineteenth and early twenty-first

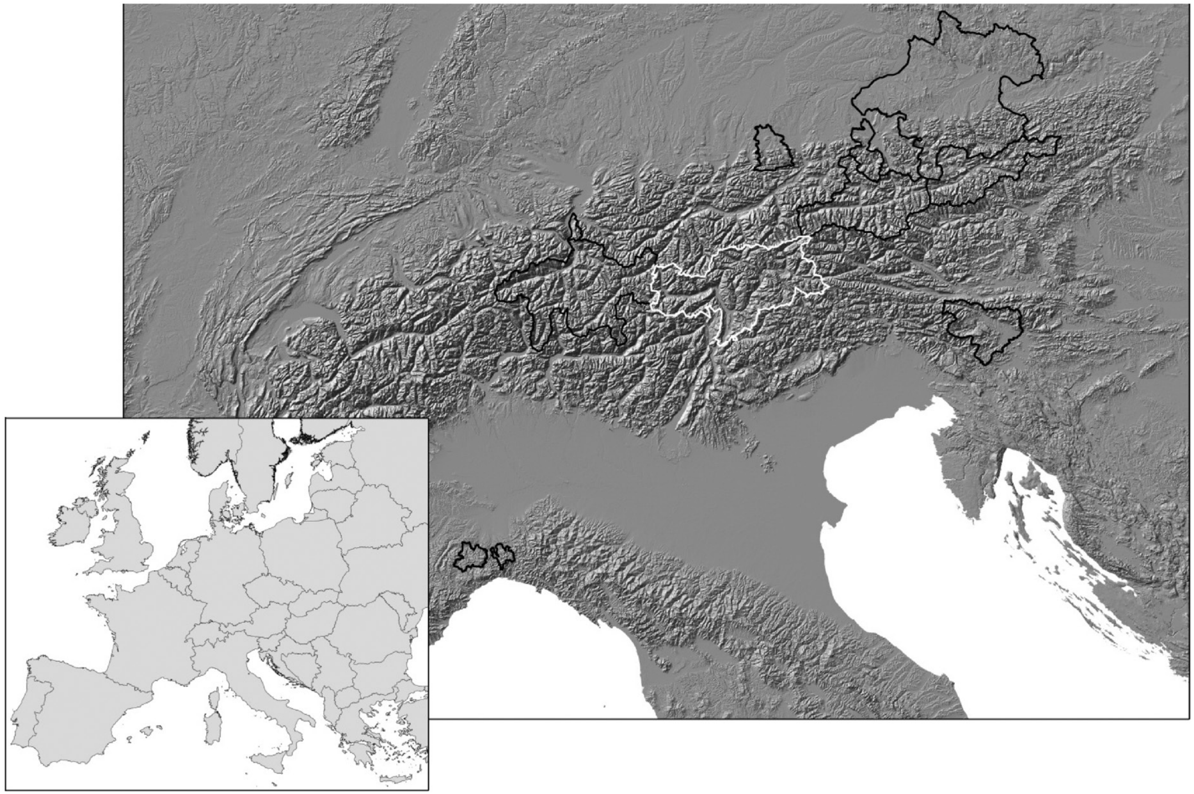

Figure 14.1 Location of test case regions of the projects CLISP and Climate change South Tyrol (South Tyrol bordered in white, the other test case regions bordered in black).

centuries, more than twice the rate of average warming in the northern hemisphere. Furthermore, a slight trend towards an increase in precipitation in the North Alpine Region with a decrease in the South Alpine Region has been recorded (Auer et al., 2007; EEA, 2009). Regional climate scenarios indicate a continuation of this exceptionally strong warming in future, with an increase in temperature of 1–3°C by 2050 and up to 6°C by 2100 (Van der Linden and Mitchel, 2009; Lautenschlager et al., 2005; Lautenschlager et al., 2009). In contrast to future scenarios of temperature development, projections for precipitation are less robust and subject to a high level of uncertainty, with partially contradictory results coming from various climate models. Nevertheless, many climate scenarios predict a decrease in summer precipitation and an increase in winter precipitation over the Alpine region. Even more critical is the interpretation of climate scenario results in order to determine changes in the frequency or severity of extreme weather events, such as heavy rainfall or storms. Small-scale processes that represent the main causes for these types of event, such as convective precipitation, cannot be properly simulated with the existing regional climate models. However, various authors suggest evidence of an increase in extreme events over recent years (for example, Schmidli and Frei, 2005) and assume a certain likelihood of future increase in frequency and strength of such extreme events (Dankers and Hiederer, 2008; Meehl et al., 2007; Hofstätter and Matulla, 2010).

Impacts of climate change

Direct impacts of climate change in the Alps and other mountain regions in similar climate zones can be allocated to three major factors:

- Changes in the water regime with a potential to cause water scarcity or floods;
- Increasing temperatures resulting in glacier melt, prolonged growing seasons, thawing of permafrost (with an increase in rockfall events), or heat-related health problems;
- Extreme weather events triggering natural hazards such as floods, avalanches or debris flows.

One of the primary anticipated impacts of climate change in the Alps is a change in water regime: a shift from snow to rain in winter with an increase in winter precipitation leading to less snow cover and more run-off in winter, combined with a decrease in water stored as snow, less precipitation and increased evapotranspiration values contributing to a reduction of run-off in summer.

Other major potential impacts include the following:

- Glaciers melting. This is one of the most obvious and prominent impacts. Between 1850 and 1980 glaciers in the European Alps lost approximately one third of their area and one half of their mass. Since 1980, another 20–30 per cent of the remaining ice has been lost. The hot dry summer of 2003 led to a loss of 10 per cent of the remaining glacier mass in the Alps (European Environment Agency, 2004).

- Snow reliability will decrease in ski resorts located at altitudes lower than 1800 m. Apart from some large ski resorts in Germany and Austria this will mainly affect smaller ski resorts (OECD, 2007).
- Natural hazards might occur more frequently and with higher intensity. More heat waves and droughts can be expected due to a shift to higher temperatures and lower precipitation in summer. Rockfall may increase due to thawing permafrost. Since this is a phenomenon limited to higher altitudes (above 2500 m), it mainly affects infrastructure (roads, ski resorts) and alpine tourism (climbing routes). Future projection of other hazards triggered by or correlated with extreme precipitation events such as flash floods, debris flows or avalanches, is highly uncertain. However, there is a likelihood of an increase in such phenomena, at least due to indirect influences (see for example Keiler et al., 2010).
- Change in the suitability of land for agriculture. In the case of temperature increase, the effects will be largely positive. The cultivation of orchards in the Alps, for example, has already reached new altitudes on mountain slopes. Negative impacts are expected in the case of reduced water availability, which will predominantly affect a small part of the central Alps (inner alpine dry valleys), which already have low precipitation levels.
- Heat and health. This is not an alpine-specific problem but does also affect the Alps. Most cities in the Alps (such as Bolzano, Innsbruck, Grenoble) are located at low altitudes affected by hot summers (40+°C in the year 2003). This is amplified by urban heat island effects and may cause various health problems and casualties.
- Biodiversity. The composition of alpine flora is already changing in the higher regions. In general, species from lower altitudes are migrating upwards and northwards. Eventually they will replace rare and protected species in the higher alpine areas. Currently, species of various altitudes co-exist and even enrich biodiversity (in numbers rather than in quality) (Grabherr et al., 2010).

The conceptual framework

There are numerous theoretical concepts that have been developed with the aim of supporting vulnerability determination by addressing the assessment of populations' or regions' vulnerability to external stressors and shocks (for example, Chambers, 1989; Turner et al., 2003; Wisner et al., 2004; Birkmann, 2006; Adger, 2006; IPCC, 2007; Bohle and Glade, 2008). These concepts have been analysed, compared, clustered and allocated to the various research communities from which they were stemming, such as the risk management community, the sustainable livelihood community or the social-ecology school (O'Brien et al., 2004; Hogan and Marandola, 2005; Birkmann, 2006; Birkmann et al., 2010; Romieu et al., 2010). Most of these framework concepts operate at meta-level and mainly support vulnerability assessments in their theoretical conceptualization and preliminary structuring of measurement approaches. However, precise rules of how to address the concrete determination of the individual underlying components and how to combine and/or aggregate them are largely missing (Harvey, 2009, Schneiderbauer et al., 2011). The application of these frameworks in practice is still a challenge.

The climate change community started off by developing its own theoretical approach, which has been established within the scope of the IPCCs assessment reports and widely disseminated. It is based on the definition of vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2007, p. 883. The main components of this concept are illustrated in Figure 14.2).

There are two major characteristics that distinguish this approach from most vulnerability frameworks developed by other research communities:

- The integration of the exposure part of the system, that is the inclusion of external pressures, shocks and/or stresses as one component of the vulnerability function.
- The explicit mention of adaptive capacity as a core component of vulnerability, which looks at the potential to reduce vulnerability in future times.

The methodology introduced in this chapter follows in principle the IPCC concept, while incorporating particular aspects of the risk management community approach. It takes into consideration the potential impact of sudden natural hazards as well as slow creeping changes. Within our work *exposure* describes the elements of climate change, caused by greenhouse gas emissions or other factors, that might change in the future. It comprises features such as temperature increase, decrease in summer rainfall and reduction of snowfall in winter. Within the context of sub-national vulnerability assessments, the exposure part of vulnerability is to a great extent independent from the geographical setting of the region concerned. The *sensitivity* component determines the potential im-

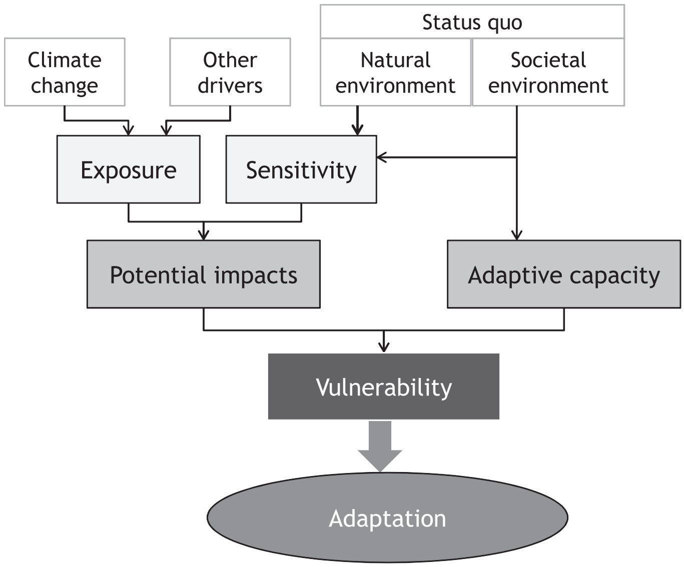

Figure 14.2 The components constituting vulnerability according to the definition of the IPCC (after Isoard et al., 2008, Schneiderbauer et al., 2011)

pact of climate change on the system under consideration "as it is", and therefore refers to the status quo. This includes all adaptation measures that have been taken in the past but excludes those actions that might be realized in the future. In contrast, the *adaptive capacity* takes into account potential additional adaptation activities and thus refers to the ability of the system to actively change. We consider only those aspects of the system that can be altered by potential future adaptation actions or measures as directly belonging to adaptive capacity (for example agricultural practices, the quality of early warning systems or the populations' awareness about possible adverse effects of climate change). Aspects that cannot be influenced by human interventions in a reasonable way or within a realistic time frame are regarded as part of sensitivity (for example the geographical setting or the altitude of the location of settlements) (Schneiderbauer et al., 2011).

Practical application of the framework – case study

We decided to consistently strive for the application of the IPCC (2007) concept within the scope of our vulnerability studies by addressing the four major elements of vulnerability: (a) exposure, (b) sensitivity, (c) potential impact and (d) adaptive capacity. As with most theoretical frameworks on this topic, the concept suffers from a lack of precision relating to the definition and explanation of how to combine individual components. In addition, it interprets vulnerability differently from other research fields, such as the risk management community or the sustainable livelihood community. Nevertheless, we selected this conceptual approach as a basis for our assessment as it is particularly valuable in evaluating and placing emphasis on how the potential impacts of climate change can be reduced by adaptation measures.

Focusing the assessment tasks

In order to focus the implementation of vulnerability assessments, we adapted the "issue concept" described by Harvey et al. (2009) and Schauser et al. (2010) and formulated three important questions that relate to the specification of vulnerability:

1. Who and what is vulnerable?
2. To which exposure/impact are these populations and elements vulnerable?
3. What geographical areas comprise vulnerable populations and elements and where are hot spots of vulnerability?

1. To answer this question, the assessments of vulnerability components were explicitly matched to selected sectors and systems of major concern. Within our study, and due to our particular focus on alpine mountain regions, these sectors and systems are agriculture, built-up areas/land development, energy, forestry, health, tourism and recreation, and water management.

2. For each sector/system identified (by responding to question 1), so-called conceptual impact chains were developed. These impact chains show cause–effect relationships and help to distinguish the more direct from the somewhat indirect effects of climate change for each sector. The identification of impacts was based on our own knowledge combined with a literature review. All subsequent assessment steps refer to these defined impacts (Figure 14.9 shows an example for the agriculture sector).

3. in order to be able to answer the last question, it is necessary to be as spatially explicit as possible. Intermediate assessment results, particularly those addressing potential impact and integrating datasets on the natural/physical environment, often provide information at a relatively fine spatial resolution and can therefore be mapped precisely. Assessments based on socio-economic data or qualitative information allow for a partial dis-

tinction at a certain sub-regional level and were used to map the final vulnerability results of each sector (see 14.11(c)).

Structuring the evaluation procedure

We proposed dividing the implementation of regional vulnerability assessments into eight working steps that help to structure the evaluation procedure into manageable individual tasks. Each of these tasks was carried out with a clearly defined objective and a specified methodology. The identification of these steps and the selection of the respective methods to carry out the required work were made based on the convictions that:

- Qualitative information, such as expert knowledge or stakeholder opinion, play an important role, particularly in a regional vulnerability assessment. Quantitative approaches, based on integrating climate scenarios outputs in statistical or physical models, are valuable and add a certain degree of objectivity to a vulnerability assessment. However, they are often not able to capture the complexity of the system and the relevant processes that render a sector vulnerable (for example, legal aspects of water management or the high water demand for frost sprinkling to protect orchards in early spring).
- The vulnerability of a system to climate change can to a certain extent be evaluated from knowledge of the status quo of the sector or system concerned, as well as its sensitivity to past weather and climate. For instance, if the agricultural sector in a given region is already in an economically critical situation having suffered from yield drops as a consequence of past dry summers, it can be stated that this sector is vulnerable to climate change, even without running detailed yield forecast models. In a similar way we assumed it very likely that a region that has had the resources, willingness and structure to adapt to stresses, shocks and changes in the past, would also be capable and willing to do so in the future.

Having pointed out the importance of qualitative information, it should be mentioned that a certain degree of ranking, quantification or measurement of vulnerability, or parts of it, significantly supports the identification of a system's weaknesses, the monitoring of the dynamic parts of vulnerability, and the comparison of aspects of vulnerability among regions or populations. However, there is no agreed integrated metric on how to quantify the vulnerability of a certain area to climate change. Since vulnerability is a theoretical concept, it cannot be measured directly in a way that an observable phenomenon such as temperature can be measured (Hinkel, 2010; Kienberger et al., 2009; Schauser et al., 2010).

Our approach was based on the development of a system containing a wide variety of indicators at different statistical scales. The evaluation, classification and aggregation of the values and characteristics of these indicators needed to be implemented as transparently and consistently as possible. Throughout the entire indicator system we applied a five-class evaluation scheme. Figure 14.3(c) illustrates the significance of the various classes for the evaluation of potential impacts and adaptive capacity indicators. When possible, directly measurable indicators, such as the number of households with internet access, were classed in comparison to average values of the same indicator at European or overall alpine levels. Detailed information about the applied evaluation criteria was always given with the results.

The aggregation of two indicator values at the various aggregation levels was predefined, as shown in the matrix of Figure 14.4(c) concerning the combination of potential impact and adaptive capacity.

The rules for initial evaluation and classification of indicators, as well as the allocated value resulting from an aggregation step, may be overruled by local experts or stakeholders in case of ambiguous classification or disagreement since the developed indicator system cannot account for all local particularities. We are aware that these rules for assessment and aggregation introduced a strong subjective component into the vulnerability assessment. The proposed eight working steps for the implementation of regional vulnerability assessments are as follows:

Step 1: Exposure – climate scenarios

Exposure includes all elements of expected climate change: for example, increase of temperature, decrease of rainfall in summer, reduction of snowfall in winter. The results should be derived from regional climate scenarios and should include different emission scenarios. Due to a high uncertainty in regional climate models it is recommended to use various combinations of driving General Circulation Models (GCM) and Regional Climate Models (RCM). A good source for regional climate projections is the European Commission's Framework Programme 6 project ENSEMBLE (Van der Linden and Mitchel, 2009). For specific applications the climate scenarios need to be downscaled to regional level by, for example, statistical downscaling methods (Wilby et al., 1998).

Step 2: Selection of sectors/system under concern

A vulnerability assessment can never provide an insight into the entire system considered and thus needs to focus on selected systems/sectors. Usually, local knowledge or estimates exist relating to sectors/systems that are particularly sensitive to climate change. This pre-existing knowledge can serve as a starting point for decision-making about what should be more closely investigated. Alternatively, certain sectors are of definite

Color code	significance – potential impact	significance – adaptive capacity (for measures)
	apparent positive impact	Very high (already implemented to a large extend)
	possible positive impact	High (partly implemented)
	no likely significant effect	Moderate (planned, decision for implementation open)
	possible negative impact	Low (in planning but not implemented yet)
	apparent negative impact	Very low (not implemented and no implementation planned)

Figure 14.3 Evaluation criteria and class description for indicator assessments (considering potential impacts – left and adaptive capacity – right).

Please see page 677 for a colour version of this figure.

potential impact \ adaptive capacity	--	-	0	+	++
--	--	--	--	--	-
-	--	-	-	0	0
0	0	0	0	0	0
+	0	0	+	+	+
++	+	++	++	++	++

Figure 14.4 Matrix for the allocation of class values within aggregation steps

Please see page 678 for a colour version of this figure.

importance for the region and are therefore designated for a scrutinized vulnerability check.

Step 3: Definition of impact chains

It is recommended that so-called conceptual impact chains should be developed for all sectors and systems of concern. These impact chains permit the structuring of cause–effect relationships and allow for visualization of interrelations and feedbacks. This supports the selection of the most relevant impacts, to which the entire set of subsequent assessment steps (potential impact and adaptive capacity) is related (see Figure 14.9).

Step 4: Qualitative assessment of status quo, sensitivity and potential impact

Qualitative information has to be collected in a structured and standardized way (ideally supported by a guideline or a manual) through expert interviews and stakeholder workshops. For each sector of concern the results of this exercise should provide information about the general status quo (unfavourable/favourable), the general sensitivity to certain weather and climate conditions (lessons from the past) and an assessment of recent and potential future trends, considering the impacts defined in the impact chain.

Step 5: Quantitative assessment of potential impact

For selected impacts, simple indicators and models are used to analyse the potential future impacts, based on regional climate scenarios. The outcomes of these scenarios are more robust when projecting variations in temperature (compared to alterations in precipitation amounts). Hence those indicators based on temperature change are most likely to represent future realities. Impacts that can be modelled in a reasonably simple way within the scope of a generic vulnerability assessment include, for instance, changes in the length of the growing season or changes in snow reliability at ski resorts. In contrast, it is very difficult to project the changes in severity and frequency of natural hazards, particularly the most common gravitational threats in mountain regions (such as rockfalls, debris flows, avalanches, landslides) because these hazards are part of complex processes closely correlated with extreme precipitation events (an exception constitutes some processes that are directly linked to permafrost thaw). Assuming that there is a general tendency for an increase in such events, bad or worse case scenarios of existing hazard indication maps may hint at areas newly affected by certain hazards.

Step 6: Integrated impact assessment

In a final step, the results of the qualitative and the quantitative assessments of steps 5 and 6 are summarized in a matrix, evaluated in a criteria-based process and classified according to predefined rules. We found a consistently applied 5-class system to be the best compromise between loss of detail due to simplicity and loss of comprehension and reducibility due to complexity.

Step 7: Adaptive capacity assessment

In accordance with the main structure of the regional vulnerability assessment that follows a set of selected sectors and impacts of concern, we recommend distinguishing three conceptual and pre-analytical levels of adaptive capacity with a decreasing degree of specificity (see Figure14.5).

1. *The impact specific* adaptive capacity is related to particular climate change impacts, identified as either intermediate or endpoints of impact chains.
2. *The sector specific adaptive capacity* represents the adaptive capacity of a certain sector within a model region but not directly linked to an individual potential impact as considered at the first level.
3. *The regional generic adaptive capacity* represents the adaptive capacity of a specific test case under consideration. The regional generic adaptive capacity is not directly linked to any specific sector or potential impact and addresses underlying contextual issues related to the societal environment.

For each level of adaptive capacity, various topic dimensions of relevance have been selected from which a number of indicators and criteria have

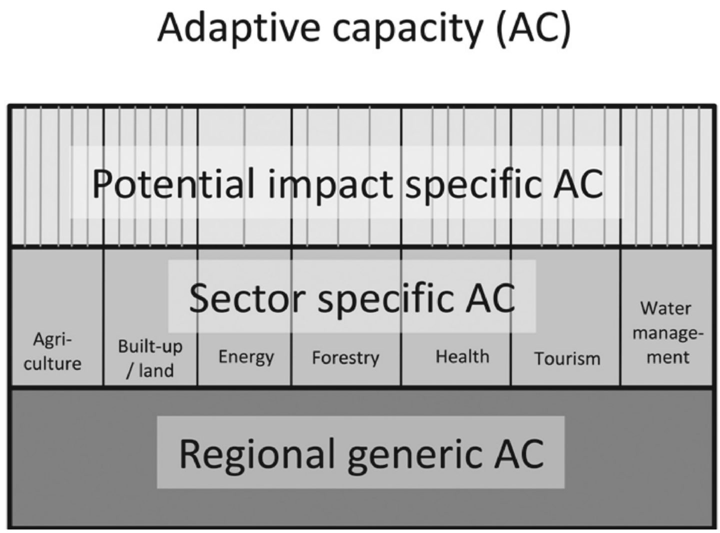

Figure 14.5 The three levels of specificity for adaptive capacity (AC) within regional vulnerability assessments (at the intermediate level the selected sectors for the test region South Tyrol are named) (Schneiderbauer et al., 2011)

been identified to describe them. Each indicator has been assessed and classified according to predefined thresholds and rules that are based on existing statistics (for example, percentiles of values of all European regions for the same indicator) or on stakeholder and expert opinions. Concrete adaptation measures are additionally assessed according to their effectiveness, cost and degree of implementation within the model region. For a more detailed discussion see Schneiderbauer et al. (2011).

Step 8: Aggregation of components and vulnerability assessment

In this final step the results of the various assessments of the components of potential impacts and adaptive capacity are aggregated to form an overall vulnerability description per sector of concern. Similar to the three levels of specificity of the adaptive capacity, we recommend introducing two levels of aggregation: the potential impact and the sector level. In practice, this means first combining the assessment of each potential impact with the respective assessment of the impact-specific adaptive capacity. This leads to an overall impact-specific vulnerability per sector that is then combined with the adaptive capacity assessment of this sector. The result of this combination represents the vulnerability of the region to this specific sector. The overall regional vulnerability is then determined by assessments of the sectors of concern. The adaptive capacity at regional level is then additionally considered. Figure 14.6 illustrates the aggregation steps proposed within this working step.

Case study South Tyrol

This section describes the application of the proposed vulnerability assessment approach, and its individual working steps as listed above, within the test region of South Tyrol. The assessment was carried out for eight sectors of concern of which the sector agriculture was selected to be illustrated here.

The Province of Bolzano, also known as South Tyrol, is the northernmost province of Italy, bordering with Austria on the north and east, and with Switzerland on the West (Figure 14.1). The province has an area of 7,400 km^2 and a total population of ca. 500,000. South Tyrol's geographical setting is typical for an alpine region, with altitudes ranging from 200 m above sea level in the southern Adige Valley to 3,905 m in the Ortler region; 86 per cent of the total area is above 1,000 m. South Tyrol shows a typical horizontal structure, with densely populated and intensively used valley bottoms (vineyards and fruit orchards in the south and west, intensively farmed grassland in the north and east). Plateaus on lower mountain ranges (between 1,000 m and 1,600 m) are dominated by intensively farmed grasslands. Adjacent there is a forest belt (between 1,400 m to almost 2,000 m) and an Alpine zone with pastures, dwarf shrubs, natural grasslands, rocks and glaciers. The climate varies from warm and dry inner alpine valleys in the west, with less than 500 mm precipitation, to a cooler and wetter climate in the east receiving more than 1,000 mm precipitation.

Step 1: Exposure – analysis of climate change scenarios

Quantitative scenarios from eight regional climate model runs for the most important climate elements were calculated. These contained a spatial resolution of between 10 × 10 km to 25 × 25 km for the time periods 2011–2030 and 2031–2050 from FP6 Ensemble (van der Linden and Mitchel, 2009) and other sources (Lautenschlager et al., 2005; Lautenschlager et al., 2009). The single scenarios differ in: (a) the underlying SRES emission scenario (B1 – low emission scenarios, A1B – moderate/high emission scenarios), (b) the driving General Circulation model (GCM) (ECHAM5, HadCm3, ARPEGE) and (c) the applied Regional Climate Model (RCM) (REMO, CLM, RegCM3, ALADIN). All parameters were calculated in terms of an absolute change from the reference period (1961–1990) to the 20-year mean of two future periods (2011–2030; 2031–2050).

Based on the analysis of eight climate scenarios, temperatures show a clear warming trend in all seasons with a more pronounced warming

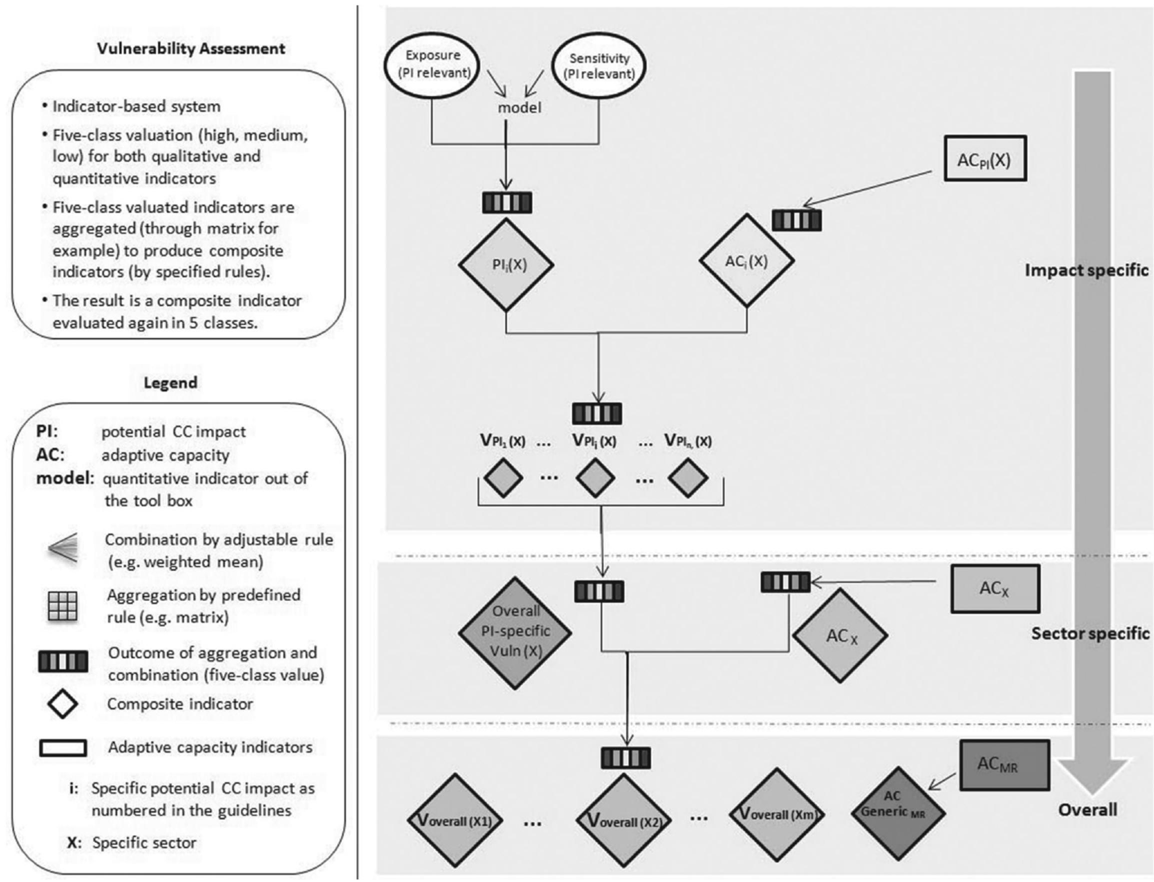

Figure 14.6 Illustration of aggregation flow of potential impact and adaptive capacity assessment within a generic regional vulnerability assessment

after 2030. Temperatures increase by between +1°C and +2°C (up to +2.9°C in summer) up to 2050 (see Figure 14.7(c)).

Precipitation shows a quite heterogeneous picture, with no very clear trend. Among the A1B scenarios, precipitation tends to decrease in summer (5 out of 6 A1B scenarios, up to −51 mm). In winter a slight increase is visible. Spring and summer show no clear trend with partly contradicting patterns (see Figure 14.8(c)). Furthermore, all scenarios indicate a shift from snow to rain in winter and early spring (not shown).

Step 2: Sector of concern

Within the study all sectors listed under "Focussing the assessment tasks" were considered. The sector of concern chosen here is agriculture as it represents an important economic sector in South Tyrol, not only due to its contribution to the regional income but also based on its historical significance, its influence on the current landscape and on the society's sense of identity.

Step 3: Impact chain

For the agriculture sector, the following climate change impacts were considered as relevant:

- A1. Changing growing season/agrophenology/agrometeorology. The timing of the crop cycle (agrophenology) determines the productive success of the crop.
- A2. Increase in water demand. Reduced rainfall, drought and heat waves affect water retention capacity as well as soil moisture content and increase the requirement for irrigation. Risk of droughts/crop damage
- A3. New crop varieties and location of production. Shift to higher elevation zones (for example. apples, grapes).
- A4. Changes in crop yields.
- A5. Increase of damage due to higher frequency and intensity of meteorological extremes (frost, hail, storm) and natural hazards (floods, torrential processes, avalanches, rockfalls).
- A6. Increase of pest and diseases.

Figure 14.9 illustrates the impacts A1–A6 including the driving exposure and intermediate impacts.

Step 4: qualitative assessment of status quo, sensitivity and potential impact

The qualitative assessment was performed in a series of expert interviews and a stakeholder workshop, with a focus on the status quo and lessons learnt from the past.

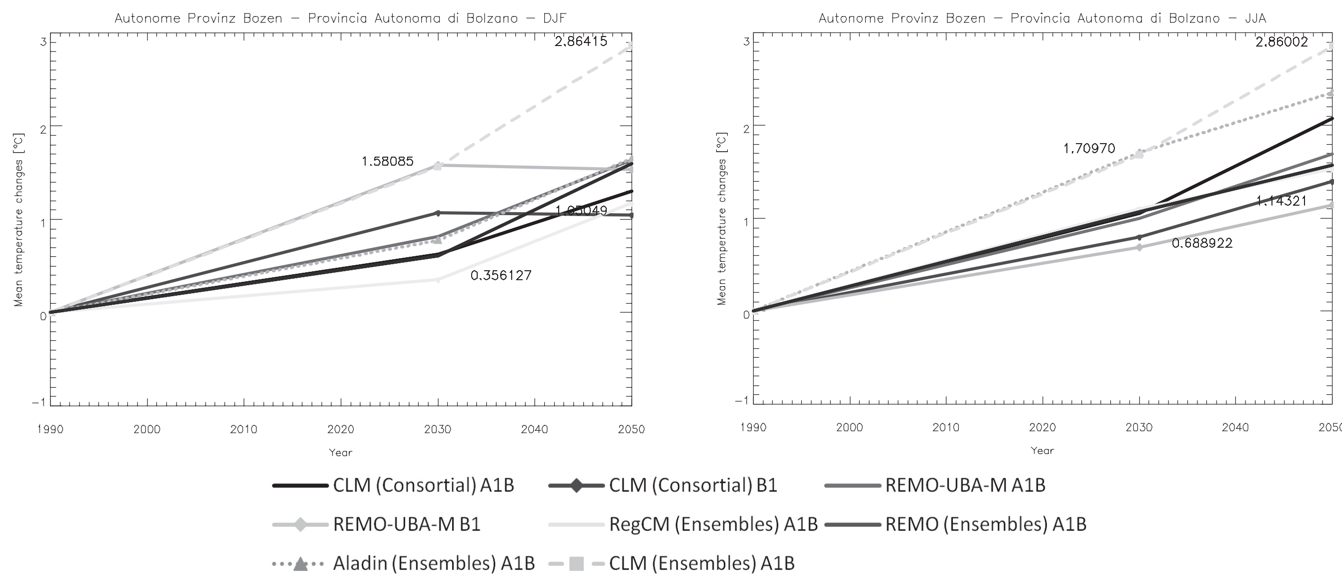

Figure 14.7 Changes in temperature up to 2050 according to eight climate scenarios from ENSEMBLE, CLM Consortial and REMO-UBA for winter (left) and summer (right)

Please see page 679 for a colour version of this figure.

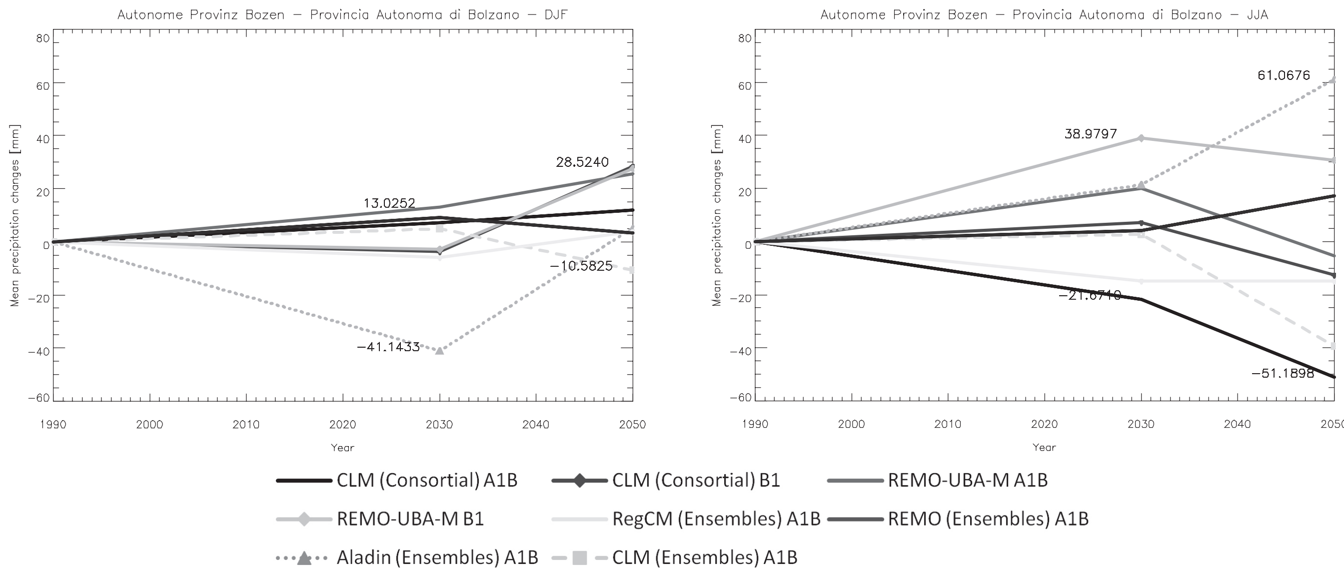

Figure 14.8 Changes in precipitation up to 2050 according to eight climate scenarios from ENSEMBLE, CLM Consortial and REMO-UBA for winter (left) and summer (right).

Please see page 680 for a colour version of this figure.

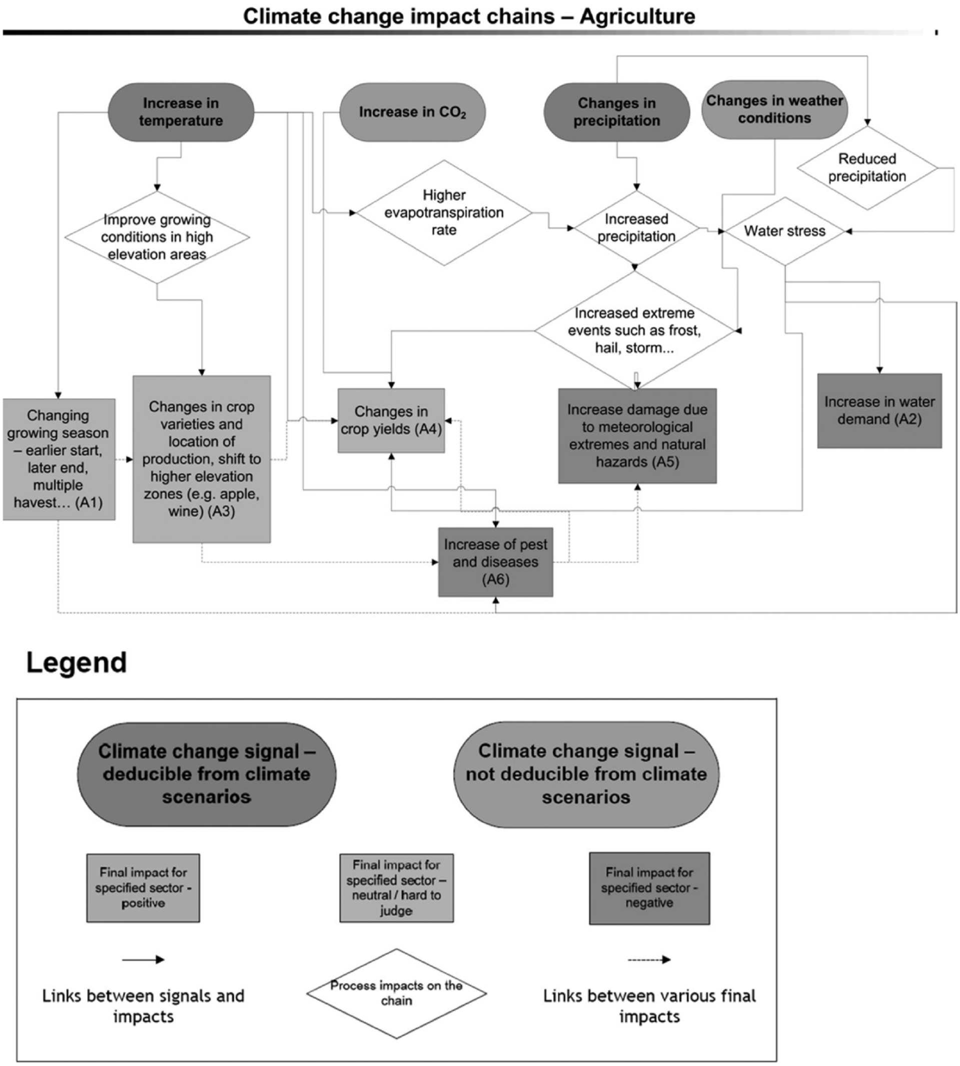

Figure 14.9 Impact chains for the sector agriculture

- General status quo of the sector: Agriculture is a key economic sector in South Tyrol, boasting high value-added production (apples, wine, animal breeding) and supporting other sectors of the local economy. including tourism and land management, against natural hazards. Generally, agriculture relies on irrigation fed by the current relatively abundant water flows. Yields and economic trends indicate grape and fruit cropping bear high values, while pastures are far less profitable. Subsidies from the state (through the CAP and additional subsidies directly managed by the province) allow for a relatively high percentage of employees in agriculture.

- A1. Changing growing season. It turned out that the growing season has already changed significantly, with earlier blossoming and earlier harvest (for example, grapes by more than 10 days) in the last decades. This is usually regarded as positive but might also go hand in hand with a decrease in quality for certain products in particular regions (for example, apples need cool days before harvesting for best quality. In the southern parts of South Tyrol temperatures have recently been too hot during the harvest period).
- A2. Increase in water demand. Between 2000 and 2006 a series of dry summers has already led to a reduction in yields. Grasslands in dryer regions which rely on irrigation fed by surface water (which has become rare in recent years), and grasslands in moderate climates which are not yet equipped with irrigation, are suffering most.
- A3. New crop varieties and the location of production. Orchards have already expanded significantly into higher regions, which is advantageous from an economic point of view. On the other hand, orchards depend heavily on sufficient water for irrigation, which might become a problem in some of the newly developed regions.
- A4. Changes in crop yields. Higher temperatures are in general regarded as positive for crop yield, where water is not the limiting factor.
- A5. Increase of damage due to meteorological extremes and natural hazards. Orchards and to a lesser extent, vineyards, are very sensitive to damage by hail. This has been a topic for South Tyrol for a long time, and large investments have been made for hail protection. No reliable statistics exist about trends in hail damage.
- A6. Increase of pests and diseases. Within orchards some pests and diseases that are new to South Tyrol have been reported. The regional experts believe that this can at least partly be related to climate change.

Step 5: Quantitative assessment of potential impact

For the impacts A1–A3 a series of indicators have been calculated based on the climate scenarios introduced in Step 1 in order to address these impacts quantitatively.

- A1. Changing growing season. Projected change in growing seasons shows a prolonged growing season by 10–25 days up to 2030 and 18 to 42 days up to 2050.
- A2. Increase in water demand. Water demand was assessed by the meteorological water balance, which is defined as the difference between

the sum of precipitation and the sum of potential evapotranspiration. Both aspects, a reduction in rainfall and an increase in potential evapotranspiration, contribute to higher demand for irrigation water. Due to the variety of precipitation projections and their uncertainty, trends remain unclear and range from a potential increase in the meteorological water balance of up to 100 mm in 2050 to a decrease of about the same amount by the same year.

- A3. New crop varieties and location of production. As an example, for a crop suitability index we calculated the Huglin Index, which reflects the growth reliability of various types of grapes. The Huglin Index takes into account the sum of mean and maxima daily air temperature during the period of April to September. In all scenarios the reliability increased significantly, indicating a potential for future expansion of vineyards.

Step 6: Integrated impact assessment

The quantitative indicators suggest trends of a warmer climate and a reduction in water availability. Projected changes were assessed as moderate rather than extreme. It could be implied that the agricultural sector in South Tyrol, which is presently water-rich, would suffer from a possible but not certain impact due to less available water. A warmer climate implies more opportunities for diversified cropping, especially in the upper valleys where present conditions are limiting for agriculture. However, this theoretically positive effect does not correspond automatically to a positive impact, as other factors such as soil or morphology might still be limiting. Moreover, it is not certain whether the crops of these possible new agricultural areas in the upper valleys would be capable of competing with those crops currently sold on the market. Therefore, the positive impact was judged only as a possibility without certainty. As a result, the impacts A1 (prolonged growing season) and A3 (new crop varieties and locations) were assessed as possibly positive while the impact A2 (water demand) was assessed as possibly negative.

The other potential impacts of concern within the agriculture sector were exclusively assessed based on qualitative information (see Step 4), resulting in "no likely significant effect" for A4 (crop yields) and "possibly negative" for the impacts A5 (meteorological extremes and natural hazards) and A6 (pests and diseases).

Overall, the potential impacts of concern were judged to be relatively neutral for the agriculture sector, insofar as positive and negative impacts would be of equal importance, resulting in a neutral impact assessment for the sector as a whole (see Figure 14.10).

Step 7: Adaptive capacity

The dimensions identified and the indicators selected for evaluating them within the agriculture sector are listed in Table 14.1. The assessment was based on existing regional statistics as well as on the outcomes of a workshop and several interviews. The assessment results can be summarized as follows.

Relatively good socio-economic position due to financial subsidies, the demographic situation and the strong cultural identity in South Tirol.

- Compared to other alpine regions the socio-economic circumstances are relatively positive. However, many agricultural activities would be economically unviable without subsidies.
- There is potential for improvement in awareness-raising and legislative as well as institutional measures.
- In general, a number of measures have been taken in the past to protect agricultural activities from external stressors, though this was done without considering climate change.
- There is a lack in prevention of meteorological extremes.

Overall, the adaptive capacity to address individual potential impacts has been assessed as slightly positive for the impacts A1–A4 and neutral for the impacts A5 and A6. The comprehensive assessment of the adaptive capacity of the agriculture sector in general and relevant generic adaptation measures has been defined as "neutral" (see Figure 14.10).

Figure 14.10 illustrates the assessment and aggregation flow of indicators within the agriculture sector. It follows the logic of combining indicators and components as described above and shown in Figure 14.6 and applies the matrix explained in Figure 14.4(c). The upper part of Figure 14.10 shows the separate aggregation of individual potential impacts and the respective adaptive capacity evaluation (here for the example A2 "water demand"). The two resulting values are combined into one assessment of vulnerability to the specific impact. The lower part shows this latter combination for all other impacts of concern. The lowest rows represent the overall assessment of the adaptive capacity, the potential impacts and finally the vulnerability of the agriculture sector.

Step 8: Vulnerability assessment

The overall description of the vulnerability of the region South Tyrol relating to the sector agriculture is a summary of the results of steps 4–7. It reveals a moderate to low vulnerability due to only moderate impacts and a moderate to high adaptive capacity. Most important issues in the findings of the assessment may be summarized by division into "Strengths and Opportunities" and "Weaknesses and Threats".

Table 14.1 Dimensions and indicators for the sector agriculture related to the adaptive capacity levels 1 "impact" and 2 "sector"

Agriculture			
Impact Specific Level		I	
Dimension	Indicator/Measure		
Changes in agricultural practice	Change agriculture practice according to seasonal changes	I1	a
	Increase crop diversity		b
Measures for adapting to reduced water availability	Enhancing residual soil moisture	I2	a
	Increase of water storage		b
	Corporation plan for stakeholders		c
	Changes/improvements in irrigation system		d
Changes: crops and land	Shift of crops/agricultural land due to warming	I3	a
Sector Specific level		S	
Dimension	Indicator/Measure		
Awareness/education	Existence/amount of workshops/round tables	S1	a
	Number and scientific level of studies, projects, university courses		b
	Scientific support/consultancy/training for farmers		c
Legislative, regulatory and institutional	Laws, regulations at national or regional level and/or administrative authorities dealing with CC and agriculture	S2	a
	Number of farmer associations, cultural practices for facing difficulties		b
Prevention of damage due to meteorological extremes and natural hazards	Existence of early warning system	S3	a
	Risk coping production systems		b

Dimension	Indicator		
Legislative, regulatory and institutional	Financial support/subsidies for new methods/species Water rights/procedures for water management	S4	a b
Economic	Farm size: average cultivated land/farm *and/or* number of cattle Agriculture as secondary occupation (trend over last 10 years) Assurance system for farmers	S5	a b c
Adapting to reduced water availability	Proportion of irrigated areas	S6	a

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<tr><th colspan="6">Sector background</th><th colspan="8">Sector measures</th><th colspan="6">PI Measures</th></tr>
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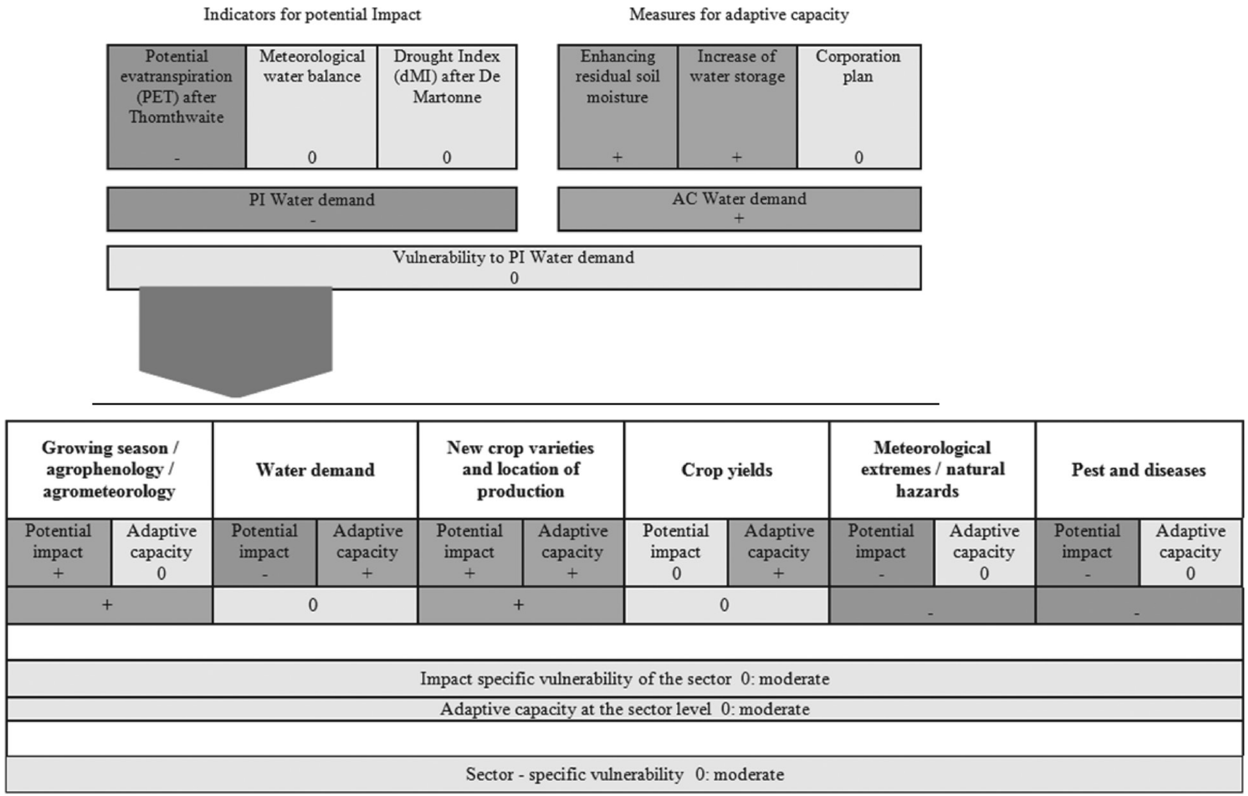

Figure 14.10 The assessment and aggregation flow of indicators within the sector agriculture applying the logic of Figure 14.3 and the matrix of Figure 14.4.

Strengths and opportunities

- Good implementation of adaptation measures, even if not undertaken as a result of climate change;
- Relatively good socio-economic position due to financial subsidies and the cultural and demographic situation → moderate to high sectoral adaptive capacity;
- Increased crop yields and potential new crops (orchard and vineyards instead of grasslands) due to a longer growing season and warmer temperatures at higher altitudes when there is enough water.

Weaknesses and Threats

- Lack of prevention measures against meteorological extremes and natural hazards → high vulnerability to these factors;
- Relatively weak implementation of legislative and institutional measures (for example subsidies linked to climate change adaptation);
- High vulnerability towards critical water availability, even if adaptive capacity is moderate to high for:

  irrigated mountain grasslands in dry areas,

  newly established permanent cultures in areas with limited water supply,

  non-irrigated cultures in areas with only moderate precipitation.

A number of these issues are valid for the whole region of South Tyrol or cannot be easily represented in a spatially explicit manner. However, it is possible to roughly allocate the vulnerabilities of the two main messages derived from the assessment of the impact A1 and A2 in a spatial manner:

- A1 potential positive effect due to warmer temperature in higher altitudes;
- A2 potential negative effect due to increased water demand.

We mapped these vulnerabilities by placing symbols representing the respective sector in colours corresponding to the vulnerability assessment in the appropriate areas of the studied region (Figure 14.11(c)). In this way we avoided delineating sharp borders on the map that would suggest spatial borders that do not exist in reality. The simplicity of the maps may also support non-expert decision-makers and trigger motivation to examine underlying information.

Conclusions

Conceptual frameworks developed for vulnerability assessments to climate change provide support for theoretical conceptualization and preliminary

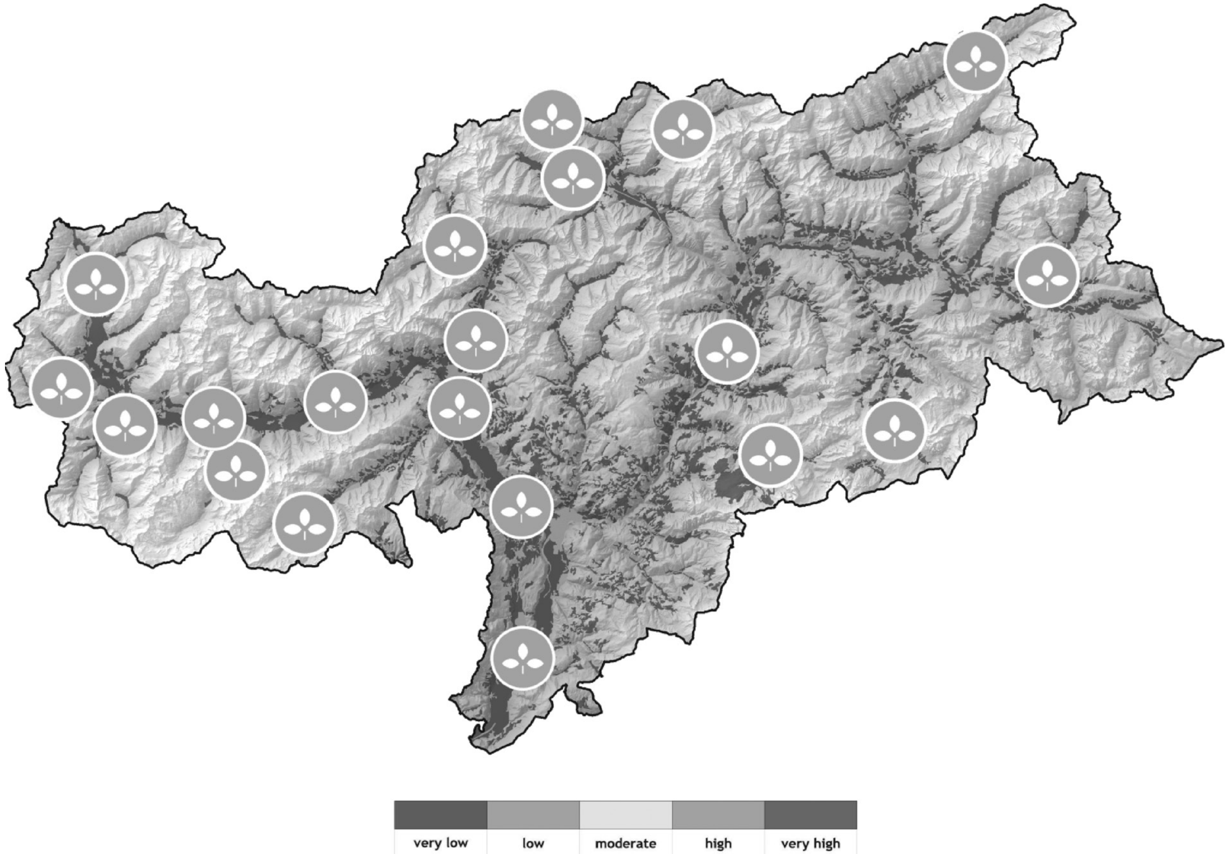

Figure 14.11 Final vulnerability map of the sector agriculture for South Tyrol

Please see page 681 for a colour version of this figure.

structuring of measurement approaches. However, they lack precise rules for addressing the concrete determination of the individual underlying components or their aggregation. The translation of these frameworks into methods and tools that allow for the measurement of vulnerability to climate change in practice and in a holistic manner requires additional resources and expertise.

When applying the IPCC framework in practice, climate scenarios are available for projecting development of future exposure. However, apart from demographic future scenarios there is hardly any dataset available that would permit assessment of future adaptive capacity. In other words, although we attempted to address the potential of future harm, we tried to do this using datasets of the past or at best with data describing the present situation.

The implementation of vulnerability assessment may be structured by posing key questions and following a series of work steps that contain concise tasks, objectives and allocated methodologies. Qualitative information, such as expert knowledge or stakeholder opinion, plays an important role when selecting sectors and impacts of concern, as well as for assessment and aggregation. Indicator systems are useful when attempting to rank, monitor or compare vulnerability aspects. One of the main challenges is the selection of such indicators and the determination of thresholds for their assessment, evaluation and ranking.

Climate scenario outputs are highly uncertain, particularly when precipitation levels and extreme events are considered, less so when regarding temperature. Both of the former aspects are important drivers for a large number of potential impacts. As a consequence, the integration of climate scenario signals into models dealing with the extent or frequency of natural hazards is questionable since these scenarios do not provide data of sufficient quality (resolution, accuracy).

In contrast to the limitations of quantitative outputs of scenarios and models, the qualitative information has the potential to describe complex phenomena in a more suitable way. We therefore recommend pragmatism; do not hesitate to use qualitative data and expert opinions as assessment sources when appropriate.

Vulnerability assessment by indicators and criteria can contribute to generating knowledge relating to vulnerability hot spots and their dynamics and can support awareness raising. If indicators for evaluating adaptive capacity are selected meticulously and local peculiarities are taken into account, the assessment can be used to point out appropriate measures in reducing impact and adapting to potentially adverse change.

Notes

1. CLISP (Climate Change Adaptation by Spatial Planning in the Alpine Space) financed by the European Commission through the Alpine Space programme (Territorial Cooperation IV), running from 2008–2011. [www.clisp.eu/content/]
2. "Klimawandel Südtirol" (= climate change South Tyrol) financed by the Autonomous Province of Bolzano, running from 2009–2011.

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Part IV

Local vulnerability assessment

15

Community-based risk index: Pilot implementation in Indonesia

Christina Bollin and Ria Hidajat

Introduction: Why do we need a disaster risk management index at the local level?

Traditionally disasters were viewed as isolated natural events, and few linkages were made to the circumstances of the people affected. Technical solutions prevailed, and the relief and rehabilitation measures that were normally taken were intended to restore pre-disaster conditions. Since the United Nations' International Decade for Natural Disaster Reduction (IDNDR) in the 1990s, and more recently under the UN-International Strategy for Disaster Reduction (ISDR), the paradigm has shifted towards an approach that is more development oriented. It incorporates hazard mitigation and vulnerability reduction concerns, and combines technical and scientific experiences, with special attention given to social, economic and ecological factors (UNISDR, 2004). The aim is to achieve comprehensive disaster risk management.

Another shift in disaster risk management occurred due to the growing evidence that prevailing top-down approaches in disaster risk management may lead to inequitable and unsustainable results. Many such programmes fail to address the specific local needs of vulnerable communities, ignore the potential of local resources and capacities, and in some cases even increase people's social and economic vulnerability (GTZ, 2004a).

The approach designed to reduce the local population's risk is called community-based disaster risk management (CBDRM). It aims to reduce

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

vulnerabilities and increase the capacities of households and communities to withstand damaging effects of disasters. Such a system contributes to people's empowerment and participation in achieving sustainable development and sharing its benefits (GTZ, 2003). According to IDNDR, the benefits of CBDRM are as follows:

- Communities are knowledgeable about their own environment. They are rich in experience of coping with emergencies. Community coping methods have evolved over time and demonstrated that they are best suited to the local economic, cultural and political environment.
- This approach has the benefit of enabling communities to be less dependent on relief during disaster periods and to increase their capacities to support their own livelihoods.
- Interventions with community participation have the potential to positively address general socio-economic concerns. Participation will empower the community with new knowledge and skills and develop the leadership capability of community members, and so strengthen their capacity to contribute to development initiatives.
- The impact of disaster situations on women, and also on women's concerns and capacity to cope and contribute, is different from that on men. Community-based approaches, which recognize this concern, have the potential to contribute towards the social issue of gender equity (GTZ, 2004b).

In addition to the community itself, the local government plays an important role in the CBDRM process. This is especially true following decentralization, which transfers power and responsibility from the national level to lower-level government units. They have the overall responsibility for delivering basic services for public safety and for supporting the general well-being of the community and its development. Local government is therefore an integral part of the CBDRM process in the community. It has the responsibility for institutionalizing local and community-based disaster risk management into the formal disaster management and development planning processes and system. It provides the policy and legislative environment that enables the community to become involved in disaster risk management.

To respond to the community-based approach and the increasing decentralization of many developing countries, the Inter-American Development Bank (IDB) in 2003 requested the Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation Agency, today GIZ) to conduct a study on "Comprehensive risk management by communities and local government" (Bollin et al., 2003) to suggest strategies and measures to strengthen local actors' capacities for disaster risk management. The study analyses institutional settings for decentralized disaster risk management systems and suggests a coherent system for developing capacity and financial resources for making decentralized disaster risk management viable. Furthermore, it presents a community-based Disaster Risk Index, which will make it possible for local governments to manage and monitor local disaster hazards and vulnerability in a comprehensive and sustainable manner.

In this chapter we present the Disaster Risk Index. The index is based on a comprehensive indicator system, which makes it possible to gather important data on local disaster risk and to identify the main risk aspects in cooperation with the community. For this purpose a questionnaire has been developed. The indicator system provides the necessary inputs for the calculation of the index to make possible, for example, a comparison between communities. First we will present the conceptual framework and the indicator system. Afterwards, the method of calculating the index is described. As this theoretical approach was verified for the first time for its application in 2003/04 in a pilot project in Indonesia, in our conclusion we will describe some lessons learned and future challenges. In order to build support for the approach and improve the application of the method, GIZ and the authors are interested in an exchange of best practice and lessons learnt.

Conceptual framework of a community-based indicator system

A community-based indicator system was developed to improve the capacity of communities and local governments to measure key elements of their current disaster risk. Using indicators at the community level in this context is still a innovative approach. The purpose of the study was to propose a methodology for use at the community and local government level that can guide decision-makers in their efforts to reduce and manage risk to natural disasters. The following conceptual framework (Figure 15.1) systemizes the key elements of risk management into the factors of hazard, exposure, vulnerability, and capacity and measures.

The framework helps to clarify the driving forces (factors) at work and serves to identify appropriate indicators. The resulting indicator system comprises a total of 47 individual indicators, arranged according to the identified four main factors and further broken down into factor components. Table 15.1 – the set of community-based disaster risk indicators – presents the indicators in brief, grouped according to the main factors and factor components. A more detailed "application guide and indicator description sheet", which also discusses the rationale and validity of the indicators, is available.[1]

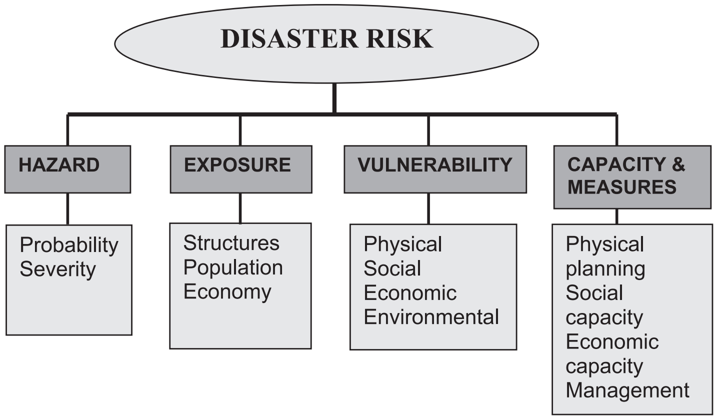


Figure 15.1 The conceptual framework to identify disaster risk
Source: Davidson, 1997: 5; Bollin et al., 2003: 67.

For each indicator, cut-off points have to be identified that result in low/medium/high classes. This gives the local government immediate feedback on whether their community is at the lower, middle or upper level with regard to a particular aspect of the indicator. The selection and formulation of the indicators were guided by the principle that the system needs to be applicable in data-scarce environments.

The indicator system is expected to bring benefits by:

- improving the capacity of decision-makers at local and national levels to measure key elements of disaster risk and vulnerabilities for communities;
- providing comparative parameters for monitoring changes in disaster risk as a measure for evaluating effects of policies and investments in disaster management;
- highlighting the major deficiencies in confronting natural disasters and thus indicating possible areas of intervention;
- systemizing and harmonizing the presentation of risk information from the community level.

Towards a community-based risk index

The indicator system can provide good insights into the current situation of a community with regard to the factors that determine risk, and makes it possible to track changes in those factors over time. However, in order to be able to compare different communities and to facilitate interpretation of the data, an indexing system has been proposed that will condense

Table 15.1 Set of community-based disaster risk indicators

Main factor and factor component	Indicator name	Indicator
HAZARD		
Probability	(H1) Occurrence (experienced hazards) or	Frequency of events in the past 30 years
	(H2) Occurrence (possible hazards)	Probability of possible events. Chances per year
Severity	(H3) Intensity (experienced hazards) or	Intensity of the worst event in the past 30 years
	(H4) Intensity (possible hazards)	Expected intensity of possible events
EXPOSURE		
Structures	(E1) Number of housing units	Number of housing units (living quarters)
	(E2) Lifelines	% of homes with piped drinking water
Population	(E3) Total resident population	Total resident population
Economy	(E4) Local gross domestic product (GDP)	Total locally generated GDP in constant currency
VULNERABILITY		
Physical/ demographic	(V1) Density	People per km^2
	(V2) Demographic pressure	Population growth rate
	(V3) Unsafe settlements	Homes in hazard prone areas (ravines, river banks, etc)
Social	(V4) Access to basic services	% of population below poverty level
	(V5) Poverty level	% of adult population that can read and write
	(V6) Literacy rate	Priority of population to protect against a hazard
	(V7) Attitude	Portion of self-generated revenues of the total budget
	(V8) Decentralization	% voter turn out at last communal elections
Economic	(V9) Community participation	Total available local budget in US$
	(V10) Local resource base	Economic sector mix for employment
	(V11) Diversification	% of businesses with fewer than 20 employees
	(V12) Small businesses	Number of interruption of road access in last 30 years
	(V13) Accessibility	Total available local budget in US$
Environmental	(V14) Area under forest	% of area of the commune covered with forest
	(V15) Degraded land	% of area that is degraded/eroded/desertified
	(V16) Overused land	% of agricultural land that is overused

Table 15.1 (cont.)

Main factor and factor component	Indicator name	Indicator
CAPACITY & MEASURES		
Physical planning and engineering	(C1) Land use planning	Enforced land use plan or zoning regulations
	(C2) Building codes	Applied building codes
	(C3) Retrofitting/maintenance	Applied retrofitting and regular maintenance
	(C4) Preventive structures	Expected effect of impact-limiting structures
	(C5) Environmental management	Measures that promote and enforce nature conservation
Societal capacity	(C6) Public awareness programmes	Frequency of public awareness programmes
	(C7) School curricula	Scope of relevant topics taught at school
	(C8) Emergency response drills	Ongoing emergency response training and drills
	(C9) Public participation	Emergency committee with public_representatives
	(C10) Local risk management/emergency groups	Grade of organisation of local groups
Economic capacity	(C11) Local emergency funds	Local emergency funds as % of local budget
	(C12) Access to national emergency funds	Release period of national emergency funds
	(C13) Access to int'l emergency funds	Access to international emergency funds
	(C14) Insurance market	Availability of insurance for buildings
	(C15) Mitigation loans	Availability of loans for disaster risk reduction measures
	(C16) Reconstruction loans	Availability of reconstruction credits
	(C17) Public works	Magnitude of local public works programmes
Management and institutional capacity	(C18) Risk management/emergency committee	Meeting frequency of a commune committee
	(C19) Risk map	Availability and circulation of risk maps
	(C20) Emergency plan	Availability and circulation of emergency plans
	(C21) Early warning system	Effectiveness of early warning systems
	(C22) Institutional capacity building	Frequency of training for local institutions
	(C23) Communication	Frequency of contact with national level risk institutions

Source: Authors.

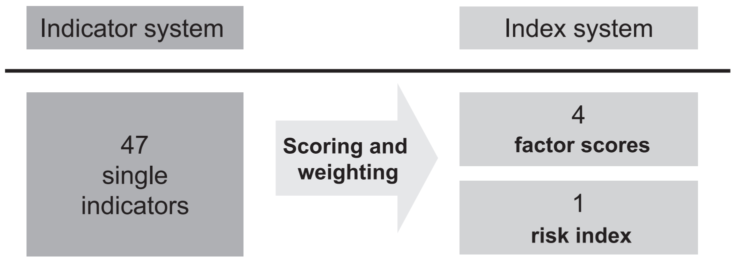


Figure 15.2 Indicator and index system
Source: Authors.

the technical and individual information of the indicators into summary figures.[2]

Indices are appealing because of their ability to summarize a great deal of often technical information about natural disaster risk in a way that is easy for non-experts to understand and use in making risk management decisions.

Indicator and factor scores (scaling and weighting)

In a first step, the different measurements of the individual indicators (for example, 50,000 residents and a 20 per cent poverty level) have to be made comparable through scaling. This is done by assigning a value of 1, 2 or 3, according to the category achieved (low, medium or high). A "0" is given when the indicator does not apply. (For clarification, an example will be given later from the questionnaire used in Indonesia.)

Next, since indicators have different meanings for specific hazards, a hazard-specific weight has to be found and applied. This is necessary because some indicators are more important than others, contributing differently to each of the factors. For example, among the "capacity" factors, an early warning system is considered to be more effective than the existence of an emergency plan. However, while this is certainly true for "predictable" floods, in the case of "unpredictable" earthquakes early warning is much less effective. Weighting represents the importance of the indicator relative to other indicators. This weight has to be adjusted for the country-specific conditions; it has been defined in Indonesia, for example, mainly with the aid of experts from national research institutions, universities, NGOs and representatives from local government. A workshop was held for each hazard to discuss and define the proper hazard-specific weight. Three different hazard-specific weights were defined during the pilot project in Indonesia for landslide, volcano eruption and earthquake.

Separate composite indices (scores) can then be calculated for the four main factors that contribute to the risk: hazard, exposure, vulnerability, and capacity and measures. All the indicators that relate to hazard are integrated into the hazard index; all those that relate to exposure are integrated into the exposure index, and so on. Depending on the scaled indicator values, the factor indices (scores) vary between 0 and 100. This can be achieved by distributing a total of 33 weighting points (actually 33 1/3) according to the recognized importance of the indicators for each factor.

The risk index

In a final step, the "overall" composite risk index is derived from the four factor indices, resulting again in a score that ranges between 0 and 100. As with indicator weighting, the actual relationship between the factors cannot be determined statistically. Following the approach of Davidson (1997), a linear relationship is assumed to be reasonable and easy to understand and implement. For the single composite risk index, the contribution of each factor is assumed to be equal. While increasing scores for the hazard, exposure and vulnerability factors represent a higher disaster risk, an increase in the capacity and measures factor reduces that risk. To use the same scale between 0 and 100 as for individual factor indices, a uniform weight of 0.33 for all factors is introduced. In this way, the overall risk index R can never exceed 100, and can reasonably be expected not to be negative.

Expressed as an equation:

$$R = (wHH + wEE + wVV) - wCC$$

where R is the overall risk index, H, E, V and C are the scores of the hazard, exposure, vulnerability, and capacity and measures indices, respectively, and w is the constant coefficient of 0.33 as a uniform weight for all factors.

The expected benefit is that the overall risk index tells us about the risk and the identified risk-determining factors of communities. It allows us to:

- Compare different communities across a country to identify and target communities with high disaster risks. This can also be done for communities that face risk from different hazards.
- Recognize the determining factors for each community behind the existing risk: that is, whether the risk stems from the hazard itself (hazard) and is due to high vulnerability levels (vulnerability) or comes from a lack of capacity (capacity and measures).

- Distinguish the different possible magnitudes of damage through the exposure score.
- Reveal deficits in risk management capacities and potential areas for interventions through a breakdown of the capacity and measures score into factor components.

Testing in Indonesia: pilot implementation in three districts

A German bilateral technical cooperation programme supported by the German Federal Ministry for Economic Cooperation and Development (BMZ) and conducted through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH supports local governments in meeting the challenges and realizing the opportunities of decentralization in Indonesia. It also builds capacity, empowers decision-makers and decision-making structures, strengthens institutions and enriches the policy formulation process. The component of the programme that deals with geological hazards works in cooperation with the German Federal Institute for Geosciences and Natural Resources (BGR).

Within the Georisk component, the "community-based Disaster Risk Index" was applied as a pilot project. Our partner institution – the Geological Agency of Indonesia – established a CBDRM working group with experts in the field of volcanology, landslide mitigation, environmental geology and regional planning. The group discussed the community-based risk index approach and also presented the approach to other research institutions, universities, NGOs and local governments at several workshops in Bandung, Jakarta and Yogyakarta.

The first visit to Yogyakarta and discussions with the local government, NGOs and universities showed how necessary and important it was that the approach works at the local level. The visit supported our assumption that the set of indicators and questionnaire developed by the working group would provide a valuable approach for this field of intervention. The new approach will help local governments in the selected areas to bundle activities that so far have been widely scattered, and to improve administrative effectiveness. We are conscious of the need for further application of this approach in Indonesia and other countries. The GIZ/BGR cooperation project made a contribution to the international discussion on risk indices at the local level, recommending the application of the set of indicators in a field operation. The CBDRM working group proposed applying the indicators and questionnaire in two different regions.

The first was in the area of Yogyakarta, Central Java, with a focus on the Sleman and Kulon Progo districts. The recent eruption of the Merapi volcano (October 2010) again shows the high risk potential of the region.

The second region was in Flores, in eastern Indonesia, with a focus on the Sikka district.

Over the past few years, many activities, covering all aspects of hazard assessment and risk evaluation, had already been carried out, especially in Yogyakarta, but the assessment of people's vulnerability (life and assets) and of their coping capacity at community level is still in its infancy (Hidajat, 2002). The working group was trained in the use of the new approach and were qualified to apply the questionnaire. To get a representative and reliable questionnaire, it was necessary to adapt the existing (very general) indicators to the local conditions in Indonesia. The following example, using vulnerability and capacity as indicators, shows how the indicators, index system and the questionnaire are applied to obtain factor scores.

Main Factor = Vulnerability
Indicator name = Access to basic service *(V4)*
Question = How good is the access to basic health centres (for example, community health centre, midwife centre, clinic, doctor)?

(a) Health centres are available and can be reached easily by car.
Low = 1
(b) Health centres are available but not easy to reach only on foot. (X)
Middle = 2
(c) There is no health centre.
High = 3

Hazard-specific weight for landslide = 2

If (b), with value 2 applies here for landslides, the factor score is 4 (2×2).

Main Factor = Capacity and measures
Indicator name = Land use planning *(C1)*
Question = Are disaster risk reduction aspects considered in land use planning?

Yes (X) No = 0

If yes, how are the measures being implemented?
(a) Comprehensive implementation High = 3
(b) Partly implemented Middle = 2
(c) Not implemented (X) Low = 1

Hazard-specific weight for volcanic eruption = 3

If in a community a land use plan exists but is not implemented, (c) with value 1 applies. As land use planning is of the highest relevance to reduce risk associated with volcanic eruptions, the factor score is 3 (1×3).

Testing the questionnaire in the districts of Sleman, Kulon Progo and Sikka

The CBDRM working group conducted workshops in three districts, bringing together local stakeholders of the different communities of each district. The aim was to harmonize their perceptions of the questions in order to verify that the purpose of the questionnaire was clear and ensure that the requested data would be available, even at the local/community level.

The index system is backed up by a database that allows for the systematic recording of the questionnaire results gathered during the workshops. The advantage of the database is that it makes it easy to create different scenarios by changing the given answers and thus identify the areas where mitigation measures could reduce risk most effectively. The results can be visualized in a chart or, if enough data are available, as a map.

Involved in the process were local government representatives from the spatial planning, finance, infrastructure, environment, health and civil protection departments, natural hazard research institutes, local NGOs, religious and traditional leaders, mayors and community leaders.

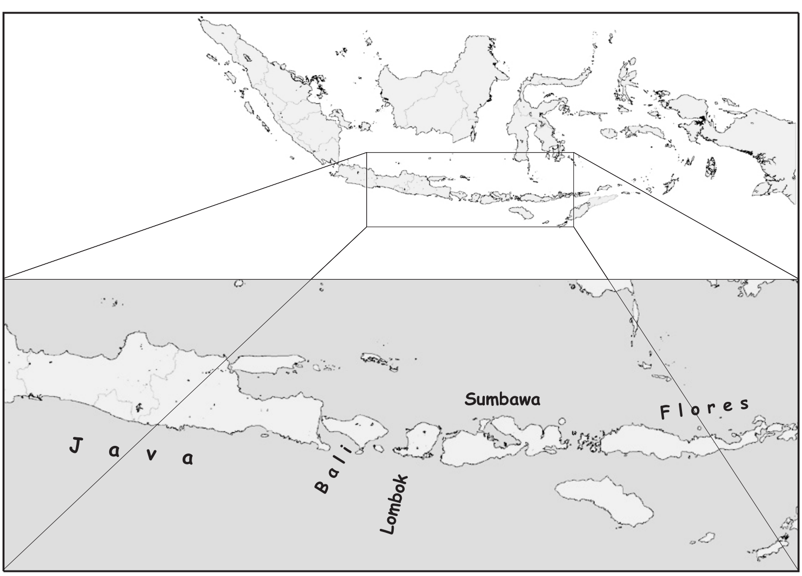


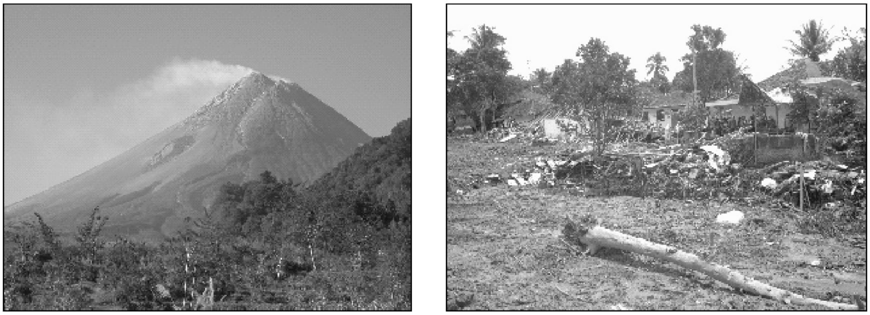
Figure 15.3 Indonesia: project location
Source: Authors.

Picture 15.1 Discussion with local stakeholders in the district of Sleman, Yogyakarta
Source: Authors.

In Central Java province, representatives of four communities from the districts of Kulon Progo and Sleman were invited to come to Yogyakarta. In east Indonesia, on Flores, six communities of the Sikka district (Nusa Tengara Timur) participated in the workshop. The CBDRM working group chose these two contrasting regions with the intention of getting representative results that were specific to the particular locations. The archipelago of Indonesia covers a huge geographical area and is very unevenly developed with regard to population density, infrastructure and economic activity, and is threatened by different types of hazards.

Java is the "main" island, with only 7 per cent of the total land area but 80 per cent of the total population. In particular, the fertile regions around the volcanoes and coastal areas are very densely populated. In Sleman district, the average population density is around 1,000 people per square kilometre, and in some villages near the Merapi volcano it is even higher. The region has a good infrastructure, most of the roads are paved, and electricity, telecommunications and fresh drinking water are available in almost every village up the slopes of the volcano. The conditions for agriculture are very favourable and provide a good income. Health care and the provision of basic schooling and higher education are also adequate (Hidajat, 2006).

The Sleman district is affected by volcanic eruption (pyroclastic flow) and lahar (debris flow) from Merapi, one of the world's most active volcanoes. During the eruptions in 2010 more than 300 people were killed and almost 400,000 were evacuated (see EM-DAT website). The Kulon Progo district is regularly and severely affected by landslides caused on the one hand by the hilly topography and geological conditions, and on



Picture 15.2 The summit of the Merapi volcano lies only 30 km away from the capital city (left). The district of Kulon Progo is predominantly affected by landslides (right).
Source: Authors.

the other by intense and inappropriate human activity. Many slopes have been cleared and the soil is already degraded and eroded.

In contrast to Central Java, the eastern part of Indonesia (Nusa Tengara Timur, Nusa Tengara Barat) is remote and less developed. The population density is on average lower but locally concentrated in the major cities, which are also important seaports. There is little diversity of economic activity; incomes are low and normally depend on few agricultural products, and manufacturing industry is lacking. Many families in rural areas have almost no income, live near the poverty line and depend on subsistence farming of barren land. Climate conditions are dry, and

Picture 15.3 In 1992 a tsunami completely destroyed the village of Wuring (left picture), but a few years later the village was rebuilt at the same site and is still extremely exposed to earthquakes and tsunamis
Source: Authors.

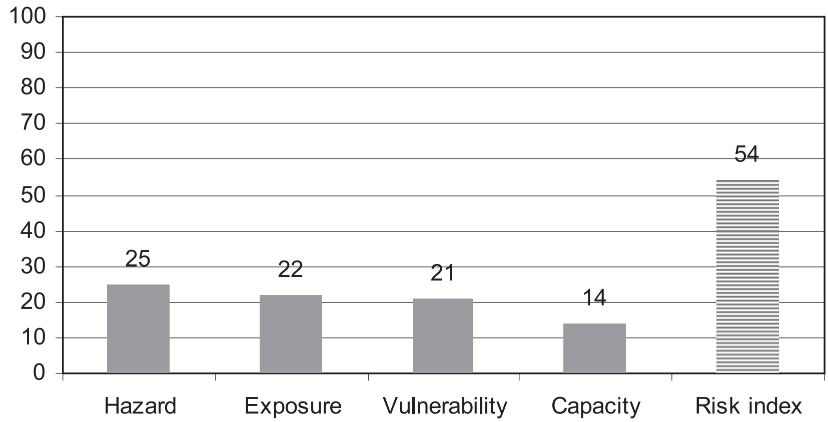


Figure 15.4 Disaster Risk Index of a community in Kulon Progo district prone to landslides
Source: Authors.

sometimes drought leads to food shortages. Basic education is available but higher education is absent or inadequate.

The project region on Flores, the district of Sikka, is prone to various natural hazards like earthquakes, tsunamis and volcanic eruptions. In 1992 an earthquake triggered a tsunami that killed 87 people, destroyed a complete village and caused much infrastructural damage. In 2003 the dormant Egon volcano became active and caused panic among the inhabitants (Hidajat, 2007).

Figure 15.4 shows the Disaster Risk Index and the factor scores of a community in Kulon Progo district, Central Java, which is prone to landslides. The hazard score is fairly high because of the high frequency of such events. Landslides happen regularly during the rainy season and emergency shelters are made available for temporary evacuation. The exposure score is high because of the density of settlements and infrastructure that are threatened. The vulnerability factor score is also high, but capacity is low. It is interesting to show in more detail the breakdown of the vulnerability score (Figure 15.5) and the capacity score (Figure 15.6)

The physical and environmental vulnerability scores show high values because many houses are in unsafe and hazard-prone areas, and much land is cleared and degraded.

A closer look at the capacity score breakdown shows deficits in the physical planning and economic capacity component. This approach could define appropriate and cost-saving intervention measures by cross-checking with the answers from the questionnaire and the results of the stakeholder discussion.

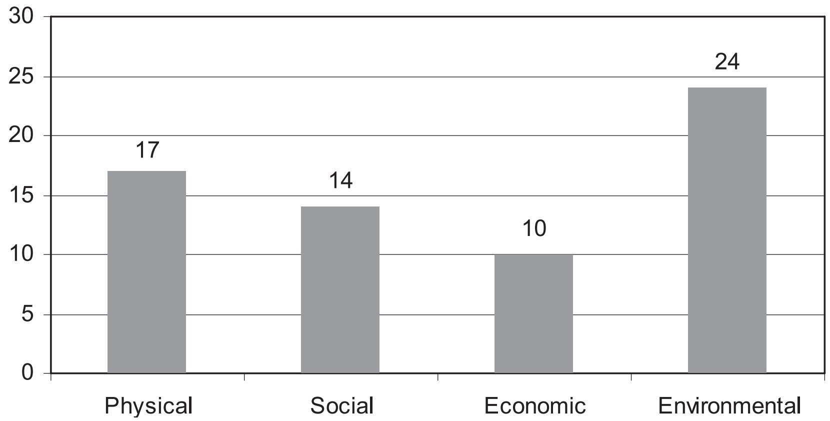


Figure 15.5 Vulnerability score breakdown of a common in Kulon Progo district
Source: Authors.

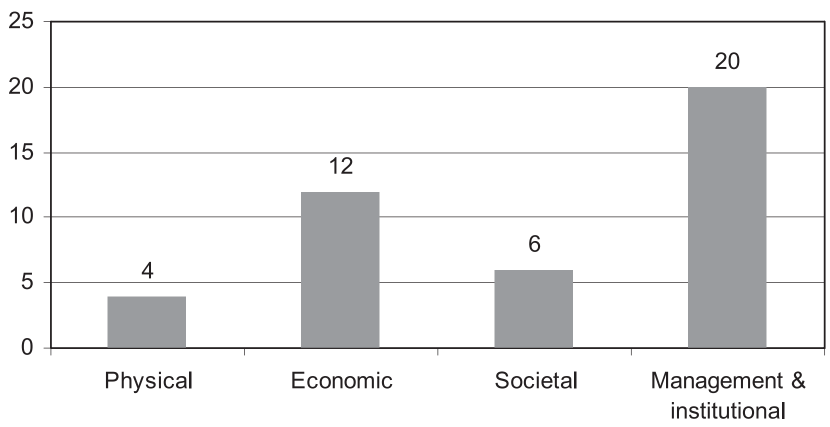


Figure 15.6 Capacity score breakdown of a community in Kulon Progo district
Source: Authors.

Figure 15.7 provides a direct comparison between a community in the Sikka district and a one in the Kulon Progo district. The risk index of the two communities is almost the same, and if planners take a closer look at the factor scores they can see that the hazard has almost the same value in each case. The difference between the two communities can be found essentially in their exposure and capacity scores. While both

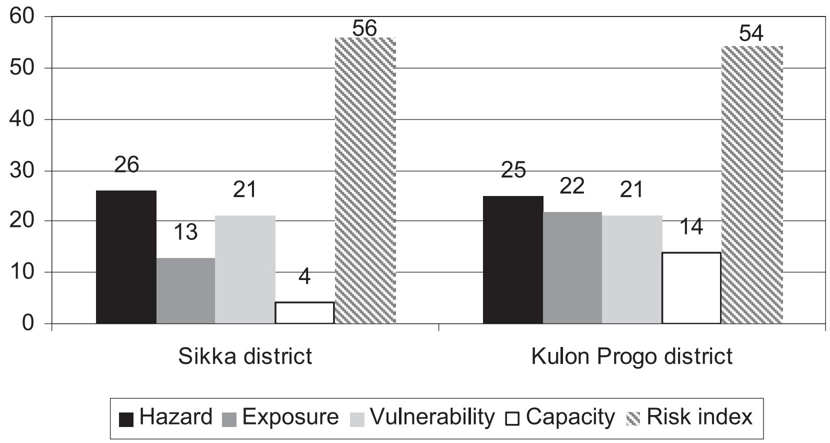


Figure 15.7 Disaster risk: Comparison of a community in Sikka district (left) and a community in Kulon Progo district (right)
Source: Authors.

communities face the same value of hazard and the vulnerability of both communities is high, Kulon Progo has more property exposed to the hazard; however its capacities and measures for dealing with disasters are better than in Sikka, and the population and local government are better prepared.

If the index were applied at regular intervals, a community risk could be observed over time and changes could be considered that might then lead to the implementation of appropriate preventive measures.

Lessons learned and future challenges

Based on the experiences in Indonesia, the index has also been tested in El Salvador, in 2008, in the context of a GIZ project on disaster risk reduction in the northern part of the country (Trifinio). As part of the process, the indicator list has been adapted, hazard-specific weighting has been defined for floods, forest fires and landslides, and a questionnaire has been developed regarding the needs and available information in and for the 12 selected rural communities. As the hazards in this region are strongly related to weather, climate change has become an important factor and issue during application.

The experiences in Indonesia and El Salvador confirmed that the indicator system is a good tool for sensitizing decision-makers and creating awareness about the complex forces driving disaster risk. It is useful to have a structured system for these different aspects of risk that helps to clarify the conceptual terms of exposure, vulnerability and capacity. During implementation, when the main task is discussion with decision-makers and the affected communities, it is better to deal with vulnerability and capacity separately. Discussing the vulnerability of a community provides the opportunity to identify deficiencies, and talking about capacity and measures shows in a positive way how to overcome vulnerability and reduce the risk. When preparing for a workshop, it is important to keep in mind that the more diverse the group of people and their knowledge is, the more representative and reliable the outcome will be. Early tests with the questionnaire showed that it is confusing to group the indicators by hazard (H), exposure (E), vulnerability (V) and capacity (C) when using the questionnaire for data collection. The questionnaire has to be made user friendly and organized more thematically, not around concepts that are familiar only to the experts. That means the indicator system and its questionnaire have to be adjusted to the political and cultural conditions of the country or region. The first field assessments backed our assumption that the index system can help in better understanding the risk as well as prioritizing and designing appropriate countermeasures for the social and management component of local disaster mitigation.

So far, however, in both countries only the first steps have been made and more effort is needed to finalize the Disaster Risk Index to make it more applicable and more user friendly. Furthermore, the described testing has been short term and limited to the utility of the index for sensibilization and planning. There has not yet been long-term testing to confirm its utility for risk monitoring over several years. Thus, some future challenges are:

- The cut-off points of the indicator value (high, middle, low) need to be verified continuously, because the more precise the index is the more significant it will be.
- The method needs to be tested in more regions to validate the system for weighting and scaling.
- There should be a longer-term testing in order to gain experiences with the utility of the index for risk monitoring at community level.
- Standardized benchmarking must be developed to interpret the index system of the Disaster Risk Index and to derive recommendations for risk reduction measures. The benchmarking should evoke the necessity to include future trends involving climate change, migration etc.

Notes

1. Available on request at the GTZ Advisory Project “Disaster risk management in development cooperation”, email: disaster-reduction@gtz.de/
2. Framework by Davidson (1997), adopted by Bollin et al. (2003). It is explained in detail in the manual “Towards a Community Disaster Risk Index”, available on request at the GTZ Advisory Project, email: disaster-reduction@gtz.de/
3. See the Georisk homepage. Indonesian–German development cooperation project: http://www.georisk-project.org/

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16

Mapping vulnerability – Integration of GIScience and participatory approaches at the local and district levels

Stefan Kienberger

The need for spatial approaches at local levels

The impact of natural disasters on human society and the global environment has become increasingly severe in recent decades and is at the centre of different scientific and public debates. This has been made particularly apparent as various severe disasters have focused global attention on the issues of risk and vulnerability. Events such as Hurricane Katrina (2005) or the earthquake in Haiti (2010) have demonstrated that institutional and societal relevant factors show how vulnerability can become manifest, even in two very distinct countries with respect to their perceived "development status". The flood events in 2000 in Mozambique have highlighted how the issue of development, in addition to the institutional issue, is strongly linked to the impacts of disasters (Christie and Hanlon, 2001; Matsimbe, 2003; Gall, 2004). Ten years after the severe flood events, it can be observed that improvements have been made to the strengthening of institutions at the national level. Within Mozambique, this change has been influenced by strong donor support and commitment as well as support and motivation in the country itself.

Gall (2004) in her work on the Mozambican flood events in 2000 focused on the need for information to deal with and identify different levels of vulnerability for actors at different levels. This has also been highlighted and clearly expressed through the Hyogo Framework of Action (HFA; UN, 2005) which highlighted the need to:

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

> Develop, update periodically and widely disseminate risk maps and related information to decision-makers, the general public and communities at risk in an appropriate format.

> Develop systems of indicators of disaster risk and vulnerability at national and sub-national scales that will enable decision-makers to assess the impact of disasters on social, economic and environmental conditions and disseminate the results to decision-makers, the public and populations at risk.

In the frame of literature and scholarly debates, Pelling (2007) highlighted the publication of "Reducing Disaster Risk: A Challenge to Development" (UNDP, 2004) and "Disaster Risk Reduction [DRR]: A Development Concern" (DFID, 2006) as important drivers which helped to take disaster risk reduction into mainstream development practice and planning. Twigg (2004) provides an overview of best practice for mitigation and preparedness in emergency management. Furthermore a review and a discussion on participatory, community-based approaches in DRR is provided in Morrow (1999), Bollin (2003), Victoria (2003), Flint and Luloff (2005), Pelling (2007), van Alst et al. (2008) and Mercer et al. (2010). An extensive review of local knowledge and its relevance to DRR was undertaken by Dekens (2007). The authors recognize the need for engagement at the community level and for integrating indigenous knowledge, which helps in identifying local needs and perceptions. The process should not be seen as a top-down or bottom-up approach but more as collaboration between the local communities and the different stakeholders (van Alst et al., 2008). It is furthermore argued that more emphasis should be placed on the discussion of solutions viewed from the communities' perspective. Challenges have been identified in the implementation of such approaches, which should be simple enough and suitable for wider application by communities within their risk reduction programmes but should also be embedded within policies/programmes that have been defined by other stakeholders (ibid.). Mercer et al. (2010) see the acceptance and realization of indigenous knowledge systems as an essential prerequisite. The clarity of procedural, methodological and ideological aspects of a vulnerability assessment and the avoidance of fuzziness in terms and concepts is challenged by Pelling (2007).

In the context of developing cooperation, different practices have emerged since the late 1980s which highlight the need for local participation (such as through Participatory Rural Appraisal (PRA); Chambers, 1994) and especially the integration of local knowledge in disaster risk reduction (Dekens, 2007). This has been additionally reflected in the recommendations provided following the World Conference on Disaster Reduction (WCDR; 18–22 January 2005, Kobe, Hyogo, Japan) and expressed in the Hyogo Framework (UN, 2005), as mentioned above. Linked to participatory approaches, a merger of GIS and ephemeral mapping embedded in the context of PRA led to the practice of Participatory GIS (PGIS; Rambaldi et al., 2006). The evolvement of these approaches is furthermore linked to the critique regarding the power of GIS that began with the publication of Pickles (1995).

Cutter (2003) highlighted the need to integrate GIScience approaches in the context of emergency planning and disaster risk reduction. This is linked to ideas developed by Hewitt and Burton (1971) who integrated the role of spatiality into the concept of risk and vulnerability, which is not often seen as a core element in the assessment and conceptualization of risk. However, vulnerability is a phenomenon which has a strong correlation with the specifics of a place (see, for example, Cutter et al., 2008, November 2008). A number of different researchers have focused on the vulnerability phenomenon at the global or national scale (for example, Turner et al., 2003; Dilley et al., 2005; Schneiderbauer, 2007). A recent comparison of various social vulnerability indicators, focusing on these, has been investigated by Gall (2007) and Birkmann (2007), while a validation of social vulnerability in the context of river floods in Germany has been presented by Fekete (2009).

Within all of these observations, the need for a spatial approach to assess vulnerability at the community and district levels through the integration of GIScience and alternative forms in the context of rural, developing countries has been identified. This is emphasized by the observation that a variety of community-based approaches in DRR (and its mapping component) have their roots in PRA; however the integration of GIS approaches is still an open issue. Currently, community-based and participatory approaches are seen as a central element for achieving success with DRR at the local level (especially in developing countries). This approach needs to be embedded in long-term active programmes which support local capacities. It is surprising that only a very small number of publications on PGIS in participatory vulnerability assessments are available, whereas no sound methodological approach has been documented as yet (in contradiction to available case studies in grey literature). From the conceptual point of view towards vulnerability, it can be observed that vulnerability has clear spatial and temporal dimensions and should be captured within a hierarchical organization for different (policy) scale levels (Kienberger et al., 2012). Different scale levels require specifically designed sets of indicators and methods on how to integrate and communicate them. International agreements, such as the HFA, specifically ask for a system of indicators at the sub-national scale to support decision-makers.

The method and concept presented below was developed in the district of Búzi and associated communities in Central Mozambique. As the method is transferable to similar settings, a more general approach in presenting the methodology has been chosen. Therefore less background information is given on the specific case study, but reflections provided in the conclusions draw on the experiences described in the Búzi case study and additional applications in Africa and Asia.

Conceptual approach towards vulnerability

A pragmatic conceptualization has been applied to this research, which allows integration into a spatio-temporal context. A core objective has been the development of methodologies which can be adapted to different conceptual approaches of risk and vulnerability.

Risk is defined as the expected probability of harmful consequences or losses resulting from interactions between natural or anthropogenic hazards and vulnerable conditions and its (human) exposure (adapted from UN/ISDR, 2009). This can alternatively be represented through the function:

$$R = f(H, E, V) \tag{1}$$

where R is defined as risk, H as hazard, E as exposure and V as vulnerability.

The formalization of the different terms and concepts should support accurate communication within the conceptualization stage and help to develop a shared language (Ionescu et al., 2008). Additionally this is of help within the quantification of vulnerability to identify relationships.

The definition of exposure follows the UN/ISDR (2009) approach which states "people, property, systems or other elements present in hazard zones that are thereby subject to potential losses". Therefore a link to the hazard side exists. For example, the spatial distribution of the population (potential exposure) intersected with the hazard zone defines the exposure of people with respect to the hazard (hazard exposure).

The definition of vulnerability builds on the BBC-Concept (Birkmann, 2006) but is slightly adapted to fit the requirements of this case study. Generally, vulnerability is defined as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard". Vulnerability is characterized through different dimensions such as economic, social, environmental and physical. It is also noted that vulnerability has "human-centred" characteristics, underlining the notion that there are no "natural" disasters. Vulnerability can be defined as:

$$V = f(SU, AC) \tag{2}$$

where SU defines the susceptibility and AC the adaptive capacity.

Vulnerability is characterized through factors which increase (negative) or decrease (positive) its degree. Important characteristics in the definition of vulnerability can be defined which help to integrate the framework into a relevant GIScience context (see also Kienberger et al., 2012):

- WHERE: Vulnerability differs spatially;
- WHEN: Vulnerability changes over time;
- WHAT: Vulnerability has different dimensions (environmental, physical, economic, social, etc.);
- WHY: Vulnerability assessments are policy oriented with the overall objective of mitigating/avoiding the negative impacts of disasters;
- HOW: Vulnerability is currently measured indirectly and is described through specific indicators which allow for representing and monitoring the different dimensions of vulnerability.

A required is that the final manifestation of risk assumption with hazard and vulnerability as – defing components – can be spatially delineated. Therefore, vulnerability and its measurement and characterizations depend on the principles of scale (see Kienberger et al., 2012). In this case vulnerability can exist everywhere at any place, but it depends on its degree, whereby in certain areas it may be close to zero, while in others it may have a higher degree. The final risk is therefore defined by the spatial overlay (and mathematically defined through a "function") with a hazard, which can be delineated spatially (for example, the extent of a flood).

Methods

The major focus of the developed methodologies specifically targets the district and community levels. The district level has been targeted – as identified in the Mozambican case but also following international/scientific observations – as it is the level of implementation of activities which bears the most responsibility with respect to disaster risk reduction. This is directly addressed through laws pertaining to disaster (risk) management issues and is also reflected through general planning activities, whereas disaster risk management can be addressed horizontally. Therefore appropriate planning and decision support tools identifying the level of vulnerability are needed at the district level.

The community level has been identified as a second target level. As various community-based disaster risk management programmes are implemented, a need for the integration of a spatial component and suitable decision support tools – especially for the community scale – arises. This factor is evident in the Búzi case study. At this level, community (hazard) maps have been developed to allow for assessment of hazards and possible vulnerabilities/risk within the community, at the same time integrating local knowledge. Local knowledge is further integrated through the identification and prioritization/scoring of vulnerability factors.

At the community level a strong emphasis is placed on the starting of learning and sensitization processes which should support community empowerment, in addition to direct outputs such as community maps and the identification/weighting of vulnerability factors. This procedure is in line with the general objectives of PRA practices and participatory approaches. It is important to note that the proposed methods and tools do not fulfil these objectives per se as there are many underlying factors which determine the success of community involvement. However, these are seen as serving to close a gap within the problem of a spatial assessment of vulnerability at the community level.

In Figure 16.1 an overview of the major results at the different levels is provided, showing how they are interrelated. It has been proposed that for general planning purposes a set of spatial indicators characterizing the district (such as land cover/land use, road network, location of schools, hospitals, etc.) should be available, unlike the research focus here, which comprises only the collection and representation of various datasets in the sense of a Spatial Data Infrastructure (SDI). As a central element, the modelling of homogenous regions of vulnerability (represented through Vulnerability Units – VulnUs) is achieved through the integration of these various datasets with knowledge from experts who have contributed to the selection of indicators and their weightings. Additionally, the factors/indicators identified by the experts can then be compared to those identified and scored at the community level. Therefore the perception and identification which took place at the community level is then also "upscaled" to the district level. An "overall" true picture of vulnerability – which might be very difficult to achieve – is not being attempted here, but differences/similarities at the various levels are identified. Therefore, policies or activities which are defined and prioritized at higher levels of decision-making can be evaluated and compared with the needs and perceptions identified at a very local level.

Community level – integrating local perceptions and knowledge

The methodology to assess, identify and quantify vulnerability and hazards at the community level has been embedded in a research project

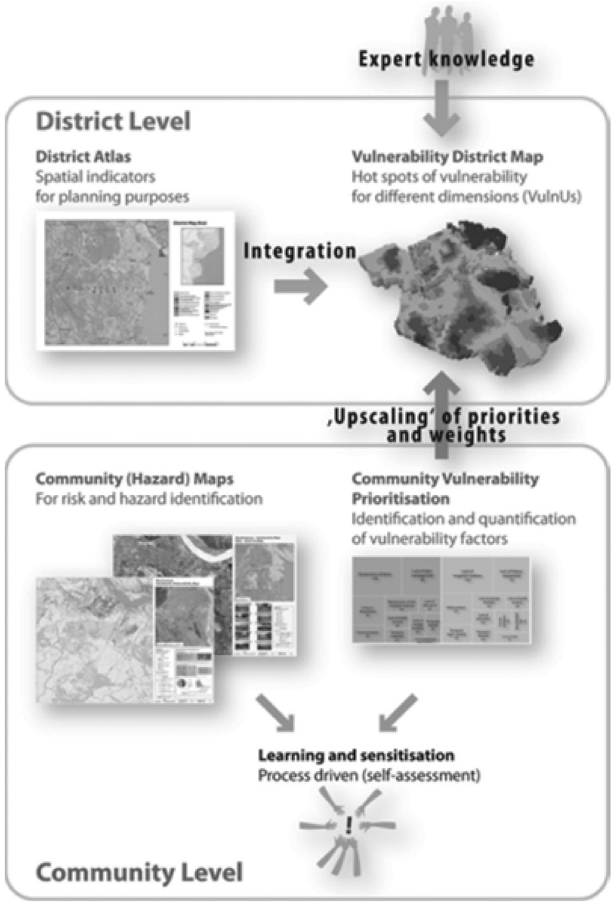


Figure 16.1 Vulnerability assessment at the community and district level

partly funded by the Munich Re Foundation. A result of this project is a toolbox and manual which describes the methodology in depth for future implementation at the practitioner's level. The manual has already been adapted and applied in various training workshops in Assam/India, Bangladesh, Malawi, Madagascar and Mozambique. In Figure 16.2, an overview on the workflow, is provided.

The major aim of the developed approach is to provide community members with the appropriate decision support and awareness tools to identify and reduce their own vulnerabilities. A central element is the provision of community maps, which should significantly assist a community with their decision-making. Answering the central questions of

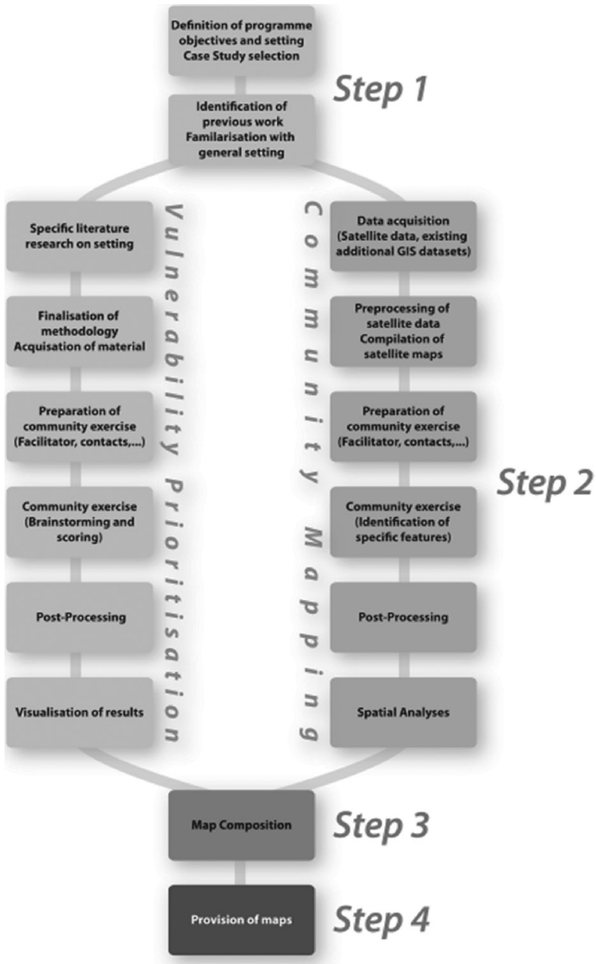


Figure 16.2 Workflow of the developed approach to assess the vulnerability at the community level

"where" and "what" is essential in dealing with challenges in a community planning context, especially in the case of disaster risk reduction. However, a "map" is not in itself a solution, as it also requires certain structures, commitments and technical expertise. Therefore, although the developed workflow/manual can contribute significantly to the support of community-based disaster risk reduction measures, it has to be embedded in the context of an integral disaster risk reduction programme.

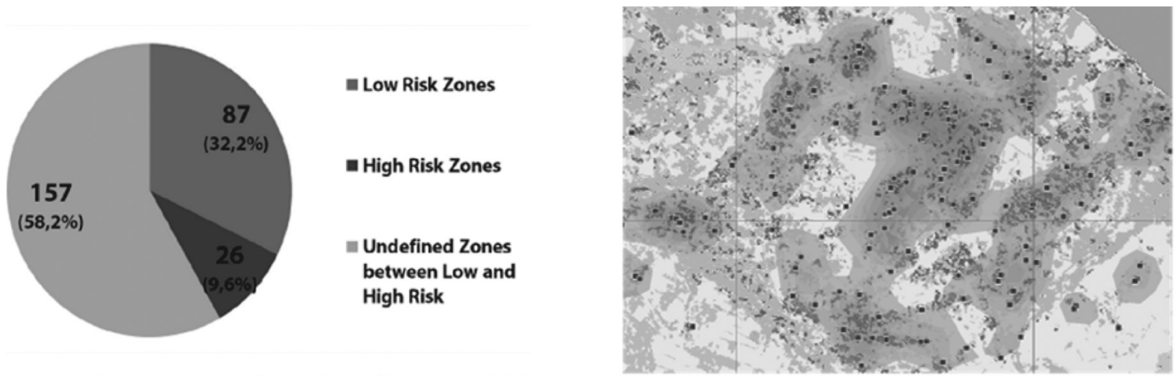
The initial common steps include the definition of programme objectives and the identification of the case study area, with the subsequent identification of earlier work and familiarization with the general setting.

This pathway addresses to some extent the issue that many of the participatory approaches to disaster risk reduction at the community level are initiated through development programmes where easy access to literature or reports might not always be possible. Therefore, a strong need arises to first evaluate what has already been investigated in the region/community to be targeted. Additionally, emphasis should be given to coordination and cooperation among different actors. Existing results should be reconsidered as many insights may have already been gained that might enhance the planned activities.

The ensuing process includes two parallel steps – community (hazard) mapping and the identification of vulnerability factors (Figure 16.1). Both exercises are carried out in a participatory manner and include using the knowledge of the community participants. The identified and weighted vulnerability factors can then be used to help to build the assessment at the district level.

For the community (hazard) mapping, the method outlined consists of two major parts: first, data and satellite imagery are acquired, printed on a large paper format and then presented to community members (for example, members of a disaster management committee) as a "blank" map where specific features in the context of vulnerability and the chosen hazard are mapped in a participatory approach. The community members are asked to mark with different coloured pens features such as the risk zones (for example, flood inundated areas); safe areas (for example. elevated areas); if appropriate, the community boundary and neighbouring communities; agricultural zones; special infrastructure of the community and the settlement area. In a second part the paper-mapped results are integrated in a GIS through digitization. These can then be enhanced through spatial analysis such as spatial queries, buffer zones and distance analysis, density analysis and a land use/land cover classification (Figure 16.3). In general, the work described here builds on GIS capacities. Therefore, it is important to consider the integration of adequate expertise within the project design and during the implementation activities.

Parallel with the mapping, the issue of vulnerability to natural hazards is addressed with the community members. The main objective here is to understand the perception of vulnerability as seen from a community perspective and to identify the relative importance of the different factors. Additionally, the exercise aims to stimulate a discussion among the community members about their susceptibility to different triggers of vulnerability. The exercise should allow the prioritization of issues within the community's own decision-making process, which should then help to



Percentage and number of houses within different risk zones

Settlement density and Land Use/Land Cover Mapping

Figure 16.3 Different spatial analysis results which should support community decision-making (especially within disaster risk measures) communicate priorities and raise the awareness of decision-makers at different levels outside the community. From a research and project implementation perspective, it is of interest to see how different vulnerability factors are perceived among the different ("sampled") communities. This might help to understand the perception of risk on a very local scale and the adjustment of development programmes targeting risk reduction at the community level in a specific region.

The main objective is to identify those factors which characterize the vulnerability of a community to a certain hazard. The challenge is to relate the term "vulnerability" to the local context. It is not recommended to directly use scientific definitions and approaches but to identify the factors as they are perceived at the local level, allowing a broader view towards the term "vulnerability". This may then include different issues, which may refer to different conceptualizations, such as the exposure or hazard domain, which can then be sorted out at a later stage. The method builds on the approaches known as the "Delphi exercise" (Helmer, 1966) or within PRA as "brainstorming" and scoring/ranking exercises (Schönhuth and Kievelitz, 1993; Chambers, 1994; Brockington and Sullivan, 2003, Parfitt, 2004). The scores collected can be visualized in the form of a treemap, and results from different communities spatially compared (Figure 16.4).

With respect to results from the community exercise, participatory-developed vulnerability/hazard maps were designed and made available to the communities' disaster risk reduction committees as a decision support and planning tool (Figure 16.5). With the identification and quantification of vulnerability factors for specific hazards accomplished, this is then linked to modelling at the "higher" district level through the consideration of factors as possible indicators and their scoring. Additionally the scores can help to produce a vulnerability map as perceived by the local disaster risk reduction committees.

District level – addressing the needs at the policy level

Next to the specific design and development of vulnerability/hazard maps at the community level, the district is seen as another important level for the development of an appropriate vulnerability assessment approach. Decentralization efforts are strongly reflected in regulations and laws. The district is a central focal point of this process, alongside planning and budgetary issues, especially in the context of disaster risk reduction. Therefore the district needs appropriate tools and methodologies for identifying priority areas for vulnerability reduction. These priority areas reflect sectorial dimensions but also have a strong spatial dimension for pin-pointing locations of people at higher risk. The scale levels of district

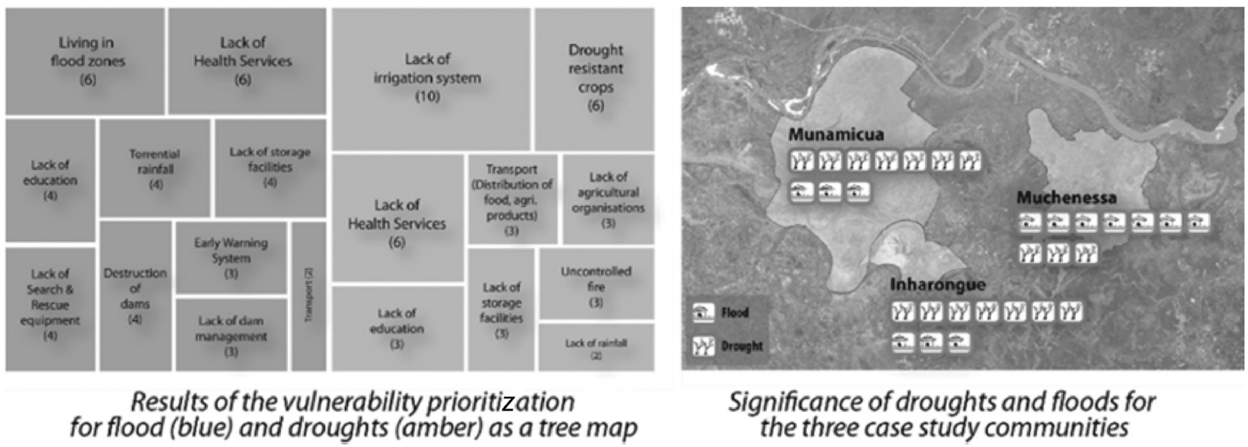


Figure 16.4 Results of the “vulnerability prioritization” summarized as treemap (left) and as a map of scores (right)

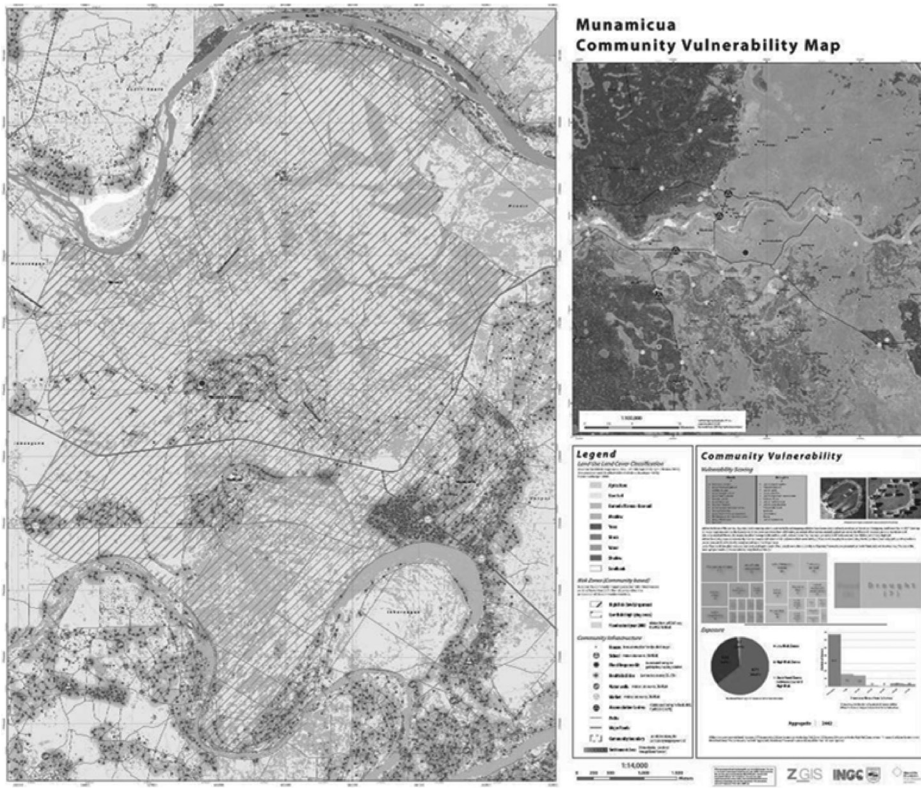


Figure 16.5 Community hazard and vulnerability map including information on the risk areas, settlement zones, results of spatial analysis and indicators on exposure as perceived by the community members (example: Munamicua – Mozambique)

and community should not be treated separately. Methods which aim to integrate qualitative and quantitative data, and which allow the up- and downscaling of assessment results at both levels, have been directed towards developing this approach (see again Figure 16.1; Kienberger et al., 2012).

A specific aim of the developed methodology is to derive spatial homogenous units of vulnerability as a specific case of a geon set, following the methodology for deriving vulnerability units developed by Kienberger et al. (2009). In order to devise integrated assessment approaches, the method developed is built on geographic regionalization concepts (Strobl, 2008) to accommodate the interdisciplinary dimensions of vulnerability. The term "geon" (from Greek gé = Earth and on = part, unit) was proposed by Lang et al. (2008) to describe generic spatial objects that are homogenous in terms of varying spatial phenomena under the influence of, and partly controlled by, policy actions. The concept can be applied with flexibility and independently of the perception of a problem (a specific policy realm, specific impact domain etc.). Geons are building blocks for conditioning spatial information, being flexible spatial units and providing a policy-oriented, scaled representation of administered space but not confined by administrative units (Lang et al., 2010).

The overall workflow to model vulnerability units as composite geons is presented in Figure 16.6, outlined for the social and economic dimension in Kienberger (2012). At the top of this workflow the concept of vulnerability is addressed. As no common understanding of the notion of vulnerability yet exists, it is necessary to choose an approach which is appropriate for the context in which the assessment is embedded (for example, climate change, hazard/risk-related). As mentioned previously, the method developed is independent from the concept chosen.

An essential step is the identification of indicator datasets, the weighting of the different indicators and, if required, domains/sub-domains. Within this research undertaking, expert interviews at the national and

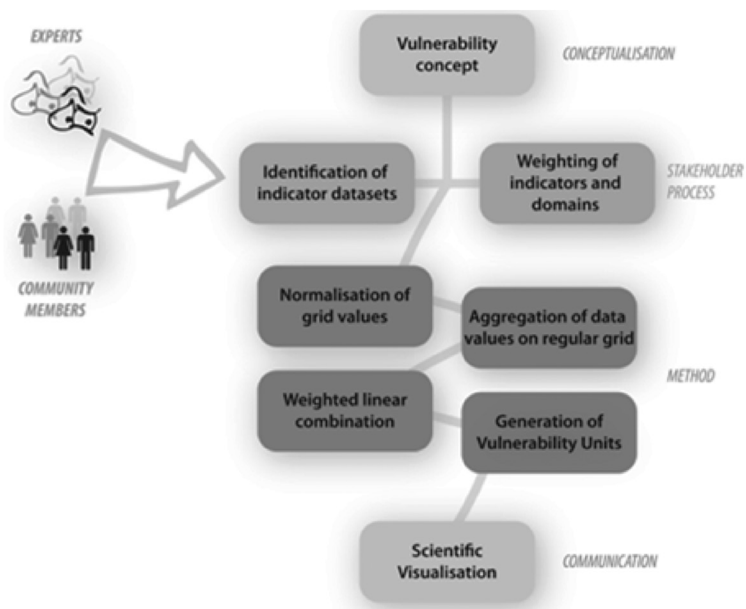


Figure 16.6 Overall workflow from conceptualization, indicator development and stakeholder process to methodological issues and the final communication of results (Kienberger, 2012, following Kienberger et al., 2009)

sub-national level were carried out to compile a set of indicators. Additionally, the input and results identified during the vulnerability prioritization at the community level were integrated, to allow the upscaling and consideration of specific factors identified at the local level. After having identified a final list of appropriate indicators, which is in practice strongly influenced by the availability of data, experts were asked to anonymously weight the indicators. The averaged weights of the experts' scores were then used to integrate the different indicators to model vulnerability units for the different dimensions. Indicators for the social, environmental, economic and physical dimension have been identified and are presented in Table 16.1.

As an example the economic dimension is presented in Figure 16.7(c). The economic dimension is characterized by "access to" indicators (access to local markets, access to road infrastructure, distance to nearest city) but also reflects the lower vulnerability along certain coastal areas and along the River Búzi (Kienberger, 2012). These are also the main areas where agriculture takes place and where most of the markets and road infrastructure exist. The area along the River Búzi is also characterized by having the lowest level of economic vulnerability as it has, in addition to the agricultural characteristic, the best access options in the district. Also the south-western and north-western clusters of low vulnerability reflect access to roads and the availability of agricultural land. The economic dimension for certain areas is the opposite of the environmental dimension, which reflects the human activity and environmental impact arising there. Only the north-eastern region has high vulnerability values in all dimensions, due to its remoteness and unsuitability of land (regular floodplain, swamp). It has to be noted again that this modelling is a human-centred approach, as vulnerability is being defined in this context, and reflects a relative measure within the district.

The developed workflow provides a methodology for modelling the complex phenomena of vulnerability through the identification of vulnerability units as integrated geons. The method allows the assessment of vulnerability independent from administrative boundaries but also applies an aggregation mode that reflects homogenous vulnerability units as outlined in the geon approach. This should support decision-makers at the district level when considering complex issues such as vulnerability on a sub-administrative level within their district, while deriving units which represent a common characteristic of vulnerability. Furthermore, there is an advantage in decomposing the units into their underlying domains. From an expert's point of view, decomposition can be extended down to the indicator level, which allows a specific investigation of problem areas and shortcomings. This aspect is a central element of the

Table 16.1 Indicators and sub-domains for the four different vulnerability dimensions

Dimensions	Indicator/Index	
Environmental	**ENV_1 Biodiversity (MODIS EVI)**	
	ENV_2 Structural Diversity (Index of ENV_2_x)	
		ENV_2_1 Nearest Neighbour
		ENV_2_2 Proximity
		ENV_2_3 Fragmentation
		ENV_2_4 Diversity
	ENV_3 Loss of Biodiversity (changes in MODIS EVI)	
	ENV_4 Ecosystem Services	
		ENV_4_1 Flood Control
		ENV_4_2 Water regulation
		ENV_4_3 Soil retention
Social	**SOC_1 Health (Distance to Health Facilities)**	
	SOC_2 Education (Distance to Schools)	
	SOC_3 Conflicts (Distance to Conflict Locations)	
	SOC_4 Access to water	
	SOC_5 Capacity to anticipate (Availability of Early Warning Systems)	
	SOC_6 Potential rescue opportunities	

Economic	**ECO_1 Access local markets**	
	ECO_2 Crop density	
	ECO_3 Ecosystem service (Food)	
	ECO_4 Access to road infrastructure	
	ECO_5 Distance to nearest city	
Physical	**PHY_1 Roads**	
	PHY_2 Accommodation Centres	
	PHY_3 Schools	
	PHY_4 Health facilities	

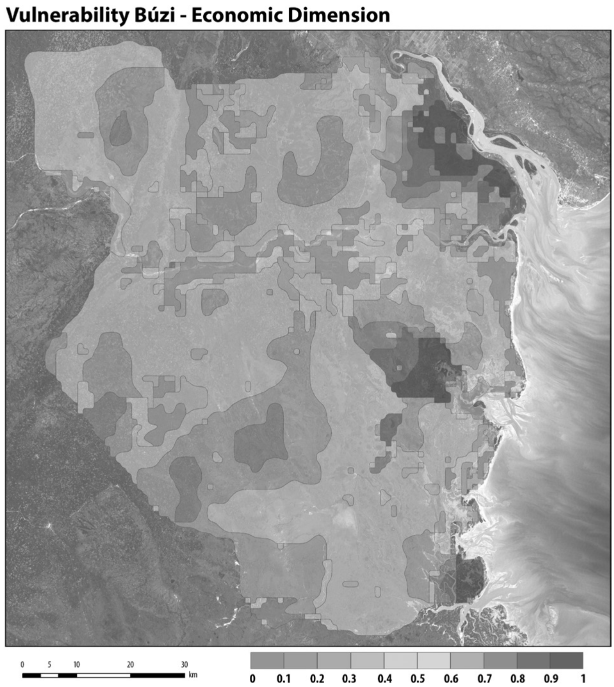


Figure 16.7 Modelling results of the economic dimension (Kienberger 2012)
Please see page 682 for a colour version of this figure.

developed approach: we have the integrated modelling of vulnerability for the identification of "hot spots" for the four selected dimensions through homogenous vulnerability units, while for an expert's view decomposability is possible down to the level of a single indicator.

Lessons learnt and conclusions

The above method was developed for the case study in Búzi, Mozambique and applied in additional case studies in Malawi, Mozambique, Madagascar, India and Bangladesh between 2007 and 2011. Based on this experience, it can be stated that the assessment of risks through the integration of community knowledge in a spatial manner through the application of paper-based satellite images is valid. For community members it was easy to orientate themselves on the maps and to draw and highlight the essential features related to hazards in the community. Once this was done, maps could be produced reflecting the knowledge of the people involved, providing a basis for improved local planning in the context of disaster risk reduction. It must be noted that mapping approaches that include a representative group from a community have to be seen as a snapshot. But for the purpose of a participatory approach it is appropriate to start such a process within the community. This has been highlighted through the identification of vulnerability factors and their weights, which may also be applied in a monitoring sense for project implementers to assess their objectives within community-based disaster risk reduction programmes. Results must be critically interpreted as there might be biases due to the facilitator's input or because of the composition of different groups or certain characteristics of specific communities. This method represents a cost-effective approach for obtaining and understanding certain needs, challenges and priorities from a community perspective. Otherwise, this can only be possible through a long period of research and fieldwork, which is difficult to implement in current project designs. It has to be noted, and this point is taken up specifically in the district approach, that to some extent such assessments reflect fuzzy boundaries, which also underlie different accuracy levels compared to a sophisticated risk delineation based on numerical and physical models. Having this in mind, which is quite an important prerequisite, it is possible to communicate with other stakeholders.

Indicators were constructed based on expert feedback and the integration of community knowledge. It has been shown that some factors/indicators were identified by both groups (experts and communities), whereas others were perceived separately. This provides ground for discussion about which indicators represent the different dimensions adequately and for the different policy levels to be coordinated among their vulnerability models. The methodology developed represents vulnerability as homogenous regions which share a common property of vulnerability for the different dimensions, and supports this as a valid approach for modelling such an integrative phenomenon. Of course data availability plays a critical role when determining the accuracy of such approaches and highlights the need for the identification of basic data for vulnerability assessments and its continuous availability over different time periods.

Finally it must again be emphasized that a map can never be guaranteed to be 100 per cent accurate and that the possibility of updates has to be considered and arranged. The decision about the integration of maps as a central decision-making tool has to involve the consideration of feedback loops, continuous updates and the strengthening of capacities at all levels. However, the spatial representation of vulnerability provides a significant basis for really capturing and understanding vulnerability based on location, integrated with knowledge and perceptions provided by the community and experts.

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17

Vulnerability assessment: The sector approach

Juan Carlos Villagrán de León

Background

Disasters have been among the many factors inhibiting sustainable development within communities in Central America and other regions of the world for many centuries. Triggered by natural phenomena, such catastrophes have been perceived until very recently as acts of nature, independent of any type of human intervention. However, in recent decades social scientists, engineers and scientists of different branches have begun to modify this view, suggesting instead that disasters are the result of a combination of natural events and the establishment of vulnerable communities, processes and services in high-hazard areas. This modern view introduces the notion of risk as a combination of hazards and vulnerabilities but also considers risks to be processes that are generated over decades or centuries, with disasters as the end result of such processes.

The reduction of risks through the reduction of hazards, vulnerabilities, coping incapacities and deficiencies in preparedness has been identified as a target since the launching of the International Decade of Natural Disaster Reduction, IDNDR. In May 1994, the *Yokohama Strategy and Plan of Action for a Safer World* issued a set of principles that continue to be the basis for risk management in terms of risk assessment, prevention, mitigation and preparedness. In an attempt to contribute to the implementation of the Yokohama Strategy in Central America, the author has embarked since 1999 on efforts that encompass the development of various methodologies for vulnerability assessment (Villagrán de León,

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

2000, 2002, 2004, 2005; Hahn et al., 2003). These methodologies, which cover various types of hazard, have been applied in communities within Guatemala and Costa Rica, and expanded to the level of municipal districts and states.

While the methodologies focused initially on the housing sector, where the greatest number of fatalities occur during catastrophic events, particularly in the case of earthquakes, in recent years it has become necessary to characterize and assess vulnerability within urban centres as well. To this end, the notion of sectors as descriptors of urban centres and societies becomes useful in terms of dividing a single urban or national vulnerability into manageable segments. The framework presented in this chapter stresses the aim of making vulnerability assessments more structured, focusing on individual sectors, and quantifying vulnerability in a way that simultaneously allows for the identification of measures to reduce it.

The approach stems from the need to provide the national disaster reduction agencies of Central America with the practical tools needed to strengthen their capacities in risk management. Improving skills is a relevant issue, because the mandates emanating from summit declarations regarding disaster reduction fall directly on such agencies – at least initially – and thus it is up to these agencies to start the process of reducing vulnerability and risk. Therefore, the characterization of vulnerabilities through sectors has an implicit policy ramification: namely, that responsibility for vulnerability management is essentially removed from disaster agencies and placed instead on the agencies in charge of the different sectors.

In addition, the methodology has been designed to be easily applicable via surveys as well as simple mathematical procedures to evaluate different components of vulnerability in a quantitative fashion. This is an important consideration, especially when such assessments have to be carried out throughout the different sectors by national disaster management institutions with limited numbers of highly trained personnel to undertake the process.

Structure and methodology

In the context of natural disasters, vulnerability can be associated with the predisposition of a system, a process, an institution, a community or a country to be affected when a natural event manifests itself. A review of the literature reveals that the term has been defined in different ways by different authors. As stated by Alwang et al. (2001) and by Brooks (2001), the literature contains terms and relationships that at times are unclear, while in some cases identical terms may have altogether different meanings. A systematic analysis of the literature allows for a classification of contexts employed by various authors when defining the nature of vulnerability (Villagrán de León, 2006). These include:

- the particular state of a system before an event triggers a disaster, described in terms of particular indicators or parameters of such a system;
- the probability of the outcome of the system, expressed in terms of losses, measured in terms of either fatalities or economic impact;
- a combination of a particular state of the system with other factors such as the inherent capacity to resist the impact of the event (resilience) and the capacity to cope with it (coping capacities).

The International Strategy for Disaster Reduction, ISDR (UN/ISDR, 2004) defines vulnerability as the set of conditions and processes resulting from physical, social, economic and environmental factors that increase the susceptibility of a community to the impact of hazards. The physical factors encompass susceptibilities of the built environment. The social factors are related to social issues, such as levels of literacy, education, the existence of peace and security, access to human rights, social equity, traditional values, beliefs and organizational systems. In contrast, economic factors are related to issues of poverty, gender, levels of debt and access to credits. Finally, environmental factors include natural resource depletion and degradation. Within the Inter-Governmental Panel on Climate Change (IPCC, 2001) vulnerability is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". It is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.

Regarding various aspects or dimensions associated with vulnerability, Wilches-Chaux (1993) has proposed that vulnerability has different dimensions: physical, economical, social, educational, political, institutional, cultural, environmental and ideological. In contrast, the author (Villagrán de León, 2001) identifies several components related to vulnerability: structural, functional, economic, human condition/gender, administrative and environmental.

Despite these different approaches to context, the notion of vulnerability as an essential component of risk has been fundamental in linking disasters to social processes related to development in communities throughout the world. The introduction of vulnerability in the context of disasters has allowed scientists to explain them as not arising solely as a consequence of natural events, such as earthquakes or floods, or social events such as fires and explosions, but as a consequence of processes associated with development that have not taken into account the possible manifestation of such phenomena, and thus are not adapted to these phenomena. However, while the worldwide academic debate continues on the notion and the nature of vulnerability, declarations emanating from summits and international conferences are already calling on governments and institutions to reduce it in order to promote more sustainable development.

From the policy point of view, this implies the recognition of vulnerability as a factor that contributes directly to risks, and hence to disasters. Following this line of thought, one way to start the process of vulnerability reduction is via a framework that defines it in terms that can be assessed, so that the process of reduction can be followed and assessed as well. However, at present this task is difficult as there are no standard, globally accepted methodologies to carry out such assessments. Pilot assessments have been developed at the global level by UNDP-BCPR (UNDP, 2004) and by the World Bank and other institutions through the Hotspots method (Dilley et al., 2005); more recently the Inter-American Development Bank sponsored an assessment using novel techniques (Cardona et al., 2003). Other methods have been developed at the subnational scale and applied in Guatemala and other countries (Villagrán de León, 2000, 2002, 2005; Hahn et al., 2003). In developing countries where disasters are frequent and resources scarce, an obvious strategy is to reduce vulnerabilities initially in those regions where vulnerability can be categorized as high. The problem then becomes one of categorizing communities or geographical regions according to low, medium and high degrees of vulnerability. The next step is to develop methodologies that span the different dimensions or components of vulnerability.

In developing methodologies to assess vulnerabilities associated with natural disasters, one must understand that vulnerabilities depend on the type of hazard in question (Villagrán de León, 2000, 2002). Furthermore, a possible intrinsic relationship between vulnerability and the magnitude of the hazard should also be considered (Bogardi et al., 2005; Cardona et al., 2003). In an effort to systematize the various aspects of vulnerability, the author has proposed considering vulnerability as a state of a particular system, excluding coping capacities, exposure and resilience. Vulnerability is considered as a dynamic quantity because there are several factors that modify it. It is a component of risk when linked to hazards and deficiencies in preparedness. In this model, coping capacities are related to the response once an event manifests itself.

The need to simplify the notion of vulnerability in terms of components becomes evident once a quantitative assessment is required. If too many elements are included within vulnerability, such as coping capacity, resilience, susceptibility and exposure, then major complications arise –

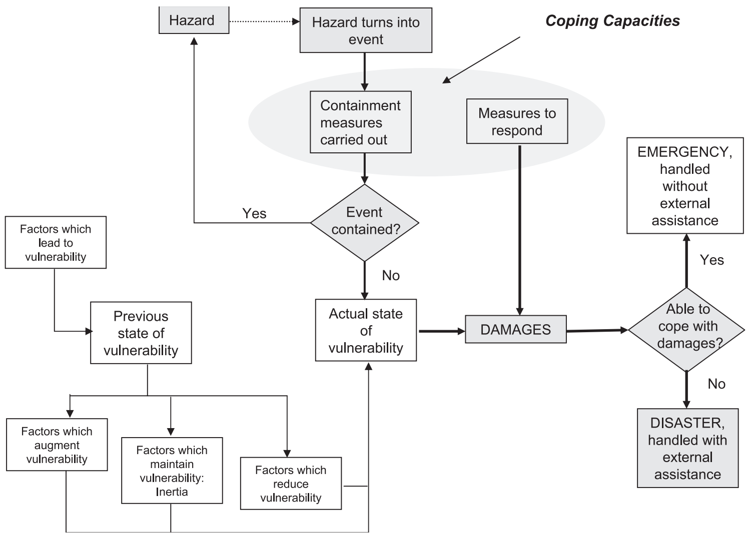


Figure 17.1 Hazards and vulnerability, and their relationship with disasters and coping capacities
Source: Villagrán de León, 2005.

first, when identifying how to assess each of these components, and then with respect to how to combine such components to obtain a final figure for the degree of vulnerability inherent in a specific system or a community. Another matter for consideration when vulnerability has to be assessed is the level at which the assessment will be carried out: is it the municipal level, the level of a single house or at the national level? Assessment at different levels encompasses different components and parameters. Integrating these previous notions regarding components of vulnerability, the level at which assessments must be carried out and the type of sectors involved, it is logical to propose that the quantitative evaluation of vulnerabilities should be set up along three dimensions (Villagrán de León, 2005):

- *The geographical level dimension*: this ranges from the human being and the single unit to the national level, and includes the local or community level, the municipal or district level, and the state or province level. The evaluation of vulnerability across this dimension is more related to public policy, as political administrations at different levels are responsible for the administration of such levels.
- *The sector dimension*: this dimension is based on the typical development framework that defines society in terms of its sectors: health, housing, education, infrastructure, energy, agriculture, industry. The

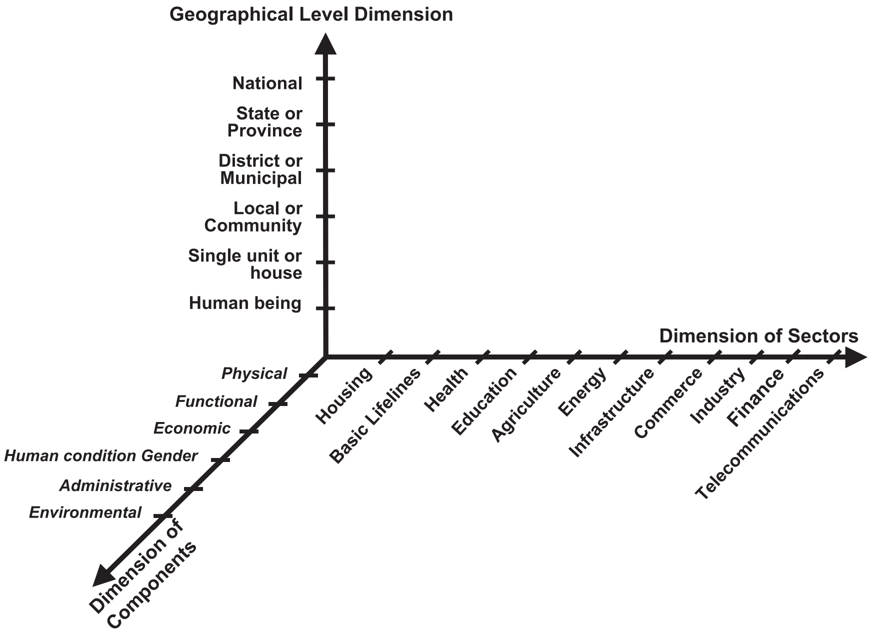


Figure 17.2 The dimensions of vulnerability
Source: Villagrán de León, 2005.

evaluation of vulnerability across this dimension is of interest to those institutions involved in managing such sectors, or which are already part of those sectors.

- *The components dimension*: this dimension is related to the various components that are included within the context of vulnerability. These include: structural, functional, economic, administrative, environmental and human condition/gender. Any assessment of vulnerability must start by identifying which components the definition will include or exclude.

The sectoral approach has been proposed from the policy point of view because it promotes the assigning of responsibilities for reducing vulnerabilities to those private or public institutions in charge of each sector, whether these be government ministries or chambers of commerce, tourism, industry and the like, or bodies at other political-administrative levels. For example, at the national level it is the responsibility of the Ministry of Health to assess and reduce the vulnerability of public health centres. In contrast, it would be up to the director of a local community health clinic to manage the clinic's vulnerability by requesting whichever resources are required for this purpose from the ministry.

The assessment of vulnerability is carried out via an analysis of the components described earlier: structural, functional, economic, human condition/gender, administrative and environmental. Elements within each component are identified a priori from a classification of damage during disasters. The method then identifies options for each of these elements and assigns weights to each option according to its disposition to be affected by an event. A simple linear combination of the elements is carried out numerically to obtain a numerical output for the intrinsic vulnerability component, which can be characterized as low, medium or high using a table of ranges. All numerical values regarding options, as well as weights for combining the vulnerable elements, have been deduced with the aid of expert judgement.

Vulnerability assessment using the sector approach must start by defining which sector is to be addressed and then defining the hazards and the geographical level at which the assessment is being made and, finally, the component of vulnerability being assessed. To assess the vulnerability one would then focus along the dimension of components:

- The physical component relates to the predisposition of infrastructure employed by the sector to be damaged by an event associated with a specific hazard.
- The functional component relates to the functions which are normally carried out in the sector and how prone these are to be affected.
- The human condition/gender component relates to the presence of human beings and encompasses issues related to deficiencies in mobility of human beings and to gender considerations.
- The economic components are related to income or financial issues that are inherent to the sector.
- The administrative component relates to those issues associated with the management of routine operations and the ways such administrative issues can be affected by an event.
- The environmental component continues to relate to the interrelation between the sector and the environment and the vulnerability associated with this interaction.

As stated earlier, the assessment of vulnerabilities spans the national level, the state and other lower levels. For example, the vulnerability of a particular hospital may require that the structural components of the building be analysed; a functional vulnerability would comprise those elements that are essential to the hospital's ability to function as a health facility and would include specialized medical equipment and the flow of gases, water and electricity, as well as the storage of certain chemicals and medicines in controlled environments, for example. In the case of private health institutions, economic vulnerability must be considered. In the case of a hospital, the human condition/gender is an issue, especially due to the higher vulnerability of temporarily hospitalized patients whose mobility is restricted due to injury, treatment or sickness, and to the intrinsic vulnerability of infants and incapacitated people due to their lack of mobility while remaining in the hospital. Additional issues related to administrative/organizational processes and functional relationships within different sections or departments are also important to consider (PAHO, 2000); in extreme cases there may be issues related to environmental contamination from the spill of particular chemicals, or solid and liquid waste, particularly of the biological kind.

Examples

Example 1: Structural vulnerability of a house in case of volcanic eruptions

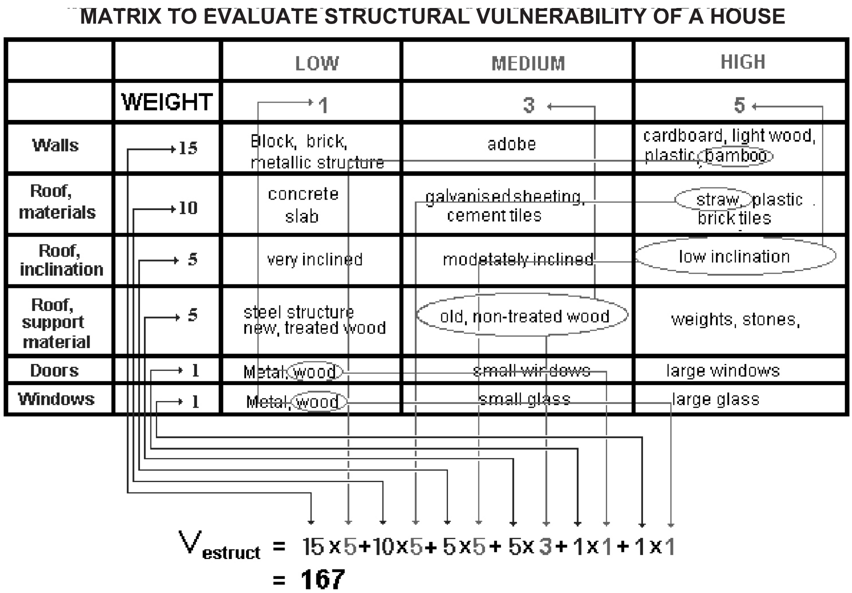
- Sector: housing
- Geographical level: single unit or house
- Component: structural

Many disasters in both historical and recent times have exposed the structural vulnerability of houses which, when collapsing, provoke numerous fatalities. In Guatemala, the recent 1976 earthquake killed more than 23,000 inhabitants in urban and rural areas when adobe houses collapsed at 3:03 am. If fatalities are to be reduced, the structural vulnerability of houses must be addressed.

The following example illustrates how to calculate the structural vulnerability of a house with respect to ash deposits from volcanic eruptions. Within this framework, a house is considered at the geographic level of a structure unit, belonging to the housing sector, and the example focuses on the structural component.

In the case of volcanic eruptions, the structural vulnerability of the house is modelled using six structural elements: walls, roof materials, roof inclination, roof support material, doors and windows (Villagrán de León, 2005). The degree of low, medium and high vulnerability of each option is introduced in terms of the construction material employed and construction techniques, recognizing that some are more likely to be damaged than others.

The classification of materials into the three categories has been based on an analysis of historical eruptions in Central America and the damage caused by such ash deposits on different types of houses. Numerical weights are assigned to the structural elements of the house and to the different construction materials for the various options, and are the com-



Degree of structural vulnerability	*Numerical Range*
Low	*37 - 80 points*
Medium	*81 - 130 points*
High	*131 - 185 points*

Figure 17.3 Matrix to evaluate structural vulnerability with respect to eruptions
Source: Villagrán de León, 2005.

bined in a linear fashion. The overall vulnerability is presented in terms of arbitrary units and is classified in three ranges according to such values: *low, medium* and *high*.

In this case, it is important to recognize several aspects:

- The indicators are forward-based. This is an important issue to consider, especially because the vulnerability is being expressed in terms of the present condition of the house and addresses those elements likely to be damaged by the deposition of pyroclastic materials in case of an eruption.
- The method is especially well adapted to handle different hazards. Adaptation to different hazards must recognize the impact of the hazard

on the various structural elements of the house, adapt the procedure and assess the specific vulnerability of various types of construction materials and techniques for each component.
- The indicators display the vulnerability of the household in an explicit fashion through the four types of vulnerability. Different types of buildings and components can, it is assumed, be classified as more or less vulnerable, and the degrees of vulnerability can be computed according to the actual condition of the house.
- The indicators do not show how vulnerability depends on the magnitude of the hazard. Rather, the method is based entirely on the likelihood of a very high-magnitude event and cannot cope with small-magnitude events at this time.
- The vulnerability assessment can be employed to assess the vulnerability of a single house but can also be aggregated at the community, municipal, province and national levels. Figure 17.4(c) displays houses in the urban settlement Las Torres in Guatemala City. Lots have been classified and identified as being of low (green), medium (yellow) or high vulnerability (red) with respect to landslides (Pérez, 2002).
- The method clearly identifies options to reduce the degree of vulnerability explicitly but has been tailored for specific regions of the world (taking account, for example, of construction materials used in a particular region). It will need to be adapted if it is to be applied in other regions of the world.
- The method requires a specific survey to gather information on the component of vulnerability being evaluated.

Thus far, the method has been applied in urban and rural communities of Guatemala and Costa Rica for a range of risks, including earthquakes, landslides, floods, high winds and volcanic eruptions.

Example 2: Functional vulnerability of a health centre in case of floods

- Sector: health
- Geographical level: single unit
- Component: functional

A similar procedure has been developed for health centres in the case of floods. In contrast to volcanic eruptions, floods are events in which infrastructure is affected by water or mud coming from the ground level. Thus, for the case of the functional component of vulnerability, the most important element is the height of the floor with respect to the ground. Experiences throughout Central America of floods in several types of hospitals and health centres indicate that the next element to be consid-

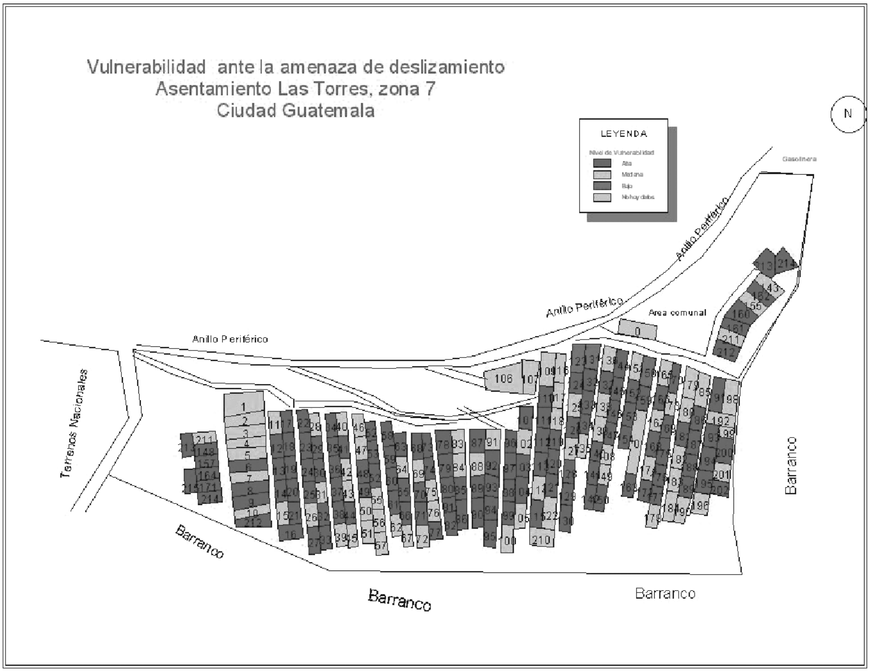


Figure 17.4 Vulnerability with respect to landslides in an urban settlement of Guatemala city
Source: Pérez, 2002.

Please see page 683 for a colour version of this figure.

ered with respect to functional vulnerability is the number of floors that the health facility may have. Facilities with several floors are less vulnerable than facilities with a single floor.

The next element relates to the personnel in charge of caring for the sick, whether doctors, nurses or other staff. The premise is that the more staff assigned to a centre, the less vulnerable it is.

Additional elements are the accessibility of the facility, the availability of emergency electrical generators and deposits for potable water, as well as issues related to the storage of supplies and chemicals used in the health facility.

As in the case of houses exposed to volcanic eruptions, vulnerability is calculated in terms of options that make the facility more or less vulnerable. The final value obtained for a particular facility can then be used to categorize the vulnerability as low, medium or high.

	WEIGHT	LOW 1	MEDIUM 3	HIGH 5
Level of floor first level	10	High, > 50 cm.	Barely higher than ground, 10 cm	At ground level or lower still
Number of floors	5	3 or more	2	1
Number of doctors and nurses attending the centre	10	More than 3, living in the community	One or two, living in the community	One, living outside the community
Potable water sources in use	3	3 or more	2	1
Alternate power supply	3	Yes		No
Access to facility	3	Paved, elevated, centrally located	Paved, centrally located	Un-paved, difficult to access
Water deposit in premises	2	Yes, elevated	Yes, underground	No
Storage of supplies, instrumentation	2	In elevated places 2nd story	In elevated places 1st story	1

$$V_{econ} = 10\times5 + 5\times5 + 10\times5 + 3\times3 + 3\times5 + 3\times5 + 2\times5 + 2\times5$$
$$= 184$$

Figure 17.5 Matrix to calculate the functional vulnerability of a health centre with respect to floods
Source: adapted from Villagrán de León, 2000.

Linking the components: risks and risk maps

In the context of risk management policy, risks should be conceived as composed of three measurable factors: *hazards* (the possibility of natural phenomena occurring in a certain geographical area), *vulnerabilities* (the pre-existing conditions that make infrastructure, processes, services and productivity prone to be affected by an external event) and *deficiencies in preparedness* (those conditions that inhibit a community or a society from responding in an efficient and timely manner to minimize the impact of the event in terms of fatalities and losses).

This model assigns responsibility for hazard management to the national institutions devoted to hazard monitoring and to municipal authorities in charge of land-use norms; responsibility for vulnerabilities remains with those who generate them, and the model makes specific reference to each sector; the responsibilities related to disaster-preparedness measures are assigned to the national disaster-management agencies and those

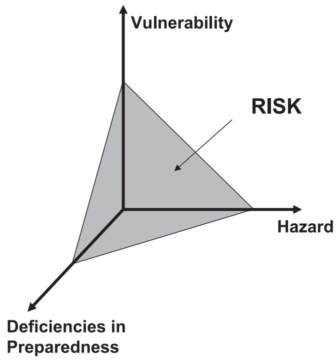


Figure 17.6 The composition of risk
Source: Villagrán de León, 2001.

agencies devoted to response in case of disasters (such as the Red Cross).

The next step in the risk management process is the assessment of hazards by scientists from different earth science disciplines, such as geology, hydrology, meteorology and vulcanology, and assessment of vulnerabilities and deficiencies in preparedness.

Once these components have been evaluated, they can be combined to generate risk maps. The map shown in Figure 17.7 depicts risks associated

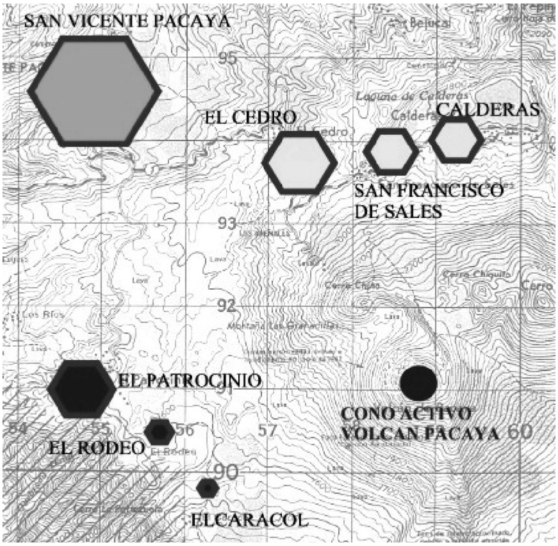


Figure 17.7 Risk map associated with eruptions, Pacaya volcano in Guatemala
Source: Villagrán de León, 2005.

with communities in the foothills of Pacaya volcano in Guatemala (Villagrán de León, 2005b). The active cone is identified by a red circle on the lower right. Communities are represented by hexagons in such a way that the size of the hexagon represents the relative size of the community. San Vicenta Pacaya, the largest community in the area, contains almost 1,000 households. El Cedro and El Patrocinio have about 250 houses each, while El Rodeo has 17 and El Caracol only two. The colour assigned to the communities represents the level or risk, which has been classified into three ranges: low (green), medium (yellow) and high (red). In this particular case, all the communities display similar vulnerabilities, but communities to the south-west of the cone are at greater risk because the hazard is larger in this region than in regions to the north.

Open questions and limitations

As described, the sector approach is based on the notion that vulnerabilities must be reduced by those institutions in charge of the sector. To this end, each sector must recognize its responsibility and start activities to reduce vulnerability. The method used to assess vulnerabilities then relates to the identification of the hazard, the geographical level at which the assessment is being made and the components which are to be targeted for the assessment.

In Central American nations, Hurricane Mitch was a catalyst to start such processes, and the health sector is advancing dramatically along these lines with the support of the Pan American Health Organization, the World Health Organization and the International Federation of the Red Cross. However, the current approach employed by these institutions does not cover all the components proposed in this approach.

In addition, the housing sector has received considerable attention, and in many countries the reduction of structural vulnerability is being addressed through building codes. However, lack of resources and the number of buildings constructed by individuals themselves for their own use are key factors inhibiting the implementation of building codes. Vulnerability assessments of the housing sector in various communities within different municipal districts that have been carried out by the author have analysed four of the six components (structural, functional, economic and human condition/gender). Matrices have been developed for each of these components, covering distinct types of hazards manifesting themselves in Guatemala (floods, earthquakes, landslides, volcanic eruptions, high winds and floods (Villagrán de León, 2000, 2002, 2005b). The major drawback so far is the need to carry out specific surveys to acquire the data necessary for the assessment.

In the case of the housing sector, the method has also been adapted to the use of census data provided by the National Statistics Institute of Guatemala, but precision is lost because not all elements are considered in the census; only the structural and the human condition/gender components can be evaluated at this time with such data (Villagrán de León, 2002).

Outlook

As main conclusions regarding the methodology presented in this chapter, the following comments can be presented:

- Vulnerability assessments using this framework are easy to perform but require a specific survey outlining the types of elements and options included in each type of component.
- The vulnerability indicators make use of "arbitrarily" set weights to combine different elements. While expert judgement has been employed, the selection of numerical weights can always be questioned.
- The indicators can deliver particular information on vulnerabilities associated with a large-magnitude event but still lack the capacity to handle different hazard intensities.

Regarding additional work to improve the methodology, the following comments can be made:

- The focus should be expanded to consider all sectors, encompassing all levels and components within the sectors.
- There is a need to develop models to analyse social aspects not covered within the "sector" approach.
- There is a need to develop models to analyse vulnerabilities at various levels (communities, states or provinces, and at the national level). The methodology presented in this chapter focuses on individual communities.
- There is a need to develop models to evaluate those factors that modify vulnerabilities.
- There is a need to expand the methods so that they can exhibit the level of vulnerability as a function of hazard magnitude.

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18

Self-assessment of coping capacity: Participatory, proactive and qualitative engagement of communities in their own risk management

Ben Wisner

Background

This chapter describes an approach to community-based disaster management that has at its core a method of self-assessment of coping and capacity. This method has developed slowly over the past 40 years, ever since development workers first began noticing the phenomenon of differential vulnerability/capacity in the face of natural hazards. In brief, it emerged as some of us began to synthesize the field observations that were coming in from different parts of the world: the Sahel famine (1967–73), the 1970 cyclone in Bangladesh and Hurricane Fifi in Honduras (1974), for example. There were several common elements in all of these observations. Chief among them were:

- Death, injury, loss and the ability to recover (that is, vulnerability) were highly associated with livelihoods (their nature and their security).
- Vulnerability was not only an economic matter but depended also on location and access to political power.
- Vulnerability was not homogeneous in "communities" but varied widely.
- Capacity also existed. Farmers had coping strategies that relied on indigenous technical knowledge, social networks and alternative income-generating activities.
- National government officials did not understand or trust such capacities, and national counter-disaster strategies generally came from

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the top down (if they existed at all in marginal, peripheral zones). On the whole these made the situation worse.

Responding to these observations, an approach was developed in the 1980s and 1990s for defining and analysing vulnerability and capacity that linked these concepts to the livelihoods, locations and ecological conditions of households, to political access and "voice", and to local knowledge and social relations. However, analysis is not the same thing as assessment. From a practical point of view, non-governmental organizations (NGOs) and other development institutions simplified the approach by creating taxonomies of "vulnerable groups" that are very familiar to us now: women, children, elderly people, people living with disabilities, ethnic and religious minorities, and the like.

Reports from Sri Lanka and India suggest that as many as a third of those killed by the tsunami of 2004 were children (Rohde, 2005). In the Great Hanshin earthquake in 1995, more than half of the 6,000 killed were over 60 years of age, and many of them elderly widows living by themselves (Wisner et al., 2004a: 293–300). There is empirical support for the use of such "check lists" of vulnerable groups, especially by hard-pressed relief personnel. NGOs like Help the Aged and Save the Children have developed sophisticated screening techniques that can pinpoint children or elderly people at risk in shelter or refugee camp situations.

While there is a lot of truth in the assertion that such groups often suffer more injury and death during disasters, and that they may have "special needs", the taxonomic approach is problematic. In between disasters, when the challenge is to work proactively with local government, civil society and other stakeholders to assess vulnerability in advance and try to reduce it, the simple taxonomic approach fails. First, it produces too many "false positives". Not *all* women are equally vulnerable in Kenya in a drought or in the Philippines in a cyclone. Therefore, in order to deal with this weakness of the taxonomic approach, civil society organizations in many places have adopted what can be called a situational and proactive approach. Some individuals, such as Paulo Friere (1973) and Robert Chambers (1983), were influential in legitimizing this kind of "bottom up", participatory approach. This approach has evolved as civil society has evolved.

Thus one of the key goals of this approach is to empower local people so that they can understand their own daily lives and situations in a way that enables them to increase self-protection and to demand and fight for social protection. The main goal is not national or international comparison, and measurement is used here essentially as a means for providing local people with more control over the conditions of their lives.

Structure, methodology and examples

A proactive and situational, dialogical approach to assessing coping and capacity

As developed and practised by a wide variety of NGOs today in many parts of the world, the approach aims to build enough trust, common purpose and motivation among a group of people so that they can use a variety of simple tools (hazard mapping, time budgets, problem trees, wealth ranking and so on) and ask key questions (for example, what are our strengths/opportunities/weaknesses/threats?) to assess their own capacities and vulnerabilities. This is the form of self-assessment at community level that is the basis of community-based disaster management, which is very different from global assessment and measurement methodologies, for example as shown in the overview provided by Birkmann in Chapter 1 of this volume.

Self-assessment is proactive because it does not focus solely on hazards and vulnerability but also on capacities. It takes a problem-solving perspective. The approach is situational because it is place and group specific. It takes into account specificities, change and surprise. It is therefore a special case of what is more formally known as "adaptive planning". What groups in the Philippines, Bolivia and Zimbabwe (among other places) are doing is also dialogical because there is no "expert" or "teacher". The facilitator seeks to understand the reality on the ground and find the way forward together with the participants. In this way, it is also natural to begin with local knowledge (for example, of soil, weather, pests, ocean tides and storms, etc.). Outside knowledge may well be brought into the mix, but as knowledge that is added and not as a replacement for the vernacular system of understanding.

An African example

A group in the drought-prone Chivi district in southern Zimbabwe has used wealth ranking in addition to other criteria to identify people who are most vulnerable (Murwira et al., 2000; Wisner, 2008). People with fewer assets are less able to produce a surplus that can be stored against a bad rainfall year, and have fewer monetary savings or possessions (such as livestock) that can be sold to buy grain during hungry times. The self-assessment of drought vulnerability included sketch mapping of people's farms in order to identify resources and environmental constraints, and also generated participants' labour profiles. These showed the various tasks that men and women have month by month in the annual cycle of agricultural production. In this way labour constraints were identified, as well as periods when people have more free time to engage in cooperative activities to reduce drought risk.

Focus group discussions also identified the range of people's coping technology. A series of "traditional" drought-proofing measures, such as seed selection, intercropping of more than one plant and small-scale irrigation, were identified. Drought-coping mechanisms, such as the sale of livestock and of labour outside of the community, were also mentioned. However, these groups were not simply open-air seminars but action-oriented circles. They discussed and tested various additional means for avoiding drought. These included the use of tied ridges in their maize (corn) fields. Earth is not only dug up to form ridges on the contour of the field but also mounded to form "ties" from ridge to ridge, forming a rectangular "box". Rainwater is trapped in the box and thus can infiltrate deeper into the rooting zone of the plant. In this way, every bit of precious rain is used.

Self-assessment that is place and group specific is likely to be quite complex. In Malawi, for example, vulnerability to drought is not simply a function of agronomic practices, numbers of disposable livestock (a banking system on the hoof) or savings (de Waal, 2002, 2005). Group self-assessments there have also focused on whether an adult in the household is living with HIV/AIDS, the dependency ratio in the household and whether there is the labour capacity to carry out some of the well-known drought-avoiding practices (for example, multiple plantings during periods of erratic rainfall, tied ridging to maximize rainfall infiltration and earning income from casual labour).

Tools for community risk assessment

The "tool kit" for those who facilitate community risk assessment (CRA) is varied and constantly growing (McCall and Peters-Guari, 2012; Gaillard and Maceda, 2009). Many of the tools used date from rapid rural assessment (RRA), and then later from participatory learning activities (PLA), which evolved from development practice. Since the late 1950s, with a great acceleration during the 1980s and onwards, there has been a fertile exchange back and forth between academic researchers in development studies, anthropology and geography on the one side, and their counterparts (and frequent partners) in development NGOs and other agencies on the other side. Within this academic–NGO nexus, tools were developed to elicit and systematize local knowledge. While many, if not most, of these tools were developed with uses other than CRA in mind, institutions working on disaster risk reduction have absorbed a number.

An array of 20 manuals and guidebooks that contain such tools can be sampled on the website of the ProVention Consortium (ProVention, 2005). Other methods have been reviewed by Wisner et al. (2004: 333–342).

A brief discussion of three representative examples will serve here to demonstrate their qualitative and action-oriented nature. These examples come from a manual developed for use in the Pacific Islands by UNDP (1998).

The recent historical timeline

Note that the timeline in Figure 18.1 goes back to the founding of the village some hundred years ago. Oral history is obviously the basis of some of this narrative. Note also that significant political, socio-economic and natural events are bundled together in the historical memory of this community: the establishment of a new chief, a major cyclone and an economic recovery programme. Group discussions that generate such a timeline provide the basis for planning for the future. The interconnection among different kinds of events becomes clearer, and people's potential agency in their own history becomes more than speculation.

In an African context, the present author and his colleagues used timeline discussions with focus groups of elders in four Tanzanian villages in 2010 to identify hazards experienced as early as the 1930s and to discuss their relative severity, especially compared to more recent hazards, as well as to discuss coping strategies and their effectiveness (Wangui et al., 2012). Large sheets of paper were taped to the wall (tricky when the wall is made of mud brick and not smooth) and coloured bits of masking tape moved around below the timeline to represent droughts by severity or above the line to represent floods. Other events such a cholera outbreaks and quarantines, insect plagues and landslides were also recorded.

The annual calendar and labour budget

Figure 18.2 also emerges from group discussion. It describes the cyclical rhythm of activities, both social and economic. Periods of greater or lesser vulnerability to disruptions appear, for example when credit for the harvest is more necessary in order to get by. In some cases, an annual timeline like this one is useful in identifying when surplus time is available during the year for women and men to work on cooperative projects that prepare for hazard events. Often such time/labour budgets are done separately for women and men.

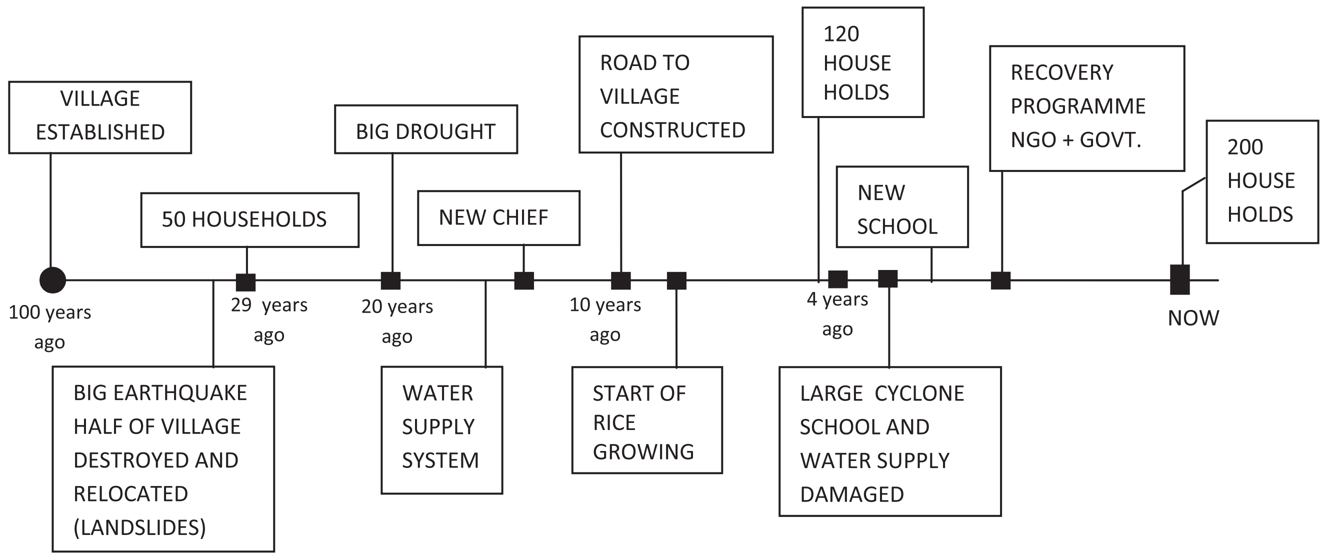

Figure 18.1 Timeline
Source: Author.

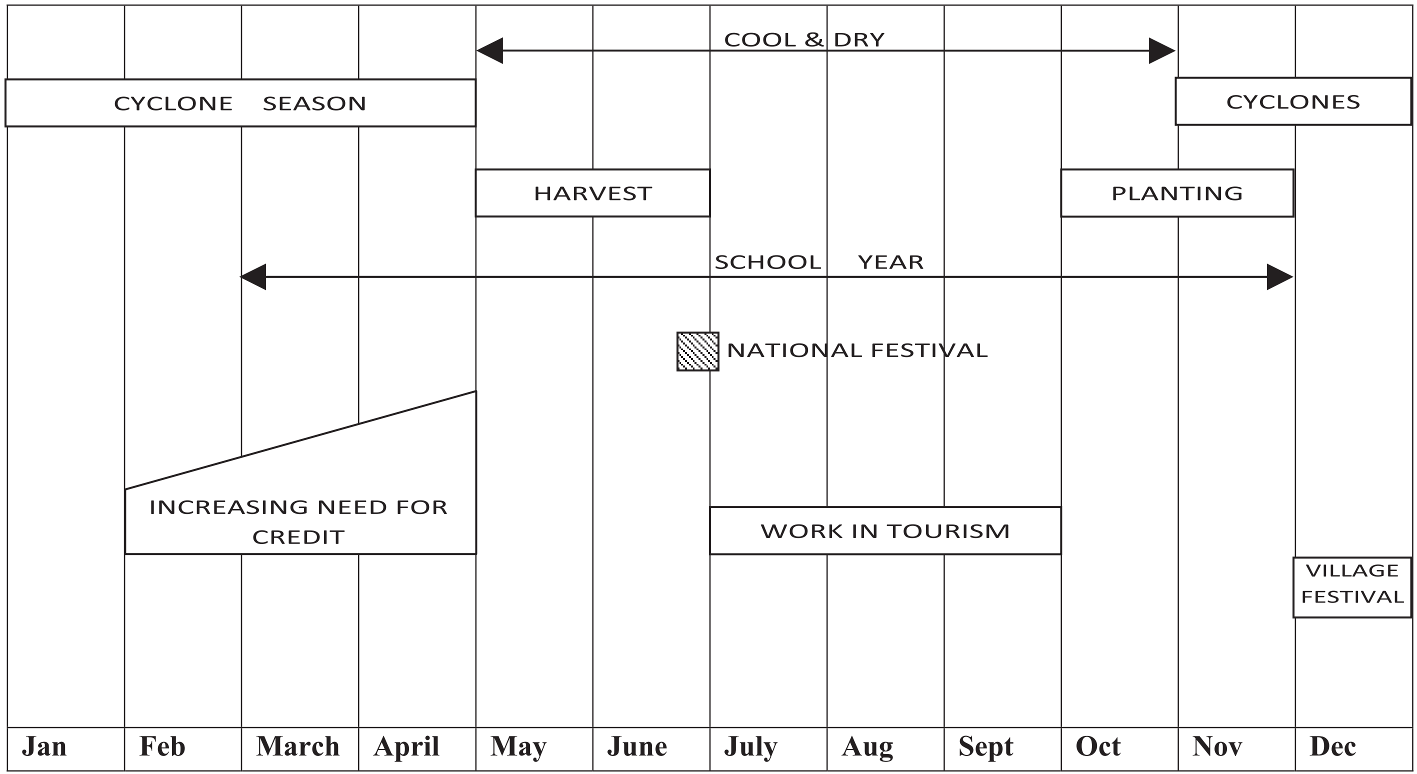

Figure 18.2 Example of a seasonal calendar
Source: Author.

The Venn diagram

Figure 18.3 is an example of a kind of brainstorming in groups that results in clarity about the interrelationship of problems and opportunities, strengths, weaknesses and threats. The figure is named after the logician John Venn. Overlapping and adjacent circles "contain" processes that are related in conceptual space. In this particular example, villagers "mapped" the relationships among significant social, political, service and economic institutions that might have some role in reducing disaster risk. What became evident in the discussion and is mirrored in the diagram is that the clinic and the bank are "outliers", without strong direct links to the village or a mediating institution, such as the women's group. This analytical result, while qualitative, can be quite important in focusing attention on a missing link and on action that is needed to make that link.

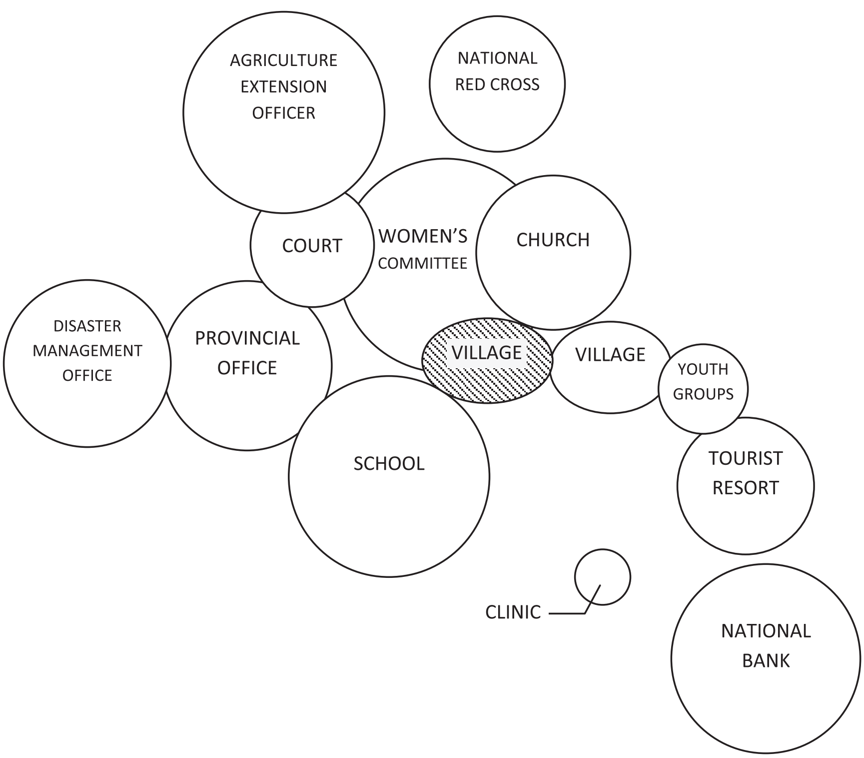

Figure 18.3 Example of a Venn diagram
Source: Author.

An American example

When one reviews the results of such group self-assessments, based on these and a wider variety of other tools from many parts of the world, it is striking how complex and variable they are. In West Hollywood, part of the greater Los Angeles megacity, there are significant minorities who have special recognized needs during earthquakes and flooding. These minorities include an elderly Russian émigré population that has minimal English and little trust in authorities because of their life experiences in the former Soviet Union. After citizen-based consultations, the city has hired a Russian-speaking liaison officer and also recruited outreach volunteers among the younger elders who live in the apartment houses where this population is concentrated. Another group includes several thousand homosexual youths and male-to-female transgender individuals. They are particularly vulnerable in some cases because they inhabit derelict buildings and, like the elderly Russians, avoid and disregard authorities and their warnings. Others, who are middle class, nevertheless have special needs for privacy in common shelter situations. The city has appointed a transgender social worker to do outreach work among this population and also to give training to police and firefighters who tend to have little understanding of these people, or even act with hostility towards them (Wisner, 2004b).

Another very important point that emerges from such self-assessments is how vulnerability and capacity are treated interchangeably. Since these self-assessments are action-oriented – proactive is the term I tend to use – they focus not only on what increases the likelihood and severity of injury, loss, psychological trauma and difficult recovery but also on what capacities can and should be developed in order to reduce these vulnerability factors. This is most striking in the case of people living with disabilities. The tendency in the past, represented by training material produced by the Federal Emergency Management Agency (FEMA) and the American Red Cross, has been to teach caregivers how to help the disabled. Little attention was given to the capacities that people living with disabilities already had or could develop. With the international "independent living movement", a more nuanced approach to disability is now emerging. The "disabled" are not simply seen as a category in a standard taxonomy; rather, each person's situation and capacities are taken into account, and the person living with a disability is seen as a partner in developing pre-disaster plans and capacities (Wisner, 2006).

Other examples

In a similar way, community-based researchers have rediscovered the large repertoire of capacities people use in Bangladesh to "live with floods" (Schmuck-Widmann, 1996, 2001, 2011) or to "live with drought" (von Kotze and Holloway, 1999). In my own PhD work, which I did in collaboration with the National Christian Council of Kenya (NCCK) in eastern Kenya during 1971–1976, I found that people knew of 76 different ways to cope with drought. These ranged from agronomic and ecological adjustment to social and economic and even political actions (Wisner, 1988). This pattern of indigenous coping with drought proved useful to the NCCK in designing alternatives to famine relief efforts with various groups of people in eastern and northern Kenya. Smucker and Wisner studied some of these sites again and provide a 30-year longitudinal study, again making use of participatory methods (Smucker and Wisner 2008; Smucker 2011).

Scale, functions and intended partner group

Scale

The approach is highly local in scale and yet very broad, including aspects of local economic, social, political, technological, ecological and geographic processes as they affect local capacity and vulnerability. However, networks of citizen-based organizations that use these self-assessment methods are beginning to develop links to national and regional hubs such as Duryog Nivaran in Sri Lanka, Peri Peri in Africa and La Red based in Colombia. At the international scale, the Global Network of Civil Society for Disaster Reduction (GNDR) groups 600 national NGOs and utilizes both conventional large-N social survey techniques and CBA tools to provide "ground truth" about the degree to which "top down" policies are benefiting local people. The GNDR conducted a major "bottom up" survey involving 7,000 respondents in 48 countries to estimate the degree of implemention of the UN's master plan for disaster reduction, the Hyogo Framework of Action (GNDR, 2009). Even more ambitious surveys were conducted in 2011 and 2013.

Intended partner group of the approach

On the whole, organizers tend to approach low-income, marginalized groups of people, often in the aftermath of a hazard event such as a volcanic eruption or coastal storm. In an effort to organize people and mobilize their energy and participation in making a village or urban neighbourhood plan for the *next* hazard event, local groups, such as the one affiliated with the Center for Disaster Planning in Manila, build on people's experience and motivation.

For example, if one were to imagine anticipatory use of citizen-based vulnerability assessment in coastal Thailand before the 2004 tsunami, a complex and shifting mosaic of vulnerability factors would emerge. Wealth and access to resources (including information and social networks) would be important. Thus poor rural migrants, who are recent arrivals, may be more vulnerable than better-established households. However, with time, such rural migrants may become well connected. Occupation is also likely to emerge as an important factor. Those reliant on fishing were particularly vulnerable to the tsunami and in general are more vulnerable to the frequent cyclones that affect the region. Their vulnerability involves not merely their proximity to the sea but their tendency not to want to abandon their only assets – a boat and nets – even if they have received an evacuation order. Without insurance, they will also find it very difficult to re-establish their livelihoods. Returning to the coast of Andra Pradesh eight years after a deadly cyclone hit there, Peter Winchester found that small farmers and small-scale fishermen had made least progress in recovery (Winchester, 1992). A citizen-based self-assessment of vulnerability might also have revealed that it is not customary for women and girls to learn to swim (just as in Bangladesh, gender-specific cyclone mortality is caused by the fact that women do not climb trees).

Thematic focus

The CBA approach discussed here usually includes hazard mapping as well as vulnerability/capacity assessment. It can be focused on a single hazard or have a multihazard focus. Vulnerability/capacity assessment can be simple or complex. The simple version would involve a census of people and assets at risk, pinpointing some individuals or households who are at extreme risk, and a review of human, financial and technical resources available to mitigate the risk. In the simplest version, the plan that emerges would not even include mitigation but only preparedness.

In more complex applications, the approach goes further to study the "root causes" of vulnerability and the blockage of capacity. This might involve discussion and eventual action to deal with the problem of land poverty or landlessness, exploitation by landlords, moneylenders or corrupt officials, and similar problems.

Open questions and limitations

Technical limitations

In many of the situations where this approach to community risk assessment is used, participants have a low level of formal education. A careful balance may be required between qualitative and quantitative characterization of hazards, vulnerabilities and capacities. On the one hand, one wants results that are meaningful to local participants and that can lead to action plans and, indeed, to action. On the other, one wants to achieve a minimum acceptable standard of accuracy. However, recent experiences show that even advanced tools such as mapping with geographical information systems are accessible to untrained lay people (McCall and Peters-Guari, 2011).

Political limitations

"Limit situations" may be reached where participants agree that they cannot take risk reduction further without a change in policy or practices over which they have no control (Freire, 1972). In such cases, politics may come into force. In democratic, open and accountable systems of governance this should not be considered a disadvantage of the method but one of its strengths. Lobbying for policy change or change in practice or implementation can result, with benefits all round. However, in non-democratic regimes, organizers and facilitators of this method may be endangered and need to be protected (Thompson, 2011).

Outlook

The ProVention Consortium collected, analysed and disseminated methods used for participatory capacity and vulnerability assessment before its unfortunate dissolution by powers-that-be. ProVention's web-based "tool kit" should still be accessible as soon as those "powers" decide who should host the content (ProVention, 2005), where a compendium of some 20 sets of methods and approaches to CRA is available. Other clearing houses and portals exist, and many are not bridging the natural hazards, DRR, humanitarian and climate change communities. Methods for accessing the knowledge and experience of sub-groups such as girls, women, fishers, pastoralists, people-living-with-HIV, refugees and people internally displaced have much in common, and sharing of methods among pratitioners in these communities is important (for example, IDS Sussex Participatory Research Centre http://www.pnet.ids.ac.uk/prc/index.htm; IIED's PLA Notes http://www.planotes.org/).

This chapter should not be misunderstood as an argument against "measurement" as quantitative assessment. The dilemma or challenge I have discussed here concerns the balance between qualitative and quantitative assessment on the one hand, and the balance between reflection and action on the other. I believe that at the local level, the balance needs to be skewed toward qualitative assessment and action, as long as that action is subject to monitoring and correction as results come in (Wisner, 2010). The reality of poor, marginal and excluded people is that they have few surplus resources, time or patience for assessment without action. If they have experienced "planning" at all, it has usually been without follow-up action or beneficial results – what villagers I lived with in Tanzania in the mid-1960s called the "fruits of freedom" (*matunda ya uhuru*).[1]

Nevertheless, the debate before, during and after the World Conference on Disaster Reduction (18–22 January 2005 in Kobe, Japan) correctly identified quantitative targets as being necessary at the national level. Here I would wholly support efforts to measure vulnerability and coping capacity in terms of the investments made by national governments in the infrastructure that supports community-based risk assessment and proactive planning. Such infrastructure logically includes the primary health care system, primary and adult/continuing education system, micro credit and micro insurance infrastructure and technical outreach in such domains as agroforestry, small-scale irrigation and soil conservation.

It should be possible to quantify investments required for developing national infrastructure that provide communities with the conditions they need to implement their own risk reduction actions while simultaneously trying to meet the Millennium Development Goals.

Note

1. In the first 10 years after independence from the colonial power, the Tanzanian people expected rapid and very concrete improvements in the quality of their lives as the result of self-rule – as opposed simply to valuing the abstraction, "freedom".

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Part V

Institutional capacities, public sector vulnerability and dynamics of vulnerability

19

Assessing institutionalized capacities and practices to reduce the risks of flood disaster

Louis Lebel, Elena Nikitina, Vladimir Kotov and Jesse Manuta

This chapter proposes a framework for an institutionally oriented analysis of the capacity of societies to reduce the risks of flood disasters, it is intended to complement other approaches to vulnerability assessment that characterize flood hazards and their impacts. The framework is most useful in situations recently affected by major floods because it requires investigation of practices and performance that often depend on obtaining primary data.

Our initial application of the framework revealed several important issues which have been hinted at before but which can now be more systematically exposed. Four stand out. First is the misplaced emphasis on emergency relief to the detriment of crafting institutions to reduce vulnerabilities and prevent disasters. Second is the self-serving belief that disaster management is a technical problem needing expert judgements that systematically exclude the interests of the most socially vulnerable groups. Third is the over-emphasis on structural measures, which again and again have been revealed to be more about redistributing risks in time and place rather than reducing them. Fourth is the failure to integrate flood disasters as inevitable challenges into normal development planning in flood-prone regions. Our empirical studies demonstrate that a systematic approach to diagnosis of institutionalized capacities and practices in flood disaster management is feasible and can yield practical insights.

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Reducing risks of flood disasters

The role of social institutions in altering the vulnerability of households and communities to extreme floods is increasingly well understood (Adger, 2000; Chan, 1997; Few, 2003). We know that it is often the poor, the elderly, children, women-headed households, ethnic minorities and other social groups with the least access to critical resources for coping and adapting who often have to bear the largest involuntary risks (Blaikie et al., 1994; Dixit, 2003; Morrow, 1999). Very often it is concurrent social and economic changes associated with modern development that amplify some of these vulnerabilities, at least temporarily, by disrupting traditional institutions that in the past provided social safety nets (Adger, 1999). We also know that much of what passes for institutional reform at the basin or state level to reduce risks of disaster might really be about redistributing risk away from central business districts and valuable property, rather than reducing risks to livelihoods of the poorest (Lebel and Sinh, 2009). We know that the flood problem is often not just one of "high water" but also one of rate of onset, duration, sedimentation, debris flows and poor water quality with their impacts on ecosystems, infrastructure, health and livelihoods. Finally, we also know that where authorities work closely with the public, from negotiating risks and preparing for flood events, to designing institutional responses for relief and recovery, that the risks of disaster can be greatly reduced (Takeuchi, 2001). After all, people in many parts of the world have been living with recurrent floods for thousands of years and have often learnt useful ways of coping with and living with floods, even the more extraordinary ones (Wong and Zhao, 2001; Sinh et al., 2009).

The overall global picture, however, is worrisome on two fronts. First, despite better understanding of disasters, losses of life, jobs and property from flood disasters remain unacceptably high and are increasing (Vorobiev et al., 2003; White et al., 2001). Second, climate change is likely to result in significantly more intense rainfall events which, depending on trends in other factors affecting runoff and river flows, will result in more extreme flood events in some places (Adger et al., 2005; Kundzewicz and Schellnhuber, 2004; Västilä et al., 2010). Clearly, it would be highly desirable to have more systematic methods for assessing institutional influences on key vulnerabilities and, consequently, on the risks of flood-related disasters.

In this chapter we propose a framework and some methods for an institutionally oriented analysis of the capacity of societies to reduce the risks of flood disasters. We focus on the formal institutions created by states to deal with flood-related disasters and how these interact with local, often informal, institutions. The interplay of institutions not only defines what and who is to be at risk but also shapes the way flood disasters are defined, perceived and acted upon. The language of "disasters" itself, for example, creates stories of uniform and large negative impacts of singular events which may or may not reflect realities very accurately (Bankoff, 2004; Lebel and Sinh, 2007).

The framework presented here is in its second iteration. It began life as part of a pilot comparative study of flood disaster risk management in Vietnam, Thailand, Japan and Russia (Nikitina, 2005). It was developed to complement emerging frameworks on vulnerability and disaster management with a more biophysical focus. We were inspired by some of the earlier work on vulnerability, risk and natural disasters, especially the book by Piers Blaikie and colleagues (Blaikie et al., 1994) and the work of Neil Adger and colleagues on vulnerability to climate change in coastal areas (Adger, 1999, 2000; Tompkins and Adger, 2004). We have also been influenced by writings on human security (Kotov and Nikitina, 2002), vulnerability (Turner et al., 2003) and resilience of social-ecological systems (Berkes, 2007; Carpenter et al., 2001; Gunderson and Holling, 2002). Each of these bodies of theoretical work, we believe, has important contributions to make to the practical challenge of assessing and measuring vulnerabilities and risks.

Our starting point is the need to link insights about social institutions important to livelihood security and social justice with the increasingly sophisticated institutional frameworks being proposed by states to *manage* disasters. To make the link requires careful attention to matters of scale and cross-scale interaction. Thus, even with a focus on the vulnerability of individuals, households and communities, we still need to consider the institutions operating at the scale of basins or regions, and, invariably, the state.

Our earlier research also suggests that matters of governance, both the institutional structures and the process by which they come about, are crucial for both reducing and redistributing involuntary risks to flood disasters (Lebel and Sinh, 2007; Lebel et al., 2010b; Manuta et al., 2006; Nikitina, 2005). Here we propose that the presence of institutionalized capacities and practices to deal with flood-related disasters is itself an important indicator and criterion of vulnerability and coping capacity.

This chapter is primarily about methods. In it we justify our approach and illustrate various measures with short examples. The chapter is organized as follows. In the section on the "Assessment framework" we describe our overall framework, defining key terms, measures and sources of data. In the next section we illustrate the core parts of the framework. The final section outlines some of the main strengths and weaknesses of our approach and the prospects for refining the diagnostic framework further for practitioners involved in reducing the risks of flood-related disasters.

Assessment framework

Institutional influences on vulnerabilities

Institutions, whether or not purpose-built to address floods or flood-related disaster risks, may influence the vulnerabilities of households and communities through several pathways (Figure 19.1). In our conceptualization the influence of institutionalized capacities and practices (inner box) on the disaster cycle (outer ring) are mediated by ecological and social resilience as well as attributes of the flood event itself (middle box). Some examples of typical institutions are shown (outer box). The pathways themselves may be complex. For instance, loans for investments in structural measures and regulatory practices with respect to land-uses in the basin will alter the attributes of floods in terms of onsets, durations and peak flows by altering runoff, retention times and river-flow regimes, Other pathways alter how involuntary risks are distributed, either

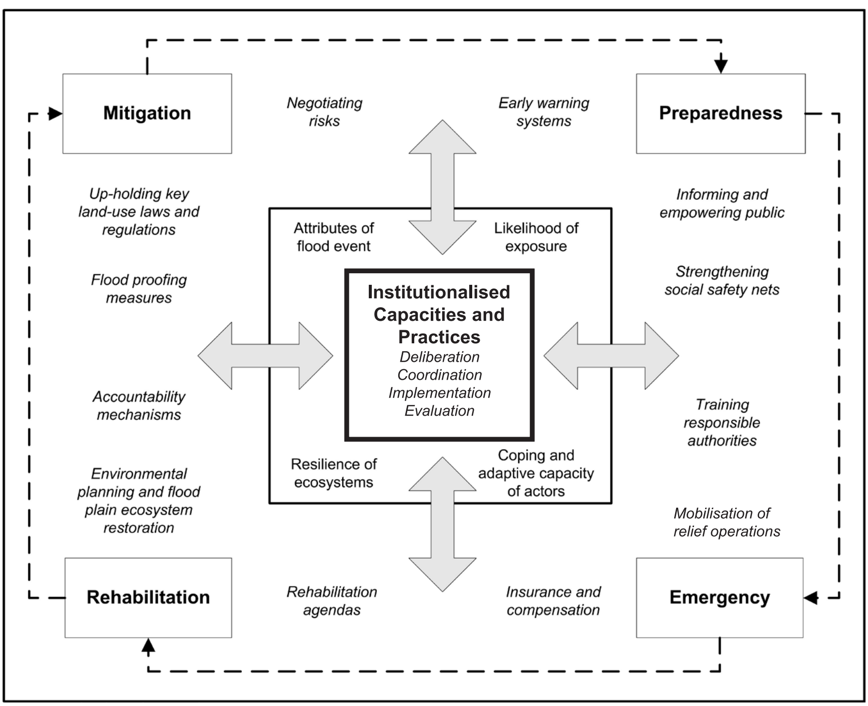

Figure 19.1 Institutions modify vulnerabilities and hence risks of flood-related disasters through several pathways
Source: Authors.

by modifying likelihoods of exposure or the capacities of different actors to avoid, cope with or adapt to floods.

The pathways most important in particular places depend on socio-economic development, political systems and the attributes of the flood event itself. Understanding these at least partially is important for the context in which institutional performance can be assessed. The hydro-climatic triggering events, for example, may be a cloudburst, a period of prolonged rainfall, snowmelt, glacial lake outburst or dam failure (Dixit, 2003). Interactions with landslides in mountainous areas are common, causing temporary blockages and breaks, scouring, deposition and massive debris flows. Although many of the institutional issues are similar, the actors involved, the preventative measures needed and technical difficulties can be quite different.

Institutional analyses can be very powerful but also confusing if terms are used loosely. In our framework institutions are rules or norms which define the roles, rights and responsibilities of actors (Young, 2002). Institutions, by definition, are relational. An organization, on the other hand, is a type of actor. Like a household, community, firm or state, an organization may host many kinds of institutions that guide the behaviour of their members. Institutions can be formal, with supporting written legal documentation, or informal, like social norms or customs which nobody articulates but most people follow. Informal institutions are often much harder to identify and assess than formal ones but nevertheless could be crucial to social responses. The emergence of informal "shadow" institutions to perform certain functions at times of crisis, like flood-related disasters, may reflect inflexibilities or gaps in the formal institutional framework. Finally, institutions are systems of rules, and rules invariably get broken. We need to explore the main reasons for gaps and deviation from norms as these may provide guides to both adaptive and maladaptive practices from which society can learn.

Capacities and practices

Significant capacities to reduce the risks of flood disasters lie both within actors and in the relationships among actors. Our focus in this chapter is on assessing capacities that are relational. We call relations that regularly define roles and responsibilities and rules of engagement in ways that enhance the capacities of actors, *institutionalized capacities*. Relationships among actors have different functions that may be institutionalized. Our assessment framework focuses on four classes of institutionalized capacities and practices (Table 19.1). The capacity for *deliberation* and negotiation is important for ensuring that interests of socially vulnerable groups are represented, that different knowledge can be put on the table for discussion and that, ultimately, fair goals are set. The capacity to mobilize and then *coordinate* resources is often critical to prevention and response actions. The capacity to use those resources skilfully to carry out actions transforms potential into implementation. Finally, the capacity for *evaluation* is important because it can be the basis for continual improvement, adaptive course corrections and learning by key actors. We illustrate each of these capacities in detail, including issues of measurement, in the section on "Institutionalized capacities and practices".

We also ask questions about each kind of relationship across four conventionally designated phases of the disaster cycle (Table 19.1). We intentionally developed our framework around the conventional idea of a disaster cycle so that we could introduce an approach to institutional analyses in a context that would be familiar for practitioners in disaster management. The phase or cycle idea is also useful because the institutional issues at times of crisis and during reorganization may be qualitatively different from periods between such events (Gunderson and Holling, 2002). Of course in any particular setting not all boxes are equally important or modifiable so the analyst will need to prioritize measurement and assessment efforts.

Finally, gaps between stated policy goals and practice, or between design and action, contribute to increased vulnerabilities. A broad *variety of factors* influence institutionalized practices. External factors that may affect implementation include financial deficiencies, administrative barriers and conflicts between organizations, corruption, poverty, lack of economic incentives, low public participation and awareness. Situational factors might block or alter the performance of institutions or modify the designed pathways for implementation of policies and tools. In our work we sought out flood disasters (of modest proportions) to try and understand which institutions come into play in practice and which remain paper-bound.

Data sources

Our research methodology is scale-dependent (Table 19.2). We assess information about institutions at the national and basin or regional scale mostly through review of documents and interviews, but we evaluate performance and practices at this and more local scales through analyses of particular flood events. Our original comparison included two-level case studies in Vietnam, Thailand, Russia and Japan (Nikitina, 2005).

We begin with the general features and structure of domestic institutional frameworks, policies and measures to reduce risk of floods. We suggest starting with an assessment of the presence or absence of key institutional relations and then moving on where possible to analyses of their comprehensiveness. Information that may need to be scrutinized

Table 19.1 Framework for assessing institutionalized capacities and practices with regard to flood-related disasters

	Phase of disaster cycle (Timing)			
Functions	Mitigation (Well before)	Preparedness (Before)	Emergency (During)	Rehabilitation (After)
Deliberation *What should be done?*	How were decisions made about what and who would be at risk? Whose knowledge was considered, whose interests were represented?	Was the public consulted about disaster preparations? How were decisions to give special powers to particular authorities made?	How were decisions made about what and who should be saved or protected first? What special directives or resolutions were invoked?	How were decisions made about what is to be on the rehabilitation agenda? Whose knowledge was considered, whose interests were represented?
Coordination *Who was responsible?*	What national and basin-level policies, strategies or legislation were in place to reduce risks of disaster?	How were responsibilities divided among authorities and public? Was an appropriate early warning system implemented?	How were specific policies targeting emergency operations implemented? Were there gaps between stated responsibilities and performance of key actors? Who was in charge?	Were the resources mobilized for recovery adequate? Were they allocated and deployed effectively? How was rehabilitation integrated into community, basin or national development?

Table 19.1 (cont.)

Functions	Phase of disaster cycle (Timing)			
	Mitigation (Well before)	Preparedness (Before)	Emergency (During)	Rehabilitation (After)
Implementation *How was it done?*	What structural measures were undertaken to reduce likelihood of severe flood events? To what extent were laws and regulations regarding land-use in flood prone areas implemented? What measures were taken to improve coping and adaptive capacities of vulnerable groups?	Were public authorities well prepared? Was the public well informed? How were specific national or basin-level policies targeting disaster preparedness implemented?	How were emergency rescue and evacuation operations performed? Were special efforts made to assist socially vulnerable groups? Were any measures taken to prevent looting?	Did the groups who most needed public assistance get it? Who benefited from reconstruction projects? Was insurance available and used and if so how were claims processed? Was the compensation process equitable and transparent?
Evaluation *Was it done well?*	How is the effectiveness of risk reduction measures assessed?	How is the adequacy of preparedness monitored?	How is the quality of emergency relief operations evaluated?	How is the effectiveness of the rehabilitation programs evaluated?
	To whom and how are authorities accountable?			
	Were institutional changes made to address capacity and practice issues learnt about in the previous disaster cycle?			

Source: Authors.

Table 19.2 Illustrations of scale-dependent actors, institutions and perceptions with regard to flood-related disasters

Scale of interest	Key Actors	Examples of institutional responses	Common perceptions of disaster
Nation	National governments, multilateral banks	Funding mechanisms, loans, debt relief, regional cooperation agreements	Infrastructure losses and re-building costs; losses of investments, debt-burden
Basin, coastal region	Local governments, river basin organizations, sector associations	State laws, policies and programmes, Insurance, state of emergency legislation	Destruction of infrastructure, disruption of regional economy
Community	Households, firms, local government authorities	Local government by-laws, social safety nets, revolving loans, micro-credit schemes	Loss of social control and safety nets (e.g. looting), Displacement-induced breaking of social networks
Household	Individual	Family, marriage, kinship networks	Loss of home, crops and family members, livelihood disruption and insecurity

Source: Authors.

includes legislation, programmes, strategies, action plans, task forces, administrative organization, financial mechanisms and tools, and insurance schemes.

Exploring specific cases of severe floods that have recently taken place is often crucial for understanding institutionalized practices, the divergence between rules on paper and in use, and underlying diversity of actor behaviours. Our approach, therefore, is most appropriate for areas that have recently experienced major floods, whether or not they resulted in disasters, as it requires asking actors to recall information about actions taken by themselves or others (Kitamoto et al., 2005; Kotov and Nikitina, 2005; Manuta et al., 2006). Although secondary information such as newspaper and agency reports is also important, good primary data is crucial for validation. In local-community-level studies of flood events in urban, rural and remote rural locations in Thailand, we used household questionnaires to: characterize flood events, identify prevention and mitigation measures; assess effectiveness of relief, compensation and rehabilitation actions; explore household and village-level coping and adapting strategies; and assess channels for public participation and accountability of decisions.

Institutionalized capacities and practices

Deliberation and empowerment

Who and what should be at risk? This is the central unasked question in disaster management. The only way the sharing of involuntary risks can be negotiated is if the interests of marginalized and vulnerable groups are represented, the quality of evidence is debated and challenged and authority is held accountable for its decisions. Alternative dialogues, the mass media and acts of civil disobedience may be critical to incorporate issues of unfair distribution of involuntary risks into the design of flood and disaster programmes. Without opportunities for deliberation, women-headed households, the elderly, children, ethnic minorities and other marginalized groups are unlikely to benefit and may even be disadvantaged by programmes and policies aimed at reducing risks of flood disasters. For example, minority households affected by landslides and floods in one of our studies were ineligible for most kinds of post-disaster assistance because they were poorly informed about correct reporting procedures or did not hold citizenship documents (which the state had failed to provide for them) (Manuta et al., 2006). Small fishers in southern Thailand had similar difficulties navigating bureaucratic barriers and corruption in compensation programmes after the Indian Ocean tsunami (Lebel et al., 2006).

Debate, consultation and planning procedures for floods and disaster management need to be assessed by criteria similar to those used to analyse "good governance" (Table 19.1). In particular, focus is needed on issues of participation, representation and sources of knowledge. In most countries such an assessment would highlight how, at least until fairly recently, the public has been treated as irrelevant to the technical exercise of assessing and managing risks and designing institutional responses.

Things may be changing: a return to community-based flood disaster management is being widely promoted by international agencies but only cautiously adopted by national ones (Few, 2003; Lebel et al., 2010c; Morrow, 1999). The key idea is that greater involvement of the public in decisions about all stages of the disaster cycle will make better use of local knowledge and capacities and help identify both risks and pragmatic opportunities to address them. Early results of community-based flood management strategy (CFMS) pilot areas in Bangladesh suggest huge dividends in reducing vulnerability of affected communities during the 2004 flood (Ahmed et al., 2004).

The area requiring the most profound engagement with a wider group of stakeholders is in assessing and addressing the underlying causes of vulnerability. State agencies usually find these tasks very difficult because fundamental issues of governance and social justice have to be addressed, and this may undermine positions of authority. Extremely low asset levels, poor access to natural resources and insufficient rights to public goods and services are often at the core of these vulnerabilities (Blaikie et al., 1994; Dixit, 2003).

In contrast to the neglect of questions about "*Who will be at risk*?", issues of "*Who will pay?*" are intensely debated from day one. The main debate is often between levels in the administrative hierarchy: should funds come from local, regional or central budgets? Local governments often find they need to obtain additional sources to fund recovery and rehabilitation operations. Thailand, for example, has a fairly clear set of rules for passing budget requests up the hierarchy depending on levels of damage. The problems are with accountability and the timeliness of available funds. In Russia, the vertical division of responsibilities is institutionally fixed by national rules, but in crisis and emergency situations the provinces and locales tend to do their best to bargain with the national administration for extra resource allocations (Kotov and Nikitina, 2005). Constant debates and controversies between the "centre" and the regions requesting increased involvement and support from the central authorities, especially at recovery stages where mobilization of significant funds is essential, can turn into conflicts and gridlocks that weaken institutional performance.

In many places there is a need to go beyond participation being defined as simply informing the public or being seen as an opportunity to shift onto communities the burden for actions that should have been the responsibility of public authorities. Participation should result in empowerment of marginalized and vulnerable groups in decision-making around who and what should be at risk.

Coordination and cooperation

Who is or should be responsible? Being able to count on institutionalized capacities to mobilize and coordinate resources when and where they are needed is crucial in all phases of the disaster cycle, sometimes with very little scope for delay or errors of judgement. Because there are many uncertainties about knowing where disasters will occur and exactly how they will unfold, it is important that this "institutionalizing" aspect fosters flexible and adaptive responses that rely on coordinated, as opposed to uni-dimensional, assignment of responsibilities.

Assessment requires attention to bureaucratic procedures for reallocating resources and the existence of coordination mechanisms (Nikitina et al., 2009). The effectiveness of public mobilization can be assessed at primary level by looking at the extent to which it is "better prepared, but not scared". The best insights, however, are usually obtained from observing actual efforts at preparedness and emergency and recovery responses to major flood events, as these provide a genuine test of the flexibility inherent within disaster management systems that may otherwise be hard to ascertain. Issues of trust in public institutions also arise. It is also useful to analyse how well activities are coordinated across government agencies and between authorities and the public in order to understand both institutionalized operations and their practice (Table 19.1). Effective mobilization and coordination means that societies' response is appropriate to the risk and that the most vulnerable groups are being taken into account.

Because most river basins cut across administrative jurisdictions (within and among nation-states), they create special challenges for coordination (Nikitina et al., 2011) and assigning responsibilities in disaster management. In Thailand, the notion of organizing water management through river basin organizations has being introduced but faces many challenges, especially managing interactions with pre-existing institutions (Lebel et al. 2009b; Thomas 2005). In 2001, the Mekong River Commission began to address more systematically international coordination issues for the Lower Mekong countries through the creation of a strategy-oriented Flood Management and Mitigation Programme (Asian Development Bank, 2003; Fox and Schmit, 2003; Lebel et al., 2009d). In Russia, river basin management administrations have been in place for a number of years, but coordination problems between state and federal agencies persist.

A lack of clearly defined roles and responsibilities among state agencies is an indication of poor institutional capacity. In Thailand the problem has been acute, so much so that nothing happens unless the prime minister personally commands and directs the response effort (Tingsanchali et al., 2003). More complex and integrated systems of disaster management, however, may have trade-offs in terms of responsiveness and reach. Thailand has reoriented its approaches to a more proactive integration of mitigation and preparedness in the overall scheme of disaster risk management. This was initially done in 2002 by establishing the Department of Disaster Prevention and Mitigation (DDPM), which consolidated several different agencies into a one-stop shop for disaster coordination. Unfortunately its mandate far exceeds the actual capacities of the organization and its relationships (Manuta et al., 2006).

The state may fail to deliver an appropriate response to marginalized people living in remote areas. Our own fieldwork in the mountains of northern Thailand confirms both the challenge and failure of the Thai state to deliver reasonable service to a remote area (Manuta et al., 2006). Floods accompanied by severe landslides in and around several villages in Om Koi district of Chiang Mai province in 2004 did not generate a relief/emergency response until three or four days after the event. It is noteworthy that nearby villages were able to self-organize food and shelter for affected people quickly and this was sustained for several weeks. An upland Karen village where crops, livestock and homes were devastated faced starvation because its livelihoods had been destroyed and no follow-up assistance after the initial emergency relief was provided by the state. The legal requirement for people to hold Thai citizenship cards before receiving compensation was an important practical constraint, and was compounded by the fact that in at least some cases the state itself has been at fault as a result of discriminatory practices for not issuing such cards to long-term residents in the first place.

Lack of trust in public institutions can also hinder the ability to prepare for emergency operations. The catastrophic loss of life in the Lena River flood in the Sakha Republic of Russia was in part caused by the combination of local cultural norms that were dismissive of future threats and mistrustful of authority (Nikitina, 2005). Warnings to prepare and evacuate went largely unheeded by both local authorities and populace, because people were afraid that if they abandoned their homes they would be looted. The response of the state disaster agency was to propose compulsory evacuation measures.

Coordination among agencies and stakeholder groups is important for flood mitigation, in particular the design and execution of programmes and policies to help address underlying causes of extreme vulnerability. In urban areas of Asia, the problems of flooding can be severe and almost chronic for slum dwellers forced into high-risk zones because of the lack of low-cost housing in more desirable areas (Lebel et al., 2009c). Insecurity over settlement rights combined with poor or non-existent access to drinking water, waste disposal or drainage services compound the risks of flood-related disasters. These are not voluntary risks but a structural outcome of urban development that is focused on serving the wealthy (Lebel et al., 2009d, 2010b; Manuta et al., 2006).

Mobilizing adequate funds, both for protection measures before an event and for recovery and rehabilitation of affected areas and livelihoods afterwards, is the core “coordination” and “cooperation” issue for local authorities because it has a large bearing on their ability to implement plans. What will be the major sources of funding? Who will benefit most from their deployment? In Russia, Vietnam and Thailand, flood insurance schemes are at a very rudimentary stage so there is a strong reliance on the state to come to the rescue. In more wealthy countries like Japan, state guarantees have allowed significant entry by the private sector into insuring against flood disasters (Kitamoto et al., 2005). Here damage is compensated for by the comprehensive insurance provided to households by the private insurance companies. Insurance is optional, but people who take out loans to build or buy houses are obliged to buy comprehensive insurance.

If local authorities have the capacity and legal framework that enables them to seek loans and private-sector cooperation, then they may be able to secure more, and more diverse, funds for disaster risk management. For example, after the 2001 Lena River flood the Sakha Republic administration applied for central bank credit for housing renovation; it also formed a partnership with the Alrossa company, a leading diamond producer based in Sakha, to help rehabilitate and restore livelihoods (Kotov and Nikitina, 2005). Elsewhere there are examples of non-governmental organizations venturing into micro-finance, training and mobilization in intervention programmes to reduce disaster risk. For example, in the aftermath of the Indian Ocean tsunami in 2004 that caused severe coastal flooding in southern Thailand, fishing communities established "community shipyards" with the support of a private firm (the Siam Cement Group) and an NGO (Save Andaman Network) (Lebel et al., 2006). A community banking and revolving fund system were established for recovering people's livelihoods (Achakulwisut, 2005).

Coordination of activities across phases of the disaster cycle is necessary because there is often a need to link or transfer responsibilities and budgets for programmes over time. One approach is through cross-agency and multi-stakeholder taskforces, set up for a limited period with clear objectives, that can help guide these transitions.

Implementation and stewardship

How was it done? Wonderful planning and coordination mean nothing when it comes to reducing the risks of disaster if there is no follow-through because of corruption or other institutionalized and ad hoc incapacities that prevent appropriate use and allocation of the resources available.

Assessing institutionalized capacities to effectively use resources and execute critical actions requires several different kinds of measures corresponding to different kinds of resources and actions. At the simplest and most conventional level we need to look at actual structural and non-structural measures undertaken in preparing for, and responding to, flood disasters.

Forecasting and early warning systems are often the weakest element in the chain of purpose-built institutions for reducing risks of flood disasters. First, there are the technical challenges of obtaining critical information and sharing it in a timely fashion. Second, there are organizational and individual behaviours that undermine otherwise sound information-sharing arrangements. For example, in Russia in 2001, the Hydromet service provided early warning forecasts of dangerous spring thaw conditions in the Lena River basin. Local and provincial administrations in the Sakha Republic were slow in responding. As a result, the population was not well informed and losses were much higher than they needed to be (Kotov and Nikitina, 2005).

In most countries a national-level institutional framework for *emergency* response is well established. Normally, such frameworks incorporate a set of administrative structures, governmental programmes and legal frameworks defining the necessary conduct and interactions between specialized task forces, which are usually well trained and able to perform skilfully in extreme situations. Often the military is involved.

States differ greatly in how they view their own involvement in recovery. In centrally planned economies like Russia and Vietnam, the state's role remains dominant in all aspects. Thus, in the case of the Lena flood in Russia, a combination of tools was applied, including (1) introduction of a programme to resettle populations from the affected areas, (2) subventions from the federal to the provincial budget for this purpose, (3) allocation of housing certificates from the State Reserve Emergency Fund for the population affected by flood and (4) material compensation for the affected livelihoods (although too modest to restore them).

For the most part, implementation always lags far behind promises and ideals when it comes to addressing the underlying causes of disasters. Consider, for example, issues related to housing and road construction both in mountain areas and in floodplains. Economic imperatives would argue for taking structural measures to protect these investments before disaster strikes, rather than exploring their role as contributing causes of disasters after the fact. Poorly constructed roads destabilize slopes or act as channels for debris in mountain areas, while in deltas and wetland areas they can prevent or alter natural drainage, thus increasing the duration and height of floods.

During post-disaster periods there is often a flurry of programmes, investments and rule changes. All such actions are far more likely to be followed-up and implemented if there is a significant group of stakeholders involved, who have a sense of ownership and responsibility for them. This means going beyond the project-bounded logic that "implementation" ends when the final budget item of the initial action has been completed, moving instead towards integrating projects and programmes into local development. In a real sense it is about creating a sense of stewardship for disaster risk management. This is most likely to be fostered when there is significant decentralization to local authorities, who are in turn accountable to local affected communities.

Evaluation and learning

Was it done well? The performance of institutions and organizations should be monitored and evaluated. This has to be done with a degree of independence or the opportunities for organizations to learn, for authorities to be held accountable and for success at reducing the risks of the next disaster will themselves be reduced.

The presence of institutionalized evaluation and monitoring procedures for the disaster management system must be present. Otherwise, there can be no improvements in performance or adjustments to take account of changing contexts such as altered flood regimes resulting from climate change (Lebel et al. 2010a, 2010c). A more thorough assessment would also need to take a historical perspective to review the extent to which learning had actually taken place (Krausmann and Mushtaq, 2006), above and beyond factors simply reflecting technological change or increasing wealth. Apart from social learning, conventional learning by key individuals about risks, vulnerable groups and places, or about experiences from other places and times may be important in reducing risks of disaster too. The capacity for current arrangements to foster these kinds of learning should be also assessed.

In our studies of upland flash flood events in northern Thailand, conflicts arose with respect to irregularities, and a lack of transparency or accountability in compensation payouts involving the village heads (Manuta et al., 2006). Mobilization by villagers was able to oust corrupt officials but delayed compensation. Similar problems have plagued recovery processes in small fisher villages in southern Thailand after the tsunami of December 2004 (Lebel et al., 2006; Manuta et al., 2005).

Changes in flood regimes arising from climate change potentially exacerbate institutional mismatches (Lebel et al., 2010b, 2013). Social learning is key to building adaptive capacities in the context of uncertain and changing risks from climate change and dealing with related normative uncertainties in water management (Lebel et al., 2010a). Climate change also increases the importance of making a shift in flood and disaster management away from the current narrow emphasis on infrastructure and controlling flows to paying much more attention to building social and ecological resilience and making space for water (Dixit 2009; Lebel et al., 2009a, 2010c; Palmer et al., 2008).

An assessment framework like the one we are now discussing could itself be part of an institutionalized learning process for key disaster organizations. Regular assessment exercises by particular publics and bureaucracies could consult expert advice as needed. Thorough and well-communicated research could contribute to such evaluations.

Prior to reforms in October 2002, the Thai approach to disaster was explicitly reactive, focusing on readiness and response. Since then a more proactive rhetoric has been adopted that aims to minimize the risks and impacts by using both structural and non-structural measures that include preparedness by mobilizing the resources of the government offices, private sector and community (Tingsanchali et al., 2003). This development might be evidence of nascent learning. The huge problems with the still technocratic institutional response to the Indian Ocean Tsunami (Lebel et al., 2006; Manuta et al., 2005) underlines just how many more lessons still need to be learned.

Limitations and prospects

The preliminary framework proposed here (Figure 19.1) for assessing institutionalized capacities is intended to complement, not replace, other approaches to vulnerability assessment that characterize flood hazards and impacts more thoroughly. The initial application of the framework revealed several important issues which have been hinted at before but which can now be more systematically exposed. Four stand out. First is the misplaced emphasis on emergency relief to the detriment of building up institutions to reduce vulnerabilities and prevent disasters. Second is the self-serving belief that disaster management is a technical problem that calls for expert judgments that systematically exclude the interests of the most socially vulnerable groups. Third is the overemphasis on structural measures, which again and again, have shown themselves to be more about redistributing risks in time and place than reducing them. Fourth is the failure to integrate flood disasters as inevitable challenges into normal development planning in flood-prone regions.

Our experiences in four countries confirm that a systematic approach to diagnosis of institutionalized capacities and practices in flood disaster management is feasible and can yield practical insights. At the same time our empirical investigations have revealed several challenges that limit the situations in which our framework can be realistically applied to help reduce risks of flood disasters.

First, there is often a lack of relevant and available data and documentation about the process through which various flood policies, programmes and laws were set up. Much of this has taken place behind the closed doors of technical bureaucracies. Deliberation has not been viewed as an important aspect of disaster risk management, because the initial assumption has been that it is primarily about emergency relief operations and this is clearly a time when authoritarian measures are needed.

Second, although direct observations and interviews at critical times during an event or in the immediate emergency response provide superb data on practice, such behaviour may be unethical and put lives at stake. Researchers and assessors caught in such events will, like other people, be anxious to help and act, and leave most reflection to later.

Third, the presence of institutionalized capacities is not on its own a reliable indicator or criterion of a capacity to reduce the risks of disaster. Some forms of bureaucratization, for example, may actually result in loss of flexibility or reduce opportunities for self-organization that could help avert the worst of a disaster – what we have called, "*institutionalized incapacities*" (Manuta et al., 2006) and "*institutional traps*" (Lebel et al., 2010b). Assessment, therefore, cannot stop at documenting capacities on paper but must also delve into relationships and practices on the ground. Major flood events provide the right kind of challenge to learn about these.

Fourth, shifting flood regimes as a result of change in land- and water-use as well as climate suggest that special attention must be given to anticipating possible future risks and being prepared for surprises (Berkes 2007; Lebel et al. 2009a, 2010c). Within the current analytical framework this can be incorporated as an element of the deliberations around mitigation (Table 19.1) where we can also ask: how is knowledge about changing risks and vulnerabilities being incorporated into planning and policy decisions? Likewise, issues of agency – as raised, for example, in the Earth system governance research framework (Biermann et al., 2010) – in adapting flood management to climate change might be addressed under coordination (Table 19.1).

Some of these limitations could be overcome through joint design and implementation of assessment exercises, especially following major events. Institutional analysts can use theory and reasoning to help provide more logical frameworks of analysis and synthesis, but at-risk communities and authorities with operational and planning responsibilities can identify more sensitive measures and estimates of institutionalized capacities. If such exercises were treated as important learning opportunities, then we think the large knowledge-to-action gaps in much disaster risk management could be narrowed.

In this chapter we intentionally developed our framework around the conventional idea of a disaster cycle (Figure 19.1 and Table 19.1) so that we could introduce an approach to institutional analyses in a context that would be familiar to practitioners of disaster management. The language of "disaster", because it focuses attention on events with large singular and negative impacts, constrains thinking about the full diversity of possible institutional responses to flood risks and events. Looking ahead, we see value in going further and treating management of flood-associated risks, together with other disturbances that can have large impacts on society, as a *normal* rather than *extraordinary* part of development. In such a reconceptualization, the language of discrete "disasters" might be replaced by an understanding of the unfolding of cycles of change across scales in a language of shifting vulnerabilities, capacities to cope and underlying changes to system resilience.

In most flood-affected and flood-dependent regions, especially in the developing world, institutionalized capacities and practices to reduce the risks of flood disasters remain weak. This is especially true in the fast-developing regions where the entire livelihood and socio-economic context is in flux; traditional institutions may no longer be relevant or functioning well, and new relationships among firms, communities and state agencies have not emerged or kept pace with shifting risks. The mature industrial and service economies have fewer institutional gaps but still face daunting challenges of escalating costs as the legacy of controlling, rather than living with, floods. The prospects of climate change further altering flood regimes, which society has already struggled to respond to, suggest that the institutional challenges are going to become more important and tougher. A systematic approach to diagnosis of institutionalized capacities and practices in flood disaster management could help societies identify critical gaps beforehand, and thus learn more from experience.

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20

Public sector fiscal vulnerability to disasters: The IIASA CATSIM model

S. Hochrainer-Stigler, R. Mechler and G. Pflug

Introduction

Governments play a major role in reducing the long-term post-disaster socio-economic repercussions by repairing damaged infrastructure and providing relief to affected households and businesses. Governmental support of relief and reconstruction is critically important for economic recovery and ultimately preventing the long-term hidden deaths and suffering from disasters. The required expenditure, however, can be a significant drain on public budgets, especially in developing and transition countries. In Poland, for example, public infrastructure losses from the 1997 floods amounted to 41 per cent of the reported direct losses (Kunreuther and Linnerooth-Bayer, 2003). The Polish government absorbed close to half of these losses, which increased its budget deficit substantially. Typically, disasters affect government budgets by reducing tax revenue, increasing fiscal deficits and worsening trade balances (Otero and Marti, 1995). Governments of developing countries that have experienced large-scale events over the last years, such as Honduras, Grenada, India and Pakistan, have faced large post-disaster liabilities to such an extent that without international assistance they would have been set back years in their development. Even with substantial international assistance, developmental losses have been significant in many instances. After Hurricane Mitch devastated Honduras in 1998, GDP growth in the following year became negative with about minus 2 per cent compared to 3 per cent the previous year (Mechler, 2004).

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2^{nd} edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

Especially in highly exposed developing countries, the government can be fiscally vulnerable to natural disasters, what we refer to in this chapter as *fiscal vulnerability.* Developing country governments frequently lack the liquidity, even including international aid and loans, to fully repair damaged critical public infrastructure or provide sufficient support to households and businesses for their recovery. For example, following the 2001 earthquake in the state of Gujarat, India, funds for recovery from the central government and other sources fell far short of promises, and actual funding only covered around 30 per cent of the state government's post-disaster reconstruction needs (World Bank, 2003). Gujarat, and other recent cases of government post-disaster liquidity crises, have sounded an alarm, prompting international finance institutions, such as the World Bank, among others, to call for greater attention to reducing fiscal vulnerability and increasing the resilience of the public sector (Pollner, 2001; Gurenko, 2004). In this context, *resilience* refers to the capacity of a social system to absorb economic disturbance and reorganize, or to "bounce back" so as to retain essentially the same function, structure and identity (Walker et al., 2002).

This chapter addresses the fiscal vulnerability of developing country governments to disasters of natural origin, and examines pre-disaster (ex-ante) measures for increasing the coping capacity and resilience of the public sector. In the next section, a framework of fiscal vulnerability and its components of economic risk and fiscal resilience are discussed, along with measurable indicators of these concepts. The IIASA CATSIM model, which is an interactive tool for building capacity of policy-makers to assess and reduce public-sector fiscal vulnerability, builds on these indicators and is presented in the following section. The model is then applied to the case of Grenada. We conclude with some observations on the opportunities and limitations of vulnerability assessments and indicators, such as those employed in the CATSIM tool.

Fiscal vulnerability

Turner et al. (2003) define vulnerability as the degree to which a system or sub-system is likely to experience harm due to exposure to a hazard, either as a perturbation or stressor. Some communities suffer less harm than others from hurricanes, fires, floods and other extreme events because they can mitigate the damage and recover more rapidly and completely. As a case in point, Bangladesh over the past four decades has become less physically vulnerable to cyclones. Deaths from cyclones in Bangladesh have decreased by two orders of magnitude as people have learned to respond to warnings and use storm shelters. Moreover, the people in Bangladesh may become less economically vulnerable to the long-term economic losses from cyclones and other disasters as affordable micro-insurance and other financial hedging instruments become available (Bayer and Mechler, 2005).

In the literature, work on economic vulnerability to external shocks (often of small island developing states) has focused on the structure of an economy (for example, commodity-based versus high technology), the prevailing economic conditions (for example, degree of inflation, economic recession) and the general stage of technical, scientific and economic development (Benson and Clay, 2000). Economic vulnerability is often assessed by a set or a composite index of indicators, such as the degree of export dependence, lack of diversification, export concentration, export volatility, share of modern services and products in GDP, trade openness or simply GDP (Briguglio, 1995; Commonwealth Secretariat, 2000). We link vulnerability to resilience as discussed in the following.

Fiscal vulnerability and resilience

Originating in the field of ecology, a key concept in vulnerability research is *resilience*, which refers to the capacity of a system to absorb disturbances and reorganize so as to "bounce back" to essentially the same function and structure (Walker et al., 2002). A resilient ecosystem can withstand shocks and rebuild itself when necessary. Similarly, a resilient social system, in our case the public sector, can absorb shocks and rebuild the economy such that the country or region stays on a similar economic trajectory. Systems with high resiliency are able to reconfigure themselves without significant declines in crucial functions in relation to primary productivity and economic prosperity. Resilience in social systems has the added capacity of humans to anticipate and plan for the future.

Because of the role of the public sector in financing reconstruction and relief, fiscal preparedness is essential for countries or regions to "bounce back" from major shocks. The preparedness of the public authorities for financing disasters depends on their access to capital after a disaster, which, in turn, depends on, among other fiscal indicators, the government's tax base, budget deficit and internal and external debt. In addition, regional governments of developing countries rely extensively on national and international loans and aid. Despite often generous international support, developing countries often encounter shortfalls in financing reconstruction and relief post-disaster. One example mentioned above is the earthquake of 2001 in the state of Gujarat in India, where planned funding from government relief funds, bi- and multilateral sources and budget diversions would have exceeded planned expenditure; however actual funding disbursed amounted to only 32 per cent of

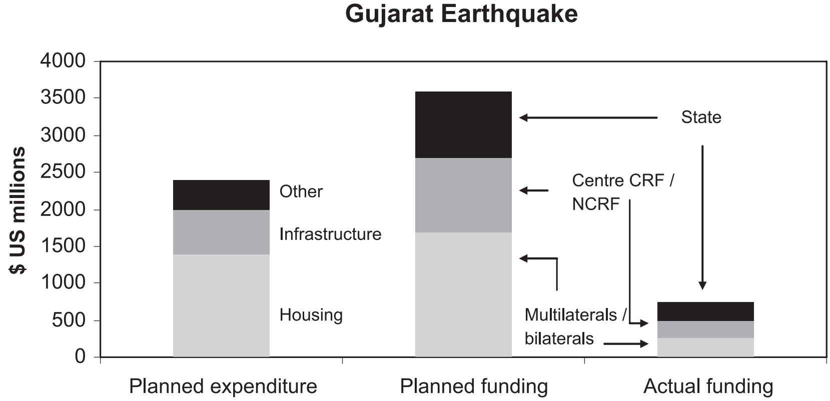

Figure 20.1 Financing gap in India after the Gujarat earthquake.
Source: Modified based on World Bank 2003: 22.

the planned amount (World Bank, 2003). As shown in Figure 20.1, the Gujarat government experienced a severe fiscal gap with regard to the planned expenditures for repairing the housing stock and public infrastructure as well as providing relief to the affected population.

This chapter focuses on the fiscal vulnerability of the public sector as a subset of economic vulnerability. Fiscal vulnerability is defined as the degree to which a public authority or government is likely to experience a lack of funds for financing post-disaster reconstruction investment and relief. As illustrated in Figure 20.2, fiscal vulnerability depends on the asset risks the country is facing from natural hazards, which can be measured by the *hazard* frequency and intensity, the public and private capital *exposure* and the (physical) *sensitivity* of the public and private assets to the hazard.

As a second important component of fiscal vulnerability, resilience of the public authorities to cope with the losses can be measured by the available financial resources for meeting unexpected liabilities of the public sector. If the government has sufficient reserves or insurance cover to finance its post-disaster liabilities, or can easily raise capital through its budget or borrowing, then it is fiscally resilient to the disaster shock. However, if the asset risks are high and the government cannot cover the anticipated losses, then a *fiscal gap* may occur. The potential for a fiscal gap is an indicator of fiscal vulnerability. The term financing, resource or fiscal gap has its origins in the economic growth literature as the difference between required investments in an economy and the actual available resources. The main policy recommendation consequently has been to fill this gap with foreign aid (Easterly, 1999).[1] In this report, we define the

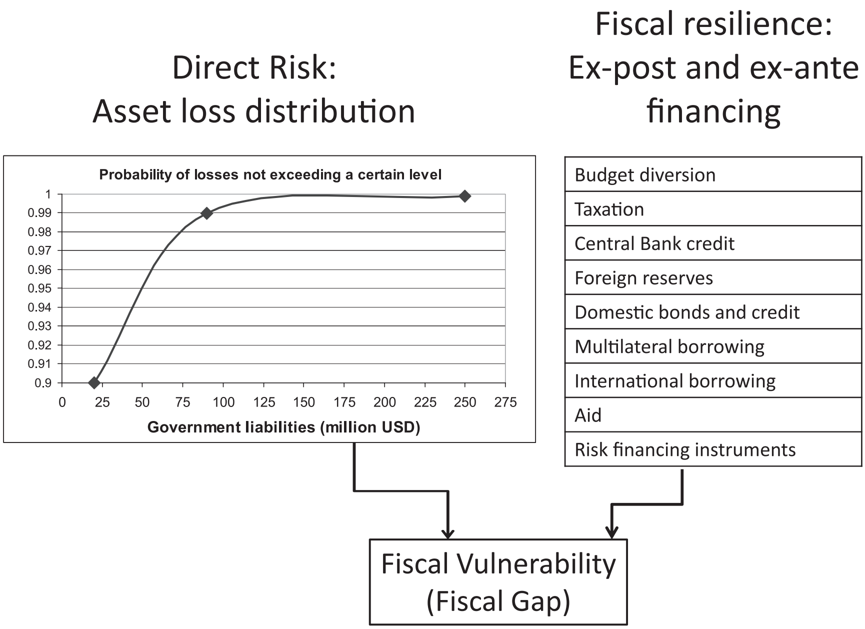

Figure 20.2 Fiscal vulnerability and resilience to natural hazards

fiscal gap as the lack of financial resources to restore assets lost due to natural disasters and continue with development as planned.

An assessment of fiscal vulnerability, or the potential fiscal gap, therefore considers the following two questions:

- Given the country's current exposure to hazards and changes in future conditions, what are the government's capital asset *risks* over the planning period?
- Given the government's financial situation and history of external assistance, is it fiscally *resilient* to these disasters in the sense of being able to access sufficient post-disaster funding opportunities to cope with losses and liabilities?

Fiscal resilience can be enhanced by pre-disaster planning. The public authorities can set aside reserves in a catastrophe fund (such funds exist in India), or, alternatively, they can purchase instruments that transfer their risk to a third party. Insurance is the most common pre-disaster instrument, but recently other types of risk-transfer instruments have emerged. These instruments and their costs will be discussed in more detail in the next section. The important message is that pre-disaster measures exist to improve sovereign fiscal resilience for highly exposed countries. Given that these measures are costly, it is important to ask which countries need them (which countries are fiscally vulnerable?) and what are their costs and benefits? These questions are addressed by the CATSIM model as described in the following section.

The risk of direct economic losses and fiscal resilience are thus essential concepts for addressing fiscal vulnerability to natural disasters. Public policy measures can focus on reducing risks by reducing asset exposure: for example, with structural measures or land-use planning, or by reducing the sensitivity of structures – for example, by seismically retrofitting the public infrastructure. In addition, policies can improve the resilience of the private or public sectors: for example, by developing appropriate systems for insuring or transferring the risks. To reduce their fiscal vulnerability, public authorities can consider investing both in risk reduction as well as financial instruments for assuring fiscal resilience.

Fiscal vulnerability, risk preference and the planning problem

The associated planning problem is one of contingency liability planning, with fiscal disaster risk emanating from explicit and implicit contingent public-sector liabilities as classified in Table 20.1. The explicit liability consists of rebuilding damaged or lost infrastructure, which is due to the public sector's allocative role in providing public goods. Implicit liabilities are related to the commitment for providing relief due to the distributive function in reallocating wealth and providing support to the needy (Table 20.1).

There are two problems to be noted: one is that it is standard practice for (central) governments to plan and take appropriate measures for

Table 20.1 Government liabilities and disaster risk

Liabilities	Direct: obligation in any event	Contingent: obligation if a particular event occurs
Explicit Government liability recognized by law or contract	Foreign and domestic sovereign borrowing, Expenditures by budget law and budget expenditures	State guarantees for non-sovereign borrowing and public and private sector entities, **reconstruction of public infrastructure**
Implicit A "moral" obligation of the government	Future recurrent costs of public investment projects, pension and health care expenditure	Default of sub-national government and public or private entities, **disaster relief**

Source: Modified after Schick and Polackova Brixi, 2004 direct liabilities, but little is generally done to systematically tackle contingent liabilities. Also, in reality, governments recognize their normative roles to varying degrees due to an implicit or explicit assumption of risk neutrality. In case of an event, governments of developing countries typically finance their post-disaster expenses by diverting from their budgets or from already disbursed development loans, as well as by relying on new loans and donations from the international community. In the past, these post-disaster sources of finance have often proven woefully inadequate to assure timely relief and reconstruction in developing countries. What is more, post-disaster assistance is not only often inadequate, but it can discourage governments and individuals from taking advantage of the high returns of preventive actions (Gurenko, 2004).

When should governments plan and engage in disaster management, particularly the financing for those liabilities? According to an early theoruem by Arrow and Lind (1970), governments do not need to plan explicitly and take pre-disaster measures, such as sovereign insurance, if they are not averse to risks, i.e. if fiscal risks faced by the government can be absorbed without major difficulty. According to Arrow and Lind (1970) a government may:

- pool risks as it possesses a large number of independent assets and infrastructure so that aggregate risk is negligible; or
- spread risk over the population base, so that per-capita risk to risk-averse households is negligible.

In theory, thus, governments are not advised to incur the extra costs of transferring their disaster risks if they carry a large portfolio of independent assets and/or they can spread the damages of the disaster over a large population. Because of their ability to spread and diversify risks, Priest (1996) refers to governments as "the most effective insurance instrument of society". Furthermore, the extra costs of insurance can be significant; for example Froot (2001) reports cost of up to seven times greater than the expected damage, due to high transaction costs, uncertainties inherent in risk assessment, the limited size of risk transfer markets and the large volatility of damages. Consequently, according to Arrow and Lind governments should behave risk-neutrally and evaluate their investments only through the expected net present (social) value.

The Arrow and Lind theorem has served as the basis for government strategies for dealing with risk. From a purely theoretical perspective, Hochrainer and Pflug (2009) recently have shown that the Arrow Lind theorem does not apply to disaster events. In practice, most governments neglect catastrophic risks in decision-making, thus implicitly or explicitly they behave *risk-neutrally*.

The case against sovereign insurance, however, does not hold equally well for governments of highly exposed countries, especially those that are not sufficiently diversified or cannot spread damages over the tax-paying public. As early as 1991, the Organization of American States' primer on natural disasters stated that the risk-neutral proposition is valid only up to certain point and that the reality in developing countries suggests that some governments cannot afford to be risk-neutral:

> The reality of developing countries suggests otherwise. Government decisions should be based on the opportunity costs to society of the resources invested in the project and on the damage to economic assets, functions and products. In view of the responsibility vested in the public sector for the administration of scarce resources, and considering issues such as fiscal debt, trade balances, income distribution, and a wide range of other economic and social, and political concerns, governments should not act risk-neutral (OAS, 1991).

In these cases governments may justifiably act as risk-averse agents. This means that the Arrow–Lind theorem does not apply to governments of countries that have (see Mechler, 2004):

- high natural hazard exposure;
- economic activity clustered in a limited number of areas with key public infrastructure exposed to natural hazards; and
- constraints on tax revenue and domestic savings, shallow financial markets, and high indebtedness with little access to external finance.

These conditions are fundamental to determining the fiscal vulnerability of a state. Governments are fiscally vulnerable to disasters if they cannot access sufficient funding after a disaster to cover their liabilities with regard to reconstructing public infrastructure and providing assistance to households and businesses. Such a *fiscal gap* is a useful measure of sovereign fiscal vulnerability. The repercussions of a fiscal gap can be substantial. The inability of a government to repair infrastructure in a timely manner and provide adequate support to low-income households can result in adverse long-term socio-economic impacts. As a case in point Honduras experienced extreme difficulties in repairing public infrastructure and assisting the recovery of the private sector following Hurricane Mitch in 1998. Five years after Mitch's devastation, the GDP of Honduras was 6 per cent below pre-disaster projections. In considering whether Honduras and other highly exposed countries should protect themselves against fiscal gaps and associated long-term negative consequences, it is important to keep in mind that risk management measures have associated opportunity costs, which means that they can reduce GDP by diverting financial resources from other public-sector objectives, such as undertaking social or infrastructure investments.

Over the last few years, many disaster exposed countries and regions have recognized the need to plan for disaster events and have taken steps to improve their assessment and management procedures using novel risk-sharing mechanisms (for more information, see Linnerooth-Bayer and Mechler, 2007; Cummins and Mahul, 2009).

The CATSIM model approach

The challenges of many disaster-prone developing countries associated with properly rebuilding public assets as well as providing relief raise the question of how policy-makers can reduce fiscal vulnerability. The IIASA CATastrophe SIMulation (CATSIM) model was developed to provide insights to this question (for a detailed discussion of CATSIM, see Hochrainer, 2006).

CATSIM uses Monte Carlo simulation of disaster risks in a specified region and examines the ability of governments to finance relief and recovery. CATSIM can provide an estimate of a country's or region's fiscal vulnerability. It is interactive in the sense that the user can change the parameters and test different assumptions about the hazards, exposure, sensitivity, general economic conditions and the government's ability to respond. As a capacity-building tool, it can illustrate the trade-offs and choices the authorities confront in increasing their resilience to the risks of catastrophic disasters.

The model underlying CATSIM was originally developed for the Regional Policy Dialogue of the Inter-American Development Bank, where it was applied to Latin American case studies (Freeman et al., 2002a and b; Mechler and Pflug, 2002). Based on this model, the CATSIM simulation tool was designed and successfully employed in other applications and workshops for informing economists, fiscal experts and policy-makers in stakeholder workshops who are interested in taking account of disaster risk in public finance theory and practice on the financial management of disaster risk (Hochrainer, et al., 2004).

The CATSIM methodology consists of five stages or modules as described below and illustrated in Figure 20.3.

- *Stage 1:* The risk of direct asset losses expressed in terms of their probability of occurrence and destruction in monetary terms is modelled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical sensitivity.
- *Stage 2:* The fiscal preparedness of the public sector to the direct losses is assessed. Fiscal preparedness is a measure of fiscal resilience and can be defined as the access of the central government to funds for financing reconstruction of public infrastructure and the provision of relief to households and the private sector. Fiscal preparedness will, in turn, depend on the general economic conditions of the country.

- *Stage 3:* Fiscal vulnerability, measured in terms of the potential fiscal gap, is assessed by simulating the risks to public infrastructure and the fiscal resilience of the government to cover its post-disaster liabilities following disasters of different magnitudes.
- *Stage 4:* The consequences of a fiscal gap to the macroeconomic development of the country are characterized with indicators, such as economic growth or the country's external debt situation. These indicators represent consequences to economic flows as compared to consequences to stocks addressed by the asset risk estimation in Stage 1.
- *Stage 5:* Strategies are developed and illustrated that build fiscal resilience of the public sector. The development of risk financing strategies has to be understood as an adaptive process, where measures are continuously revised after their impact on reducing fiscal vulnerability and risk has been assessed within the modelling framework.

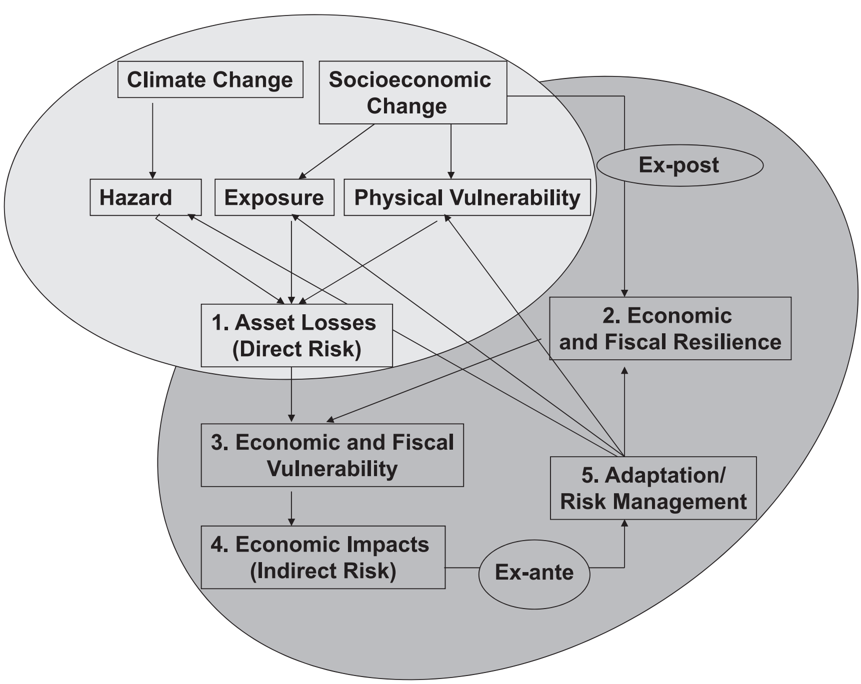

Figure 20.3 CATSIM framework for assessing fiscal vulnerability and the management of extreme event risk

Stage 1: Assessing public sector risk

The stage 1 CATSIM module assesses the risk of direct losses in terms of the probability of asset losses in the relevant country or region. Risk is generally defined as the probability and magnitude of an adverse outcome, and includes the uncertainty over its occurrence, timing, and consequences (Covello and Merkhofer, 1993). Risks of extreme events can be characterized by the frequency and intensity of the events, as well as the exposure and sensitivity of physical assets. A common measure is the probabilistic loss exceedance curve, which indicates the probability of certain losses exceeding a certain amount: for example, there is a 1 per cent probability (called a 100-year event) that losses may exceed 1 billion USD. Consistent with general practices, risk is modelled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical vulnerability (Burby, 1991; Swiss Re, 2000).[2] In more detail,

- Natural hazards, such as earthquakes, hurricanes or floods, are described by their intensity (for example, peak flows for floods) and recurrency (such as a 1 in 100-year event, i.e. with an annual probability of 1 per cent).
- Exposure of elements at risk: total private and public capital stock is estimated.
- Physical Vulnerability describes the degree of damage to the capital stock due to a natural hazard event. Fragility curves, which set the degree of damage in relation to the intensity of a hazard, are commonly used for this purpose.

Using data on the return period and losses in per cent of capital stock, CATSIM generates loss frequency distributions describing the probability of specified losses occurring, such as a 100-year event causing a loss of US$200 million of public assets, a 50-year event causing a US$40 million loss, and so on.[3] It should be kept in mind that top-down estimates at this broad scale are necessarily rough. Since most disasters are rare events, there is often little historical data available; furthermore it is difficult to include dynamic changes in the system: for example, population and capital movements and climate change. Potential changes in hazards due to climate change as well as changes in exposure and vulnerability such as in assets and economic resilience can also generally be considered in this framework.

Stage 2: Assessing public sector fiscal resilience

Using the information on direct risks to the government portfolio, fiscal resilience can be evaluated by assessing the government's ability to finance its obligations for the specified disaster scenarios. Fiscal resilience is directly affected by the general conditions prevailing in an economy: for example, changes in tax revenue have important implications for a country's fiscal capacity to deal with disaster losses.

The specific question underlying the CATSIM tool is whether a government is fiscally prepared to repair damaged infrastructure and provide adequate relief and support to the private sector for the estimated damages of all (for example, 10- 50- 100- and 1,000-) year events. For this assessment, it is necessary to examine the government's resources, both those that will be relied on (probably in an ad hoc manner) after the disaster and those put into place before the disaster (ex-ante financing). These sources are described below.

Ex-post financing sources

The government can raise funds *after* a disaster by accessing international assistance, diverting funds from other budget items, imposing or raising taxes, taking a credit from the Central Bank (which either prints money or depletes its foreign currency reserves), borrowing by issuing domestic bonds, borrowing from the IFIs and issuing bonds on the international market (Benson, 1997; Fisher and Easterly, 1990). Each of these financing sources can be characterized by costs to the government as well as factors that constrain its availability; these are assessed by this CATSIM module. Sources not considered feasible are not included in the module.

As shown in Table 20.2, ex-post financing can be constrained. As an example, disaster taxes are expensive to administer and generally not part of the public-sector financing portfolio. As a second example, borrowing can also be constrained by the existing country debt. CATSIM assumes that the sum of all loans cannot exceed the so-called *credit buffer* for the country. In the Highly Indebted Poor Countries Initiative (HIPC) the credit buffer is defined as 150 per cent of the typical export value of this country minus the present value of existing loans (HIPC, 2002). These ex-post instruments have (sometimes high) associated costs; even budgetary diversions have associated opportunity costs in terms of other government investments such as building highways or schools.

Ex-ante financing sources

In addition to accessing ex-post sources, a government can arrange for financing *before* a disaster occurs. Ex-ante financing options include reserve funds, traditional insurance instruments (public or private), alternative insurance instruments, such as catastrophe bonds, or arranging a

Table 20.2 Ex-post financing sources for relief and reconstruction

Type	Source	Considered in model
Decreasing government expenditures	Diversion from budget	×
Raising government revenues	Taxation	×
Deficit financing	Central Bank credit	–
Domestic	Foreign reserves	–
	Domestic bonds and credit	×
Deficit financing	Multilateral borrowing	×
External	International borrowing	×
	Aid	×

contingent credit. The government can create a reserve fund, which accumulates in years without catastrophes. In the case of an event, the accumulated funds can be used to finance reconstruction and relief. A catastrophe bond (cat bond) is an instrument whereby the investor receives an above-market return when a specific catastrophe does not occur, but shares the insurer's or government's losses by sacrificing interest or principal following the event. Contingent credit arrangements call for the payment of a fee for the option of securing a loan with prearranged conditions after a disaster. Insurance and other risk-transfer arrangements provide indemnification against losses in exchange for a premium payment. Risk is transferred from an individual to a (large) pool of risks. These ex-ante options can involve substantial annual payments and opportunity costs; statistically the purchasing government will pay (on average) more with a hedging instrument than if it absorbs the loss directly.

The government's portfolio of ex-ante and ex-post financial measures is critically important for the recovery of the economy should a disaster occur. For this reason, an assessment of the government's asset risk and fiscal resilience is an essential part of disaster risk management. Past IIASA studies have carried out, for example, such an assessment for four highly at-risk Latin American countries: Bolivia, Colombia, the Dominican Republic and El Salvador (Freeman et al., 2002b). The study revealed differences in their fiscal preparedness for disasters. At the time of the study, none of the four countries had ex-ante instruments in place, like reserve funds or insurance. Yet, Bolivia and Colombia were better prepared than the Dominican Republic and El Salvador to meet their liabilities. The reason was that they could more readily divert funds within their current budget. Colombia, however, was far more constrained with respect to other ex-post options, such as borrowing domestically and internationally. These indicators of fiscal resilience can be combined with the risk each country is facing to yield an indicator of potential fiscal vulnerability. The results are discussed below.

Stage 3: Measuring fiscal vulnerability by the fiscal gap

Comparing available financing with the government's post-disaster financial obligations yields an estimation of the potential fiscal gap. In the already mentioned IIASA study, the potential fiscal gap for Bolivia, Colombia, the Dominican Republic and El Salvador was assessed for a range of probabilistic disaster losses. Figure 20.4 illustrates this gap only for the 100-year event in each country. In this figure, financing sources available to the governments of the four countries are compared with the governments' potential financial obligations calculated for the 100-year disaster. The shortfall between financial sources and obligations is the fiscal gap.

Estimates show, for example, that the losses to the Bolivian government due to a 100-year event would have amounted to US$500 million (from damaged public infrastructure and obligations for relief). If this event had occurred in the 2002 budget period, Bolivia could have financed all but about 1 per cent of its obligations by accessing the following: international and domestic capital markets, support from international financial institutions, international donor aid and, most importantly, di-

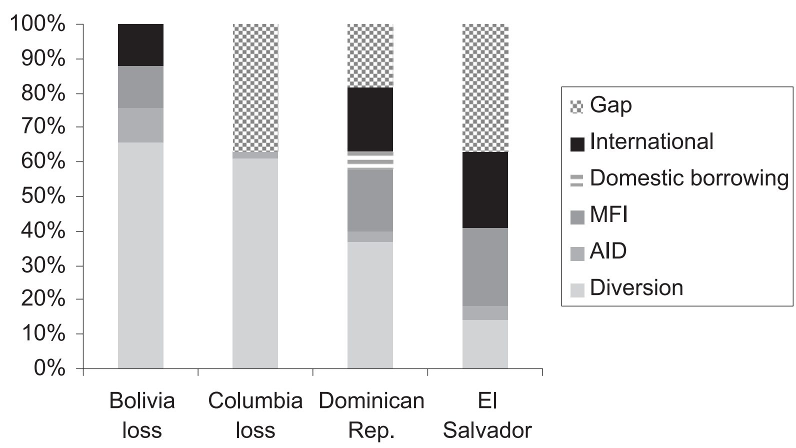

Figure 20.4 Financial vulnerability to 100-year event in four Latin American countries
Source: Authors.

versions from its domestic budget. Colombia, the Dominican Republic and El Salvador can expect far larger fiscal gaps mainly because of less slack in their domestic budgets. Because of their lack of resilience and the risks they are facing, in 2002 these governments were highly fiscally vulnerable to the 100-year disaster event.

Stage 4: Mainstreaming risk into development planning

Disaster risk can be planned for and mainstreamed into different policy levels as shown in Figure 20.5. Our focus is on national-level strategies.

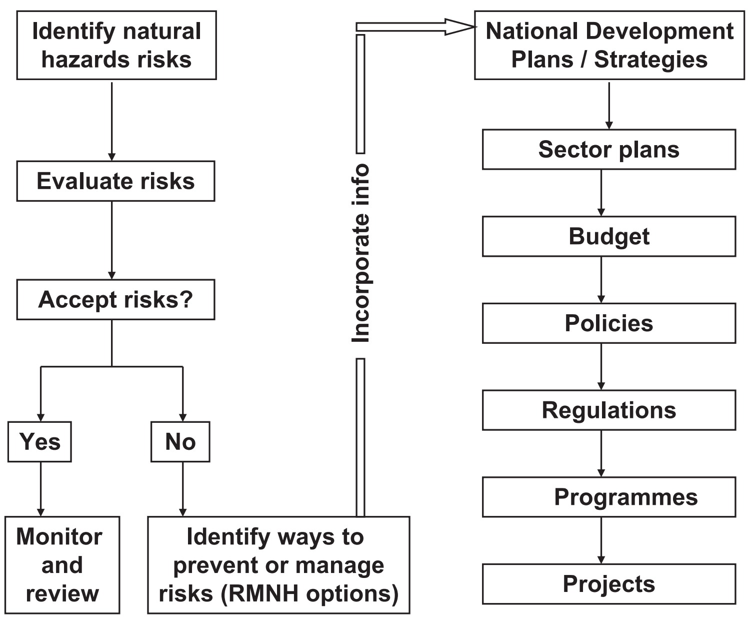

Figure 20.5 Planning for disaster risks
Source: Bettencourt et al., 2006

Ultimately the implications of disaster risk on economic development and other "flow variables" is of major interest when mainstreaming disaster risks into development planning and macroeconomic management. For that matter, fiscal risk, fiscal vulnerability and the prevalent economic conditions are combined in order to derive an estimate of potential fiscal and macroeconomic impacts, such as on GDP. Fiscal vulnerability can have serious repercussions on the national or regional economy and the population. If the government cannot replace or repair damaged infrastructure – for example, roads and hospitals – nor provide assistance to those in need after a disaster, this will have long-term consequences. The consequences on long-term economic development can be illustrated by CATSIM. For example, Figure 20.6(c) shows the results of the simulations of growth paths in El Salvador with and without the purchase of sovereign insurance for public assets as an ex-ante financial tool.

As seen in Figure 20.6(c), El Salvador is expected to grow over time (with the current year as the base year) as investment adds to the capital stock. However, the country can experience disasters, which can be thought of as stochastic shocks to the growth trajectory. CATSIM simulates 5,000 trajectories, although in Figure 20.6(c) only 100 are summarized for illustrative purposes. The trajectories do not have equal

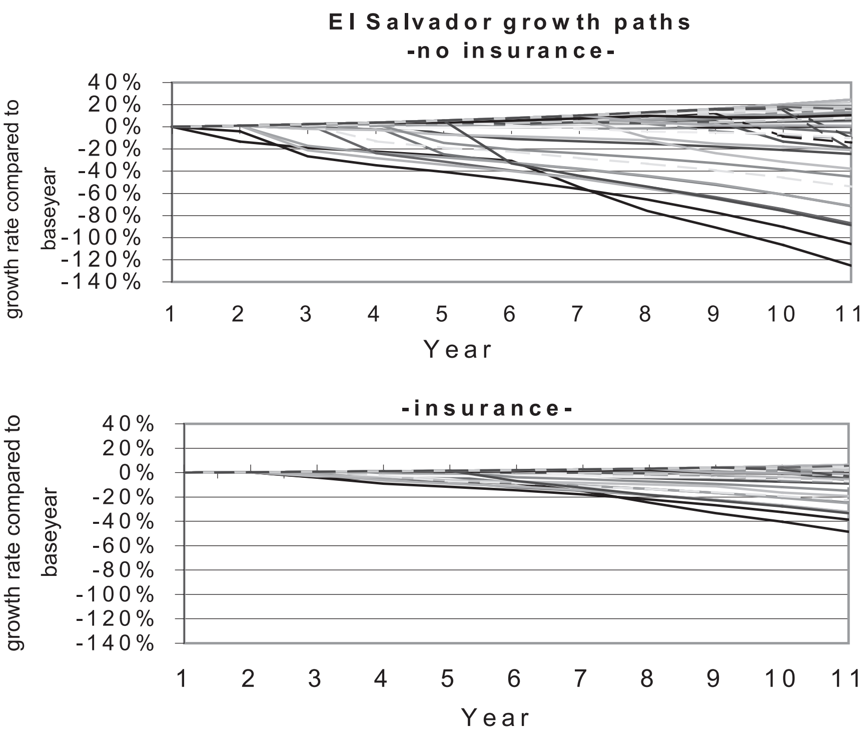

Figure 20.6 Simulated growth versus stability for El Salvador over a 10-year time horizon.
Source: Authors.

Please see page 684 for a colour version of this figure.

probabilities. The trajectories in the upper part of the figure, which show economic growth proceeding in the absence of shocks, have a higher probability of occurrence than the catastrophic cases in the bottom of the figure. Economic growth in El Salvador is higher on average if the government does not allocate its resources to catastrophe insurance (upper figure), but the economy has fewer extremes and is more stable with public-sector insurance (lower figure). Investing in the risk-financing instruments can thus be viewed as a trade-off between economic growth and stability. Budgetary resources allocated to catastrophe reserve funds, insurance and contingent credit (as well as to preventive loss-reduction measures) reduce the potential fiscal gap, and thus can ensure a more stable development path. On the other hand, ex-ante financing and prevention measures come at a price in terms of other investments foregone and will inevitably have an adverse impact on the growth path of an economy. The IIASA model assesses this trade-off by comparing the costs of selected ex-ante measures with their benefits in terms of decreasing of the possibility of encountering a fiscal gap.

Stage 5: Reducing fiscal vulnerability and building resilience

Vulnerability and resilience must be understood as dynamic. In contrast to ecological systems, social systems can learn, manage and actively influence their situation. There are two types of policy interventions for reducing fiscal vulnerability: those that reduce the risks of disasters by reducing exposure and sensitivity and those that build the fiscal resilience of the responding agencies. Based on an assessment of the fiscal gap and potential economic consequences, CATSIM illustrates the pros and cons of strategies for building fiscal resilience using ex-ante financial instruments. Four ex-ante financing policy measures are currently considered in the CATSIM tool: sovereign insurance, contingent credit, reserve funds and catastrophe bonds. Also, one generic option for risk reduction measures has been implemented in the model in order to analyse the linkage with risk financing. More detail on the model can be found in Hochrainer (2006).

The case of Grenada

As an example of an instance of substantial fiscal vulnerability, we now present the case of Grenada. Grenada is a Caribbean country that is classified as middle income and composed of three islands with a total land area of 350 square kilometres only holding a population of around

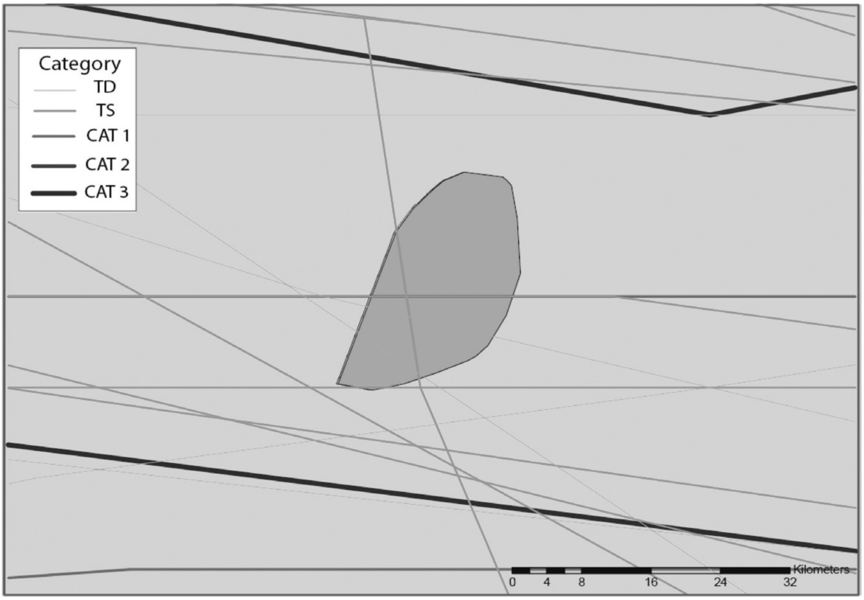

Figure 20.7 Storm tracks for Grenada over the period 1851–2004.
Source: Bach (2006) based on *Hotspots* data by Dilley et al. (2005)

Please see page 685 for a colour version of this figure.

110,000, a third of which lives in the capital city. The island economy is small, open and lacks diversification, rendering it highly vulnerable to external shocks and natural disasters. While Grenada is exposed to all types of natural disasters, its main risk is hurricanes. Grenada lies on the edge of a hurricane belt and hurricane seasons last from June to November. Figure 20.7(c) shows storm tracks that have passed over Grenada in the past (severe storms are marked in red). On average a tropical cyclone has brought about damage every seven years (UNDP, 2004).

Grenada's economic performance has been negatively affected by hurricanes in the past. In 2004, Hurricane Ivan caused the largest historical damages ever, exceeding over US$890 million (more than 200 per cent of GDP), killing 39 people and affecting more than 80,000 people (90 per cent of the population). This was followed by Hurricane Emily in 2005, which caused about US$50 million in economic losses. Given the scale of the damages, Grenada's economic performance was negatively affected by the 2004 and 2005 hurricanes. The left panel of Figure 20.8 shows an illustration of the economic growth path for Grenada after Hurricane Ivan in comparison to an estimated growth path had the hurricane not occurred.

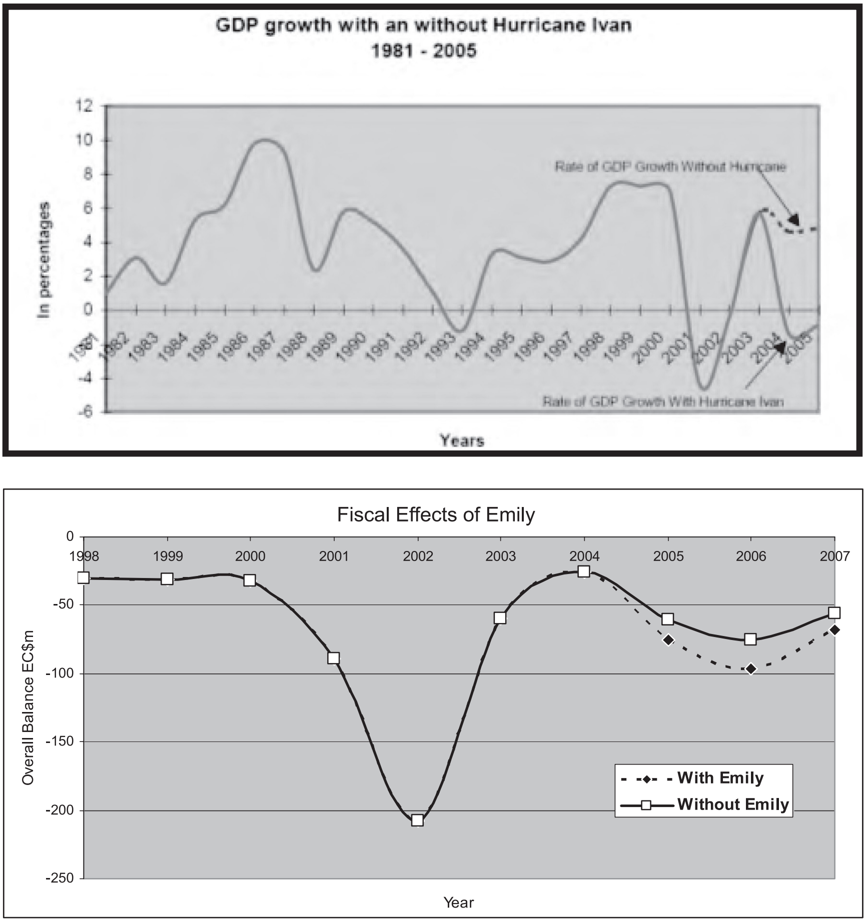

Figure 20.8 Fiscal and economic effects of hurricanes on Grenada
Sources: OECS, 2004, 2005.

Without the event, positive economic growth was expected, yet actually growth became negative, as the event knocked out a large part of export cash crops. Also, fiscal effects were noted, as shown on the right panel in Figure 20.8, estimating effects on the budget compared to the counterfactual without the hurricane.

Relying on historical data the CATSIM simulation tool can provide insights on the overall risks due to hurricane events in the country, and the ensuing liabilities for the government. Information on the intensity and frequency of hazards as well as the sensitivity of the exposed assets to these hazards was obtained from various sources including Em-Dat, Munich Re and Swiss Re databases. This data was used to estimate return periods for corresponding losses using extreme value theory (Embrechts et al., 1997). Capital stock was estimated at US$2.2 billion. Furthermore, it was assumed that about 30 per cent of capital stock is public and that government will finance another 20 per cent of total capital losses due to its political commitment of relief to private victims after disasters (Freeman et al., 2002b). These assumptions are consistent with country data and past experience.

Based on this information, direct asset losses in percentage of total capital stock were gauged. Figure 20.9 shows a screen shot of CATSIM (web application version) for the direct asset risk estimation. Based on input parameters of risk as a share of exposed assets (upper part) and exposure information (lower part), a loss distribution for Grenada's public-sector liabilities can be generated.

As shown in the figure, for very rare events (once in 1,000 years) liabilities could approach above 50 per cent of capital stock in Grenada. Lower frequency events, for example, a 100-year hurricane, are estimated to destroy around 40 per cent of total capital stock. The expected annual loss due to hurricanes, graphically the area above the curve, amount to 0.75 per cent of total capital stock.

Figure 20.10 displays another CATSIM screen shot (again taken from the web version) illustrating the fiscal vulnerability of the Grenadian government to hurricanes. As shown in this figure, the government can depend on traditional sources to finance the losses from moderate hurricane disasters (with a recurrence period of less than about 67 years) and thus may not need to consider a form of risk transfer covering these events. But for rarer, high-consequence events – once in 67 years or worse – there is a sizeable fiscal gap. This means that Grenada will neither be able to provide sufficient relief to private victims nor repair its infrastructure in a timely way, which could ultimately mean a serious setback for the country in its socio-economic development.

To provide more detail, Figure 20.10 shows the financing strategies for a range of return periods starting from the no event (zero loss) up to the 90-year-event loss. For example, a 50-year event would cause losses of about US$270 million which would be financed mostly by taking credits from abroad (MFI and bond credits) as well as domestic credit arrangements. Diversion from budget is very limited and can only contribute a little bit to finance the losses. Hence, an increase in the indebtedness level after a hurricane event is very likely. Based on an assessment of fiscal vulnerability and its economic consequences, a case for increasing fiscal resilience using ex-ante instruments may be justified. The IIASA CATSIM model illustrates the cost efficiency and economic consequences of

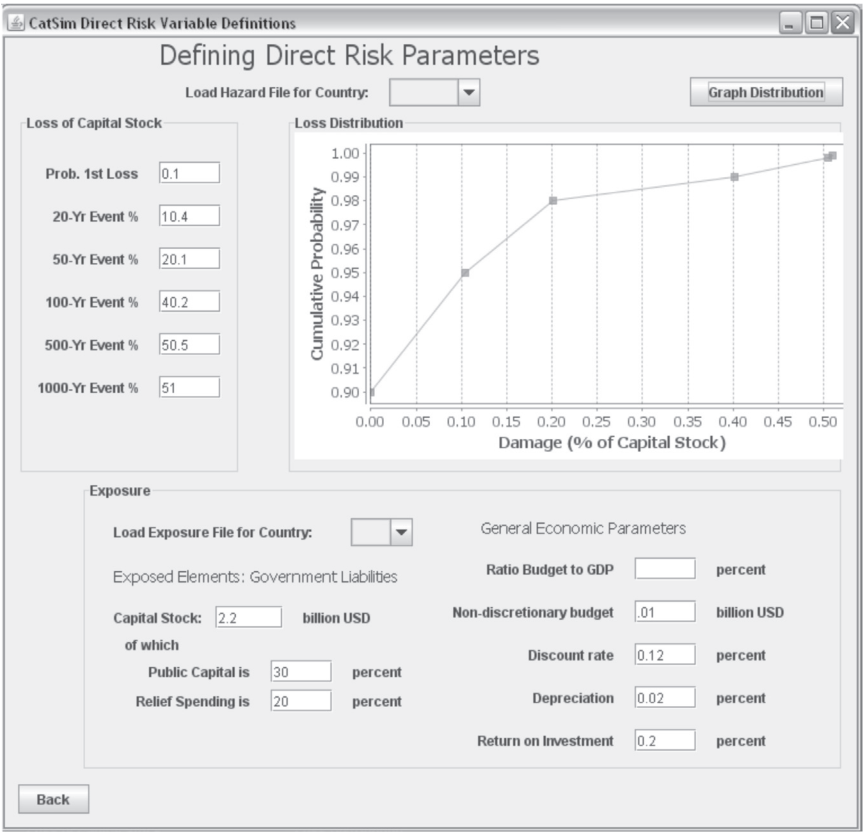

Figure 20.9 Cumulative probability distribution of direct asset damages for hurricanes for Grenada

selected ex-ante instruments, including their consequences on public sector indebtedness and economic growth.[4]

Beyond vulnerability indicators: building capacity for vulnerability and risk reduction

Fiscal vulnerability represents only one facet, albeit an import one, of vulnerability to natural hazards. Other indicators are necessary to provide a more complete picture of vulnerability. For example Cardona et al., for the Information and Indicators Program for Disaster Risk Management of IADB, ECLAC and IDEA, have complemented the IIASA methodology of fiscal vulnerability (termed Disaster Deficit Index in this

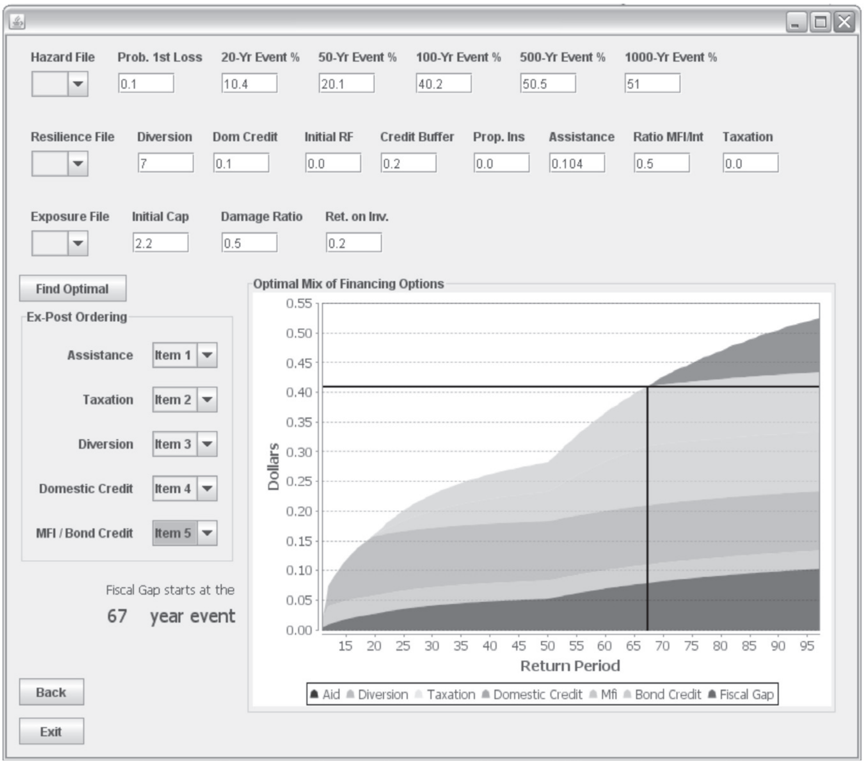

Figure 20.10 Assessing fiscal vulnerability to hurricane risk in Grenada

report*)* with other vulnerability indicators, such as the Prevalent Vulnerability Index that accounts for social vulnerability in terms of exposure in hazard-prone areas, socio-economic fragility and social resilience (Inter-American Development Bank, 2005).

These and other indicators of vulnerability generally rely on quantitative measurements and thus communicate a degree of objectivity, which can be misleading if not handled with great care. Since the numbers often rely on incomplete data and numerous assumptions, there can be large uncertainties and subjective choices. Because of these uncertainties and subjective judgements, indicators may work best if they are created and applied within a participatory approach that includes key stakeholders and scientists (Morse, 2004; Hochrainer and Mechler, 2009).

CATSIM is organized around a graphical user interface, which the user can utilize to consider financing strategies in the probabilistic context of natural disasters, change important parameters and test the sensitivity of outcomes to those changes. We consider this user interface a crucial component as it allows for dealing with the considerable uncertainty concerning economic and catastrophe parameters. Furthermore, as we discussed above, when identifying strategies that build fiscal resilience and preparedness, trade-offs emerge. With the CATSIM approach, the user may decide which trade-off to commit to as well as which indicators to use for assessing policy impacts and trade-offs.

The graphical user interface makes CATSIM a truly participatory, interactive tool for building capacity of policy-makers by allowing them to devise and assess multiple disaster risk management strategies and sensitizing them to the trade-offs inherent in planning for disasters. Over the last years, IIASA has successfully applied the model to cases and participatory workshops in Latin America, the Caribbean, Africa, Asia and Europe. IIASA is committed to further work with disaster-exposed governments and civil society in order to assess and help find equitable and efficient risk management strategies; to this effect in 2012, a free web version was made available, which can be accessed at http://www.iiasa.ac.at/web/home/research/modelsData/Models--Tools--Data.en.html

Notes

1. This approach has been criticized among others by Easterley (1999) as generally failing to account for the role of incentives and institutions in economic growth. Nevertheless, it is without doubt that capital investment plays an important role in stimulating economic growth.
2. In the hazards and risk community, "sensitivity" is referred to as "vulnerability", and exposure is often included in the sensitivity component; thus, risk is defined by hazard and vulnerability. In catastrophe models carried out for insurance purposes, the contract specifications of the underwritten and exposed portfolios are added as a fourth component (for example, Swiss Re, 2000).
3. It is standard practice to refer to 20-, 50-, 100-, 500- and 1000-year events.
4. More details on the development and illustration of ex-ante risk financing strategies can be found in Hochrainer (2006).

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21

Dynamics of vulnerability: Relocation in the context of natural hazards and disasters

Jörn Birkmann, Matthias Garschagen, Nishara Fernando, Vo Van Tuan, Anthony Oliver-Smith and Siri Hettige

Introduction

Displacement due to disasters is increasing. The internal Displacement Monitoring Centre (iDMC) and the Norwegian Refugee Council (NRC) have said that in 2010 the number of people displaced due to disasters caused by natural events was over 42 million, with the highest numbers in Asia (see iDMC and NRC, 2011). This chapter examines vulnerability dynamics due to resettlement, specifically focusing on resettlement in the context of natural hazards. Such resettlement is often conducted by countries to reduce disaster risk. Resettlement in the context of Disaster Risk Reduction (DRR) involves a complex planning process similar but not identical to development-induced displacement and resettlement (Correa, 2011; Oliver-Smith, 2009). While many research papers have focused on the effects of resettlement due to development projects, fewer research and vulnerability assessments have dealt with the various consequences of resettlement related to natural hazards. Using quantitative indicators and qualitative criteria, this chapter will explain how to assess and monitor the effects of relocation and resettlement on the vulnerability of people exposed to natural hazards. Compared to development-induced resettlement, hazard- and disaster-induced resettlement processes may imply a more diverse set of negative as well as positive development pathways. The chapter will link theoretical concepts and applied assessments from different case studies to derive lessons learned from the

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

assessment of the dynamics of vulnerability due to relocation of people exposed to natural hazards and climate change.

Theoretical and conceptual perspectives on resettlement and vulnerability

Resettlement is a process generally planned and administered by some central authority, most frequently the state or its agents, in which individuals and/or groups (communities) are moved to another location. Formal resettlement projects may involve settlement design, the provision of housing assistance, compensation for lost resources and public services such as schools and medical facilities. Therefore, theories of resettlement must factor in both pre- and post-event vulnerability in reconstruction and the recovery of losses. Communities that have been displaced and resettled are communities that must be reconstructed, either by themselves or with assistance. In either case, an infrastructure has to be built to replace the one that has been lost and a community, as a social body, has to reconstitute itself (Oliver-Smith, 2005a). In this context research findings regarding development-induced relocation processes conclude that affected people are confronted with a complex, cascading sequence of events most often involving some or all of the following risks: dislocation, homelessness, unemployment, the dismantling of families and communities, adaptive stresses, loss of privacy, political marginalization, a decrease in mental and physical health and the daunting challenge of reconstructing social fabrics, family and community (Colson, 1971; Cernea, 1997, 1990; Scudder, 1981, 1991). However, these approaches generally do not address relocation to reduce exposure and vulnerability to natural hazards and climate change, such as sea-level rise or the nuclear accident triggered by the tsunami in March 2011 in Fukushima Japan, where moving back to the former location might not be an option.

Improving the understanding of how post-disaster resettlement of populations in high risk areas may influence vulnerability requires systematically identifying, assessing and evaluating dynamics and changes in vulnerability before and after relocation (Correa, 2011). An analytic framework is required to assess the dynamic nature of vulnerability before, during and after relocation processes, emphasizing identification of key aspects of vulnerability that can be measured by quantitative or qualitative means and that permit the comparison of different stages or dynamic phases of post-disaster relocation processes.

From an integrative perspective on vulnerability, risk and adaptation, such as outlined in the MOVE framework (see Figure 21.1; Birkmann et al. 2013), three key factors determine vulnerability: exposure, suscepti-

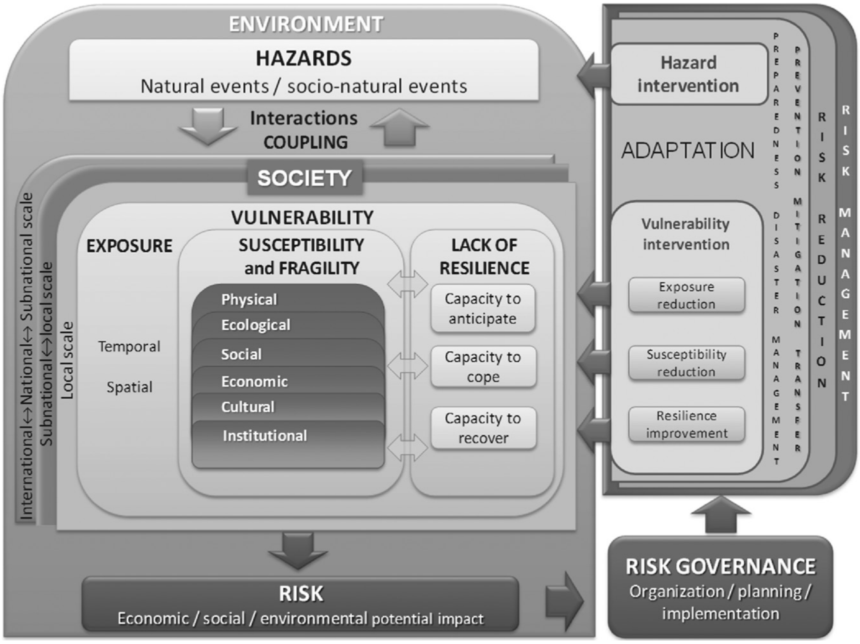


Figure 21.1 The MOVE framework
Source: Birkmann et al. 2013, based on concepts of Cardona, 1999a: 65; Cardona, 2001; Turner, et al., 2003; Bogardi and Birkmann, 2004; IDEA, 2005; Birkmann, 2006b; Carreño, et al., 2007a.

bility and societal response capacities. It is necessary to consider key factors (for example, susceptibility, coping etc.) and multiple thematic dimensions (social, environmental, economic and institutional issues) when assessing vulnerability to natural hazards and climate change. In addition it is essential to investigate vulnerability to understand risk and to develop appropriate adaptation strategies. While hazards may trigger loss and reveal vulnerability, vulnerability in its multi-faceted nature is mainly linked to the inner conditions of a society or community and the contexts in which a society is embedded (Birkmann, 2011a and b; IPCC 2012). In this regard society is embedded in the broader context of the environment just as the environment is shaped by human action (Oliver-Smith, 2002). Hence the framework also refers to social-ecology (for example Becker and Jahn, 2006) and coupling processes in human-environmental systems in the context of hazards (see Birkmann, 2011b) as well as general system theory and cybernetics (for example, Vester, 2002 and 2008). The MOVE framework (see Birkmann et al. 2013) is a further development of so-called holistic approaches and builds on the work of Cardona, 1999: 65; Cardona, 2001; Turner et al., 2003; Bogardi and Birkmann, 2004; IDEA, 2005; Birkmann, 2006; Carreño, et al., 2007.

From this perspective, vulnerability is not limited to economic susceptibility (like poverty) or the physical fragility of built structures but encompasses six interdependent dimensions that need to be better understood when aiming at a holistic and integrative assessment of vulnerability and risk. These dimensions are the physical, ecological, social, economic, cultural and institutional. While exposure describes the extent to which a unit of assessment falls within the geographical range of a hazard event, susceptibility describes the predisposition of elements at risk (social and ecological) to suffer harm. The question whether exposure is actually a category on its own or a sub-component of vulnerability is still debated (Birkmann, 2006; IPCC, 2012). In this chapter we find it more important to differentiate exposure, susceptibility and capacities of societies to respond to hazards and changing conditions, such as coping and adaptive capacities. Susceptibility can be addressed by policy independently of exposure. Susceptibility is revealed through physical, ecological, social, economic, cultural, and institutional components and processes. The societal response capacity is conditioned by the ability of societies or socio-ecological systems exposed to natural hazards to access resources and to apply adequate strategies to respond effectively to identified hazards and actual events. Compared to adaptation, coping as a direct response process to a stressor or hazard focuses mainly on the ability to maintain the system as it is in the context of a hazard event impacting on the system or element that is exposed (see for example, Birkmann, 2011a). Adaptation in this framework aims to modify and change the situation in order to improve the ability of a society to live with the environmental and socio-economic changes that occur or are expected to occur over time. Finally, risk governance (see for example, Renn, 2008) and also “Earth System Governance” (see for example, Biermann, et al., 2009), as even broader concepts, are important factors that modify vulnerability and risk. Governance in a more general sense includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated and, for example, how management decisions about resettlement are taken.

Research on resettlement

Most work on resettlement has been carried out in the field of development-forced displacement (see for example, Scudder, 2005; Scudder and Colson, 1982, Cernea, 2000, McDowell, 2002, Oliver-Smith, 2009). Forced displacement and resettlement by development projects has been framed as a four-stage process in which changes in vulnerability and risk differ from phase to phase (Scudder, 2005; Scudder and Colson, 1982). Each of the four phases is characterized by a particular behavioral pattern (Scudder, 1981, and 2009 and Scudder and Colson, 1982). The first phase is called “planning and recruitment” and deals with activities relating to the pre-resettlement period, such as planning for the removal of the people who might need to resettle. Scudder argues that the stress level of displaced people increases owing to various concerns, such as an uncertain future, particularly when the time of their removal draws closer. The second stage is defined as “coping and adjustment”, which involves the physical removal of communities for resettlement. The third stage is named “community formation and economic development”. In this stage resettled households may invest in children’s education, small business and other assets. Resettled households also tend to buy new furniture, electrical items and add more room(s) to the house during this stage. Moreover, they pay more attention to community formation activities by forming different community-based societies. The fourth and final stage deals with the successful integration of relocated populations into a regional or national political economy. Scudder concludes that in many cases it is not until the second generation that resettlers are able to achieve this fourth stage of “handling over and incorporation”. This analytic concept of relocation by Scudder can thus be used as a general framework to assess vulnerability in the different stages. Yet, considering its broad level of generalization, it does not allow for detailed exploration of differences and complexity in relocation processes. In addition, the framework itself does not directly show the failures of such relocation processes; although Scudder in his application of the framework clearly outlines that many development-induced resettlement processes may never reach the fourth stage of incorporation. However, the four-stage model can inform the assessment of vulnerability dynamics in the context of relocation. Hence, it helps to differentiate phases that correspond with changes and transitions in vulnerability from one phase into another.

Within the process of transition from phase to phase, displaced people face new threats and risks related to economic, social and cultural impoverishment when they settle in new locations (Cernea, 2000). Mediating between the social actors engaged in resettlement and reconstruction, (for example, affected community members, government officers, private business project developers, civil society actors such as NGOs, community representatives or social researchers) is another challenge according to Cernea. Overall, he identified eight risks which are particularly relevant when dealing with (forced) relocation: landlessness, joblessness, homelessness, marginalization, food, insecurity, increased morbidity and mortality, loss of access to common property resources and social disarticulation (see in detail Cernea, 2000).

All of these risks of resettlement may affect the levels of aggregate vulnerability, through changes in one component of vulnerability (for example, exposure, susceptibility etc.). A focus on institutions associated with access to resources is recommended to understand the effects of disaster-induced displacement and resettlement processes. Such institutions may be key in shaping resettlers' adaptation strategies and link time frames of reconstruction with specific livelihoods (McDowell, 2002). However, in terms of post-disaster relocation and resettlement there may also be positive impacts from relocation, such as the reduction of exposure to natural hazards. Our interest here is to understand changes of vulnerability due to relocation for disaster risk reduction and adaptation to extreme events.

The question remains, however, whether improved planning and adequate input can mitigate the eight risks of impoverishment by resettlement identified by Cernea (2000). The inherent complexities of such relocation processes may hamper plans for managing these processes. Linear planning approaches may be unable to capture the complexities that are involved in relocation, especially the institutional vulnerabilities that might be linked to the way planning approaches are perceived (de Wet, 2006). Therefore, the broader context conditions also need to be evaluated in such an assessment.

The complexity of which de Wet speaks points to a process that is unfolding and changing over time, that does not follow a linear causal chain. In this context, the concept of first- and second-order adaptations indicates the complexity and the cascading nature of adaptation (see Birkmann, 2011a). First-order adaptations are those strategies and measures that households, communities, or societies develop to adapt to expected (future) and actual climate change consequences and natural hazards. Examples include relocation or migration. These adaptation measures and processes can happen at a more formal level, i.e., they may be planned and organized by official organizations and institutions or be more informal in terms of adjustments by individuals and households. Compared to these processes, second-order adaptations encompass processes, strategies and measures that can and most likely need to be undertaken by individual households, communities and societies to adjust to the direct and indirect consequences of the measures and structures implemented within the scope of first-order measures (Birkmann, 2011a). The concept can be applied to resettlement processes, since resettlement often also implies a first-order adaptation – the physical relocation and movement process – as well as the need for resettled households to adjust or redevelop their livelihoods, daily activities and social networks due to the new environment in the relocation site. Thus, resettlement processes are not solely a transfer of material assets that have been damaged or lost due to a hazard event or disaster. Rather, relocation modifies physical and social geographies (Downing and Garcia-Downing, 2009). Moving into a new location and housing area implies major structural changes that add to the complexity already caused by the disaster or the prior high-risk situation before resettlement. The new environment in many cases requires additional individual or behavioral changes that need to be understood in order to capture the dynamics of vulnerability before, during and after relocation processes. These individual and behavioral changes are called "second-order adaptation processes" in this approach. Factors that constrain successful and rapid second-order adaptation can also be identified as determinants of vulnerability or factors that reduce coping and adaptive capacities to other new hazards.

Advancing resettlement theory: hazards, disasters, displacement

When framed as complementary, the constellation of theoretical approaches previously outlined provides an overall framework with which to conceptualize disaster-induced displacement and resettlement and guide the empirical analysis. In the final analysis all decisions regarding disasters and the displacement and resettlement of affected people are made in the context of local vulnerability, which is the combination of exposure, susceptibility and response capacities. Of these three components, exposure is the most salient for decisions about displacement and resettlement. In the most basic sense, displacement and resettlement are often undertaken to reduce exposure, thus constituting a first-order adaptation to particularly severe hazards. For example, after the Indian Ocean tsunami of 2004 in Sri Lanka, as well as after the 11 March 2011 disaster in Japan triggered by an earthquake and tsunami followed by an accident in a nuclear power plant (Fukushima), displacement and resettlement to reduce risk through the reduction of exposure to hazards are being controversially discussed. Susceptibility and societal response capacities are elements that may or may not be affected by or affect the resettlement process. In some cases, resettlement has increased susceptibility and undermined societal response capacities, particularly in the second stage of coping and adaptation in the new circumstances (Scudder, 2005). Indeed, the trauma of disaster impact and loss may be compounded by the subsequent displacement and resettlement process. Many of these stresses are occasioned by the emergence of the risks of impoverishment and consist of the conditions which necessitate a variety of second-order adaptations, many of them largely characterized by conservative strategies of risk avoidance.

Next to the reduction of exposure to natural hazards, the quality of the resettlement project will be key in either the reduction or increase in levels of susceptibility (Oliver-Smith 2005a and b, 2010). By the same token, the resettlement project will also play a major role in whether the second-order adaptations support or undermine the societal response capacities of the affected community. Research has shown that nourishing the close relationship in affected communities between social relations (and local institutions), resource acquisition and livelihoods can enhance the transition to the third stage in which community formation and economic development take place. In turn, projects that undermine this relationship may stall for long periods in the second stage of coping and adaptation, in which communities continue to struggle for food security and adopt risk avoidance strategies. Since marginalization and social disarticulation undermine the community's societal response capacities, the restoration of social networks is essential for restoring resource access and resuming livelihood activities. However, restoring social networks is a complex process that rarely conforms to the dictates of linear planning and requires a flexible and adaptive response on the part of governmental agencies hoping to enable the community to transition to the fourth stage in which the community is able to sustain itself economically and to re-engage as a full-fledged participant in local and regional systems.

While previous research has focused largely on the many negative impacts of resettlement, it has to be remembered that many relocation projects in the context of natural or technical hazards, climate change and disaster risk management aim at reducing the hazard exposure of households, hence targeting a reduction in their vulnerability. Thus, assessments of relocation processes for disaster risk reduction have to account for positive and negative implications with regard to the three key factors of vulnerability: (a) hazard exposure, (b) susceptibility and (c) response capacities (coping and adaptation). Furthermore, relocation processes have to be understood as being complex and highly dynamic and that cannot fully be controlled (deWet, 2006). This is particularly true for relocation related to natural hazards, where the resettlement often happens in the aftermath of disaster, often under conditions in which governmental institutions do not function well.

Based on the discussion above, we derived the following key questions for our own case study and empirical work. The key questions combine different elements of the various approaches discussed:

- How are people exposed and susceptible to natural hazards or changing environmental conditions before the relocation process?
- How does hazard exposure affect the susceptibility and response capacity of affected households?
- How does relocation reduce exposure?

- What does relocation imply for the livelihoods of the affected households?
- How do vulnerability and, especially, characteristics of susceptibility change due to the physical relocation?
- How do the new conditions in the resettlement site affect coping and adaptive capacity? What kinds of coping strategies do people apply with regard to the new risks?
- How do resettlement-induced changes of different vulnerability factors interact?
- How can we measure and differentiate those households which gain from those who lose due to the relocation process? Which time scales are appropriate for measuring the success or failure of relocation processes for disaster risk reduction or climate change adaptation?
- How can we characterize non-linear development and potential socio-economic tipping points in post-relocation processes?

Figure 21.2 illustrates how the conceptual questions translate into the assessment modules used to organize the research in the following case study analysis (Sri Lanka and Vietnam).

Case Study Sri Lanka: Relocation after a disaster in Galle

Introduction

The Indian Ocean tsunami hit the coastal regions of north-east, east and south Sri Lanka on 26 December 2004. This tsunami took the lives of 231,452 people in 12 countries, ranging from South and South East Asia to East Africa. Subsequently, 1.7 million people lost their homes (UNDP, 2005, p. 15). In Sri Lanka approximately 35,322 people lost their lives and 516,150 persons were displaced by the tsunami event (UNDP, 2005). In addition, massive damage was caused to houses, public and private property, railways, bridges, communication networks, hospitals, schools, other infrastructure and personal assets. In view of the destruction the tsunami caused in the coastal communities of Sri Lanka, the government declared "no construction zones" of 100 m in the western and southern coastal areas and of 200 m in the eastern and the northern coastal areas. Those displaced by the tsunami and living within these zones had to resettle in donor-built settlements. While a major argument for the resettlement was to improve security and reduce risk, the actual consequences of resettlement processes were rarely understood or examined.

In this context, a vulnerability assessment using various data collection methods was conducted in three tsunami relocation settlements – Katupolwaththa, Cinnamon Garden and Tea Garden[1] – that are situated 8 to 12 km from the city of Galle (see Table 21.1 and Figure 21.3).

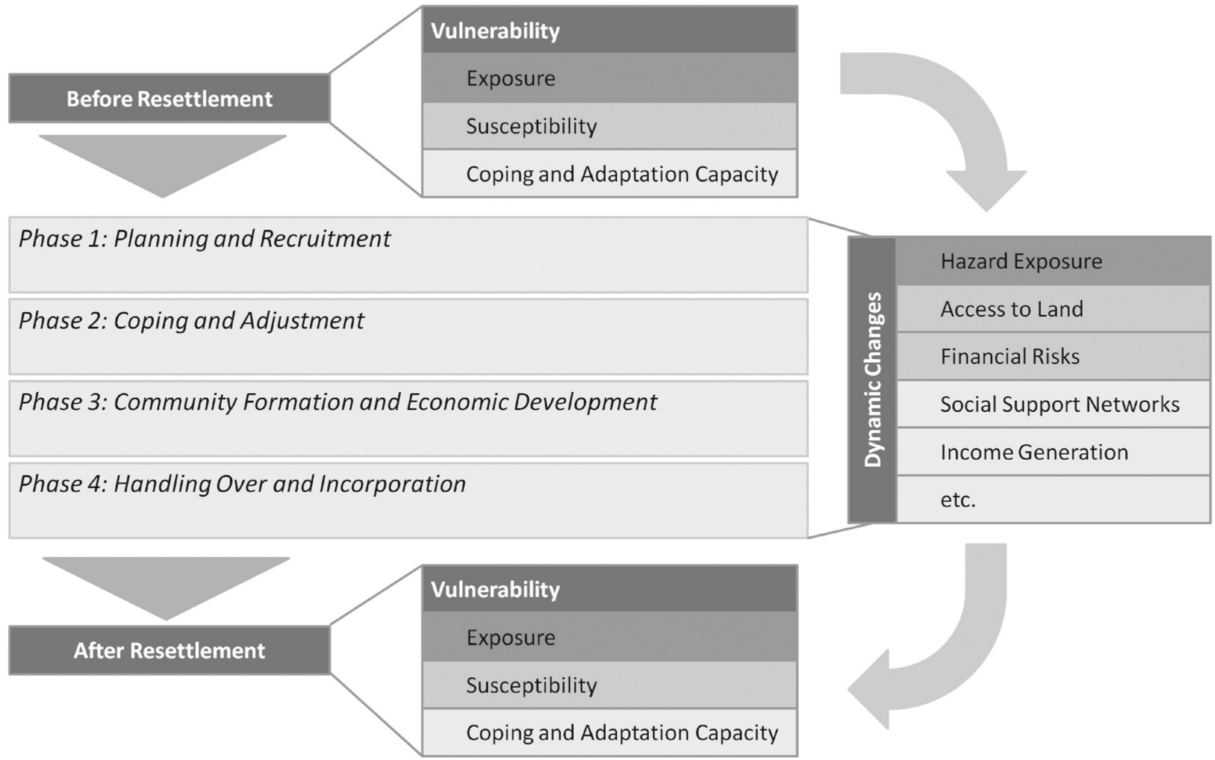


Figure 21.2 Core assessment criteria used before and after resettlement
Source: own draft.

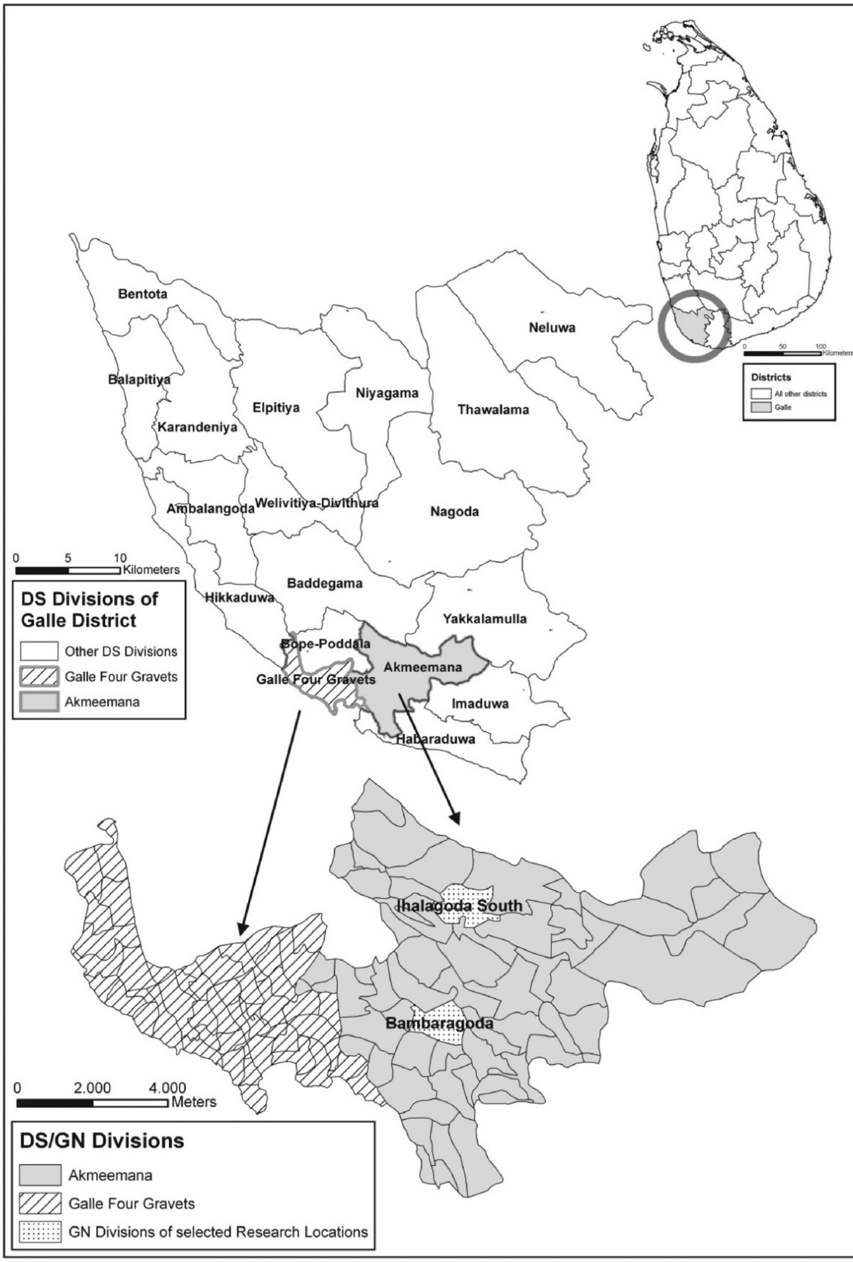


Figure 21.3 Research locations in Galle, south Sri Lanka

Table 21.1 Overview of the study villages in southern Sri Lanka (DS Akmeemana)

	Katupolwaththa	Cinnamon Garden	Tea Garden
Distance from Galle city	8.5 km	10.5 km	11.5 km
Total area allocated per resettlement	8 hectares	6 hectares	15 hectares
Area allocated per house	10 perch	8 perch	10 perch
Total number of houses	78	145	135

Source: GN officer Katupolwaththa, Cinnamon Garden and Tea Garden statistics; additional own data.

A randomly selected sample of 143 relocated household heads was used to examine the consequences of relocation on the vulnerability of people to natural hazards. In-depth interviews with selected household heads, key informant interviews with government and non-government officials and semi-structured interviews with the host community were also conducted 1.5 to 2 years after the devastating Indian Ocean tsunami.

Pre-resettlement vulnerability: before the tsunami disaster

Interestingly, only a small number of interviewed people knew about tsunami before the 2004 disaster, thus preparedness for such disasters was very limited. All the households interviewed in the relocation sites resided in the buffer zone for 10 years or more before the tsunami disaster and most of them experienced coastal hazards but no tsunamis. Hence it can be concluded that coping capacities were very low due to the limited awareness of tsunami hazards. In terms of socio-economic susceptibility, the survey showed that 37 per cent of the people who previously had lived close to the sea were encroachers and did not have a permanent income source. Most of them were daily paid labourers in the fisheries sector or in other informal sectors (for example, street vendors) in Galle city. Thus, numerous encroachers were facing poverty or chronic poverty due to their land insecurity and/or income insecurity in addition to coastal hazards before the tsunami.

More than 96 per cent of the people interviewed had completely lost their housing and all of their valuables. The majority had initially to stay in temporary camps close by. A smaller proportion (26 per cent) stayed with relatives and friends in non-tsunami affected areas. The displaced people often stayed in the temporary camps for more than six months before they moved into temporary wooden shelters. The long length of this transition period underscores the limited functioning of governmental agencies in terms of providing effective recovery support. In addition, most of the transitory shelters did not reduce vulnerability and promote fast recovery; rather, the situation in these camps was characterized by inadequate access to water for sanitation and for drinking. People also constantly struggled with high uncertainty, since they did not get sufficient information from the government about how long they would have to stay in the temporary camps and where they would receive permanent housing (Ingram et al., 2006). A lack of proper information is an indicator for institutional vulnerability that increased the insecurity of people displaced by the tsunami. This insecurity also contributes to marginalization processes as Cernea points out in his studies (Cernea, 2000). Considering the various hardships encountered by displaced people, particularly those who moved into camps and transitional or temporary shelters, there is no doubt they were desperate to find permanent places to settle. Most of the displaced household heads could not find work for at least the first three months, and some for more than six months, after the tsunami. They needed some time to mentally prepare themselves to face the future after losing family members, close relatives, homes, valuables and dealing with injuries to other household members (Stirrat, 2006; de Silva, 2009).

Exposure and susceptibility – after the tsunami

About half of the affected people (53 per cent) were frightened of another tsunami and did not want to stay in their previous dwelling, irrespective of the buffer zone regulation. Most of the interviewed households wanted to live outside the buffer zone, somewhere in Galle city. However, about a third, who were engaged in fishing or related income earning activities, wanted to live in their previous places close to the sea. A small proportion of squatter settlers seeking houses with secure land titles wanted to move out of the "no construction zone" with the intention of increasing security in the event of another tsunami. All of the interviewed household heads wanted to live in Galle city.

Transition into a new environment

In terms of access to information, nearly 90 per cent of affected people received names of possible relocation sites from the GN (Grama Niladhari – smallest administrative unit) or Divisional Secretary officials before they completed the relevant application forms for resettlement. However, the majority (nearly 62 per cent) were not informed about the housing structure and quality (i.e. single or two-storey), or the availability of common facilities and social infrastructure (for example, schools, community facilities etc.) in the new location. Only a few households were given an opportunity to provide their inputs either regarding the settlement plan or the housing structure. In this context, most of the forced relocatees were not involved in the planning and implementation process of resettlements, which is critical to the sustainability of the settlements (Lyons, 2009).

The majority of relocated settlements were constructed on available government land far from Galle city despite officials' intention to relocate people close to their former villages. One argument for this was that the high demand for houses in Galle city could not be met, due to the scarcity of government-owned land in the city area. The Divisional Secretary officials did not receive funds from the government to buy private land in Galle city, although the amount of international funding available for the tsunami recovery was quite high.

Post-resettlement vulnerability

Most of the tsunami displaced people had little choice other than to rebuild their lives from scratch in the settlements they were relocated to, too far from Galle, despite their desire to live in the city. The combined effect of the tsunami disaster and the relocation far from the city (8 to 12 km) influenced the exposure and susceptibility of people heavily. While the relocation process reduced the spatial exposure of households to coastal hazards (including tsunamis), it increased the socio-economic susceptibility due to two main factors: (a) disruption of income-earning activities and (b) new household expenses. The two factors cumulatively reduced the monthly disposable income of relocated households.

Exposure

Those relocated presently living in the three study locations complained that this *new distance* from the city of Galle and the coast is one of the key factors that has caused a disruption to their primary income-earning activities. This is largely because most of the occupational groups still work in Galle but no longer have easy access to the city due to a lack of public transport. The majority of the main income earners in these locations are casual labourers (25 per cent), for example at Galle harbour or the cement factory. Another 20 per cent of the relocated households are making a livelihood from fishing while another small proportion are working as fish sellers, boat engine mechanics or are involved in other fishing-related activities. About 20 per cent of the relocated households are engaged in small-scale businesses such as running small grocery

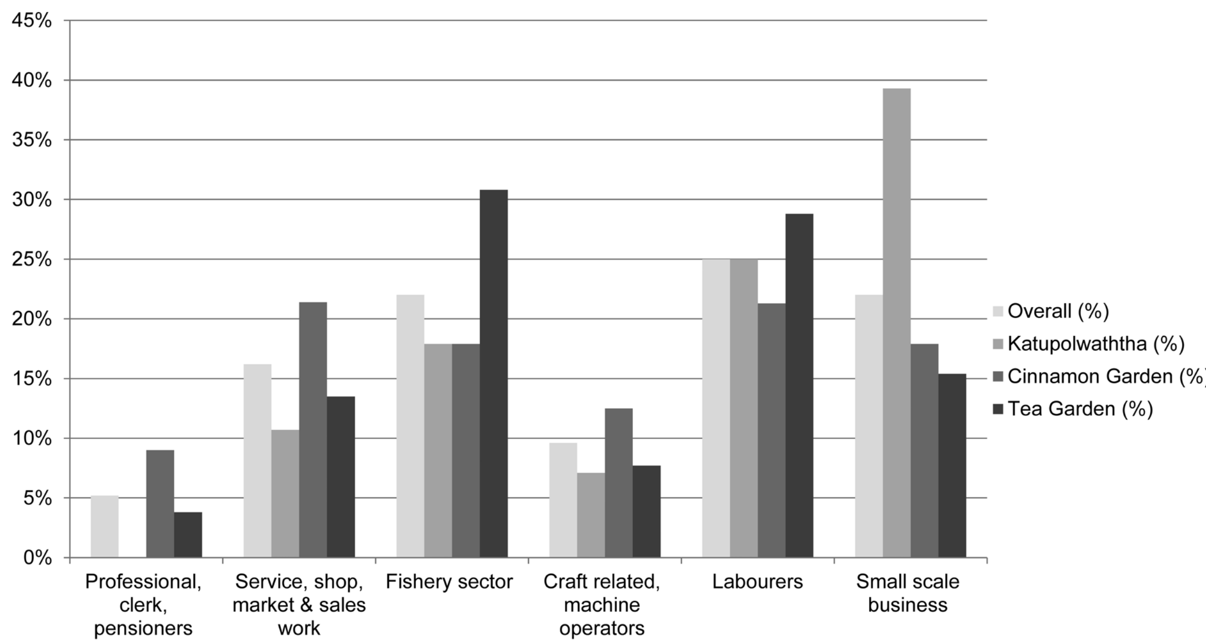


Figure 21.4 Main income earning activities of households by location
Source: Field Survey.

shops, or as street vendors. That means many households in the relocation site are still engaged in income-earning activities that are linked to a specific landscape – the coast or the city centre of Galle (occupations coupled with the coastal environment) (see Table 21.2).

Notably, almost two thirds (nearly 66 per cent) depend on public transport (bus) to commute to the city and other places of work. A significant proportion of those engaged as labourers (76.5 per cent) and workers in the fisheries sector (nearly 81 per cent) use public transport (bus) compared to those who are engaged in service, market and sales occupations (nearly 39 per cent). The reduction in exposure to coastal hazards in the new settlement has increased the difficulties in accessing the place of work which, for a large part of the relocated households, is still located in the coastal zone. The difficulties of the daily commute pose a new threat to livelihoods and livelihood recovery.

Susceptibility – changes after relocation

In terms of employment opportunities the new location provides less variety compared to the city of Galle. Mostly using family labour, 30 per cent of people in the DS division where the relocation site is situated are cultivators of rice, tea and rubber on small plots of land. As a result, new settlers from the coastal belt complain that it is not easy to find manual labour as old settlers hire mainly old villagers. Shifts in employment are also rather difficult, since the relocated households do not have enough land for such cultivations nor the right knowledge for such work. The relocation site and its employment environment have therefore increased the socio-economic susceptibility of relocated households due to a lack of alternative job markets.

Changes in access to basic infrastructures

A significant proportion of resettled householders acquired educational, health and banking services in the city because these are unavailable (i.e. hospital, banks) or of poor quality (i.e. schools) in the resettlement site. Commuting to the city for income-earning activities and for having access to social infrastructures, such as schools or hospitals, is a new monthly expenditure for the majority of relocated households.

A comparison of the monthly transport expenses before and after relocation (see Figure 21.5) revealed that 65 per cent of interviewed householders did not spend money on transport before the relocation. Those who lived within the Galle city, but not that close to their places of work or other services, had to spend less than Rs.1000 on monthly transport costs (24 per cent) before relocation.

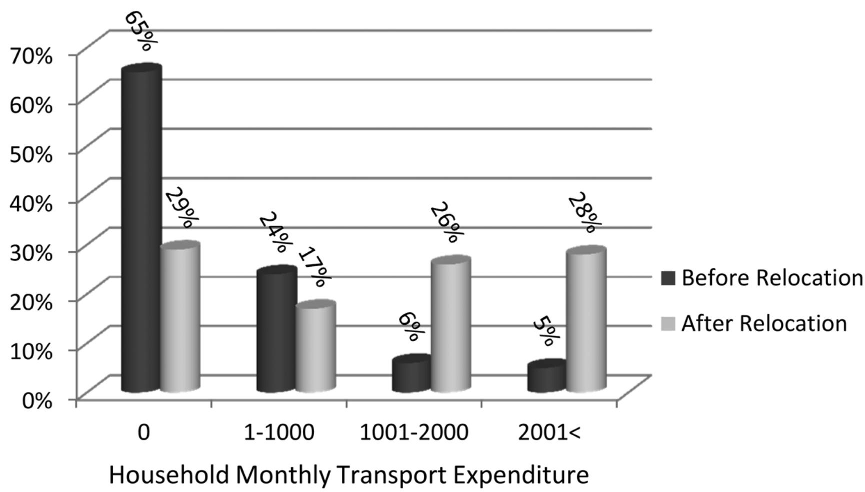


Figure 21.5 Average monthly transport expenses: Before and after resettlement
Notes: Before valid n* = 143 and after valid n** = 140
Source: Field Survey.

Electricity and water

All newly built housing units received individual water and electricity connections. While these connections are a clear improvement on the housing situation for the majority of relocated people compared to the situation before, the improved access to electricity and piped water also means that resettlers must pay monthly bills for these services. Before relocation, more than 30 per cent of the resettlers used public or common infrastructures to access water (common wells) free of charge. The gradual increases in monthly water and electricity bills, and lower household income to meet these expenses, are a new socio-economic insecurity that increases the susceptibility of households, particularly for poor households. According to our research, 38 per cent of the households who categorized themselves as “poor households” could not pay the full amount of the monthly bills, or ignored paying them, meaning that at the end they were disconnected from these services. Hence, their socio-economic susceptibility increased due to the improved infrastructure services and the respective costs linked to it.

Rapid response versus quality in housing and land allocation

In general, the huge pressure after the tsunami, both from politicians as well as from displaced people, to speed up the housing construction in resettlements, increased the likelihood of failures in planning and construction. Most of the respondents in the new settlement site complained that building contractors deliberately used poor materials to increase their profits, since there was no proper supervision either from relevant government officials or from donors. In addition, government officials indicated that some land allocated for resettlement projects was only partially suitable for housing. The lack of a functioning common social infrastructure (for example, schools, public transport etc.) before settling beneficiaries in their new location also contributed to new risks of livelihood disruption and additional costs for commuting, such as for sending children to school. Finally, a proper coordination between relevant divisional secretaries and local authorities was absent (Mulligan and Shaw, 2007; de Silva, 2009), thus revealing the institutional vulnerabilities relocated people had to deal with.

Lack of common infrastructure

In most of the relocation sites neither a proper drainage system for either rain water or waste for individual houses, nor for the settlement as a whole, was in place. Some households even reported that they were now exposed to new hazards, such as flooding of the house during monsoon times. Health risks were also likely to increase in the new relocation sites due to the lack of public garbage collection or the inappropriate treatment of waste. The latter included burning it, burying it in the garden or dumping it on abandoned lands or on street corners as reported by some of the interviewed households.

Landownership and new conflicts

The relocation process could have reduced socio-economic susceptibility, for example through the provision of an official land title for those who previously were landless. However, none of the new occupants in the three study locations had received formal landownership of their new land when the interviews were conducted in 2009, five years after the tsunami disaster.

Conflicts between host and guest (resettled) communities were particularly evident in terms of tensions over resources, such as land, access roads and the community centre. In addition, conflicts also emerged due to the different cultures of the host and guest communities, for example in terms of different ways of communication, different forms of attire and employment, and even different eating habits.

While the new physical conditions (new location) often offered improvements (for example, housing standards), the lack of the provision of an official land title and the conflicts over resources between the host and guest communities, as well as the differences in cultural habits, clearly

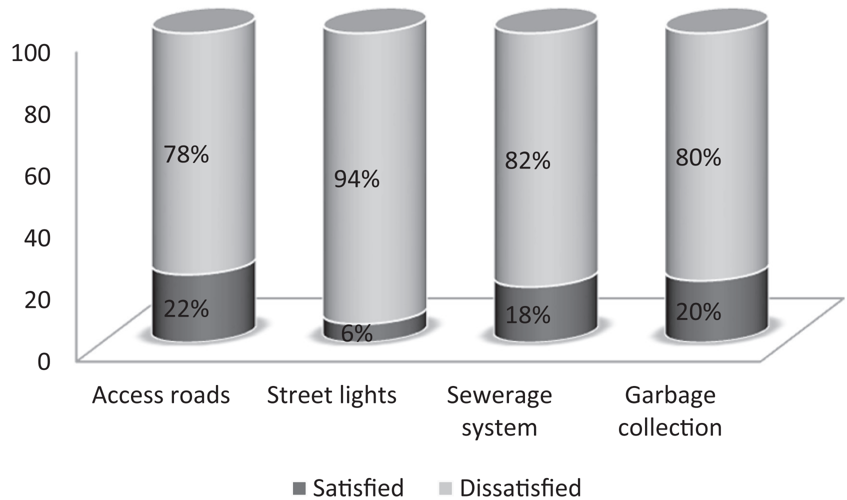


Figure 21.6 Satisfaction with common infrastructure facilities
Source: Field Survey; N. Fernando, 2009.

show that households had to deal not only with being in a new physical location but also with second-order adaptation processes in terms of the new socio-economic and cultural conditions that often implied actual conflicts between the guest and host community.

Coping and adaptation strategies to deal with new risks – after resettlement

Households which had to face increased household expenses, and at the same time were dealing with severe difficulties in income generation, mainly relied on their relatives (24 per cent), not only to borrow money but also to borrow food items (see Figure 21.5). The intensive stock of bonding social capital that poor households possess plays an important role as a safety net to temporarily protect these households from income-related stress. Twenty per cent of households were buying essential goods on credit from grocery shops. Another 10 per cent of the households obtained money from informal moneylenders at high interest rates, while 12 per cent of the households sold their jewellery and electrical items (i.e. televisions, radios etc.) to meet their regular expenses. The last two coping strategies, particularly, result in further debt and increase the risk of chronic poverty. Some households that could not meet their daily expenses with their current income also did not send their children to school or buy new clothes. Hence, the phase of "incorporation" has not been reached by many of the resettled households after the Tsunami disaster.

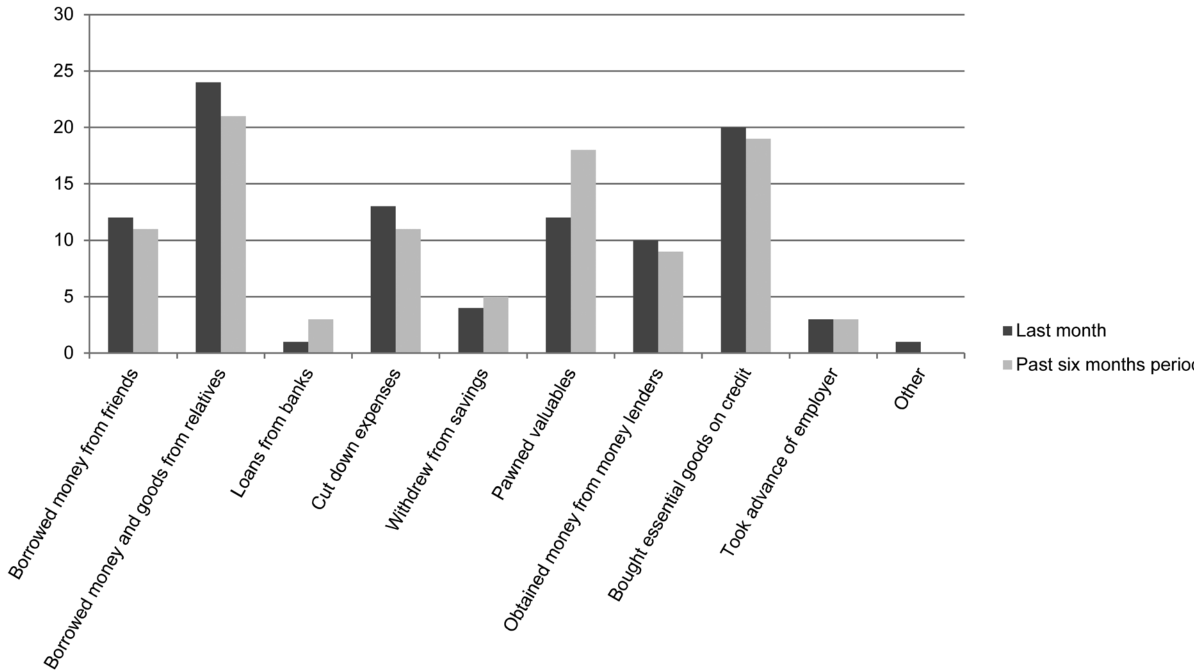


Figure 21.7 Coping strategies employed by households
Notes: valid n^1 of responses = 139 and n^2 = 147
Source: Field Survey.

Moving back into the buffer zone

A small proportion of resettled households wanted to move back to their old location close to the sea or to another location near Galle city. These households intended to sell, rent or close down their present house in the near future. A number of houses were reported as closed, sold, or rented, even prior to this research. Those who moved back to their previous place in the buffer zone, or somewhere close to the sea, run the risk of being exposed to tsunamis or other coastal hazards in the future, but they avoid the various stresses related to forced relocation.

Case Study Vietnam I: Resettlement in the context of flood hazards in rural areas of Dong Thap Province

Introduction

In Vietnam, resettlement in the context of natural hazards has been strongly enforced since the historic floods in 2000. It is considered by the government as an effective measure to reduce flood risks, particularly in the rural Mekong Delta. Although rural households in the Vietnamese Mekong Delta (VMD) have been living with floods for centuries, the flood disasters in 2000 and 2001 with more than 900 fatalities clearly revealed the vulnerability of rural communities to large floods. Slow-onset annual floods occur from late July through December, peaking in late September or mid-October. The flooded area accounts for around 53.3 per cent of the delta's natural area (more than 1.8 million ha), and half of its population is affected. Flooding levels over 4.5 m in the upper delta are classified as big floods which cause serious risks for people and economic assets. In general, flood-prone households have enhanced livelihood assets and have developed response strategies in order to mitigate flood impacts in addition to taking up flood-related benefits. However, economic development trends and flood disasters in 2000, 2001 and 2002 triggered large-scale governmental projects for the resettlement of flood-prone households to non-flood-prone areas.

The study was carried out in two case study sites which are located in both inland and river bank areas in the flooding region in Dong Thap Province, one of three provinces most prone to floods. The province is characterized by its agricultural land-use pattern. Rice is the major crop, accounting for 94 per cent of annual crops (Dong Thap Statistical Office (DTSO), 2008 and 2010). Double rice cropping is the most popular farming system, and triple rice cropping has been increasingly applied in the fully flood-protected areas. Using a standardized questionnaire, 370 households were interviewed, with interviewees located in the floodplains (rice fields), along roads and in the residential clusters protected by dykes.

Resettlement vulnerability

After the big floods in 1996, the government initiated the development of so-called new residential clusters (relocation sites) and dyke systems. After the historical floods in the early 2000s, the first phase of the residential clusters was built in the period of 2001–2005. More than 1,000 residential clusters were proposed to relocate approximately 200,000 households (with 1 million people) prone to slow-onset floods (Danh, 2007; Danh and Mushtaq, 2011; Xe and Dang, 2007). In this first stage, 728 residential clusters and dykes were completely established (Hoi, 2005) that can be differentiated into two categories: a residential cluster built at a high elevation with parallel rows of houses, and a tall residential dyke built along a canal with only one row of houses. Residential clusters are usually constructed near communal centres while residential dykes are built along the main canals.

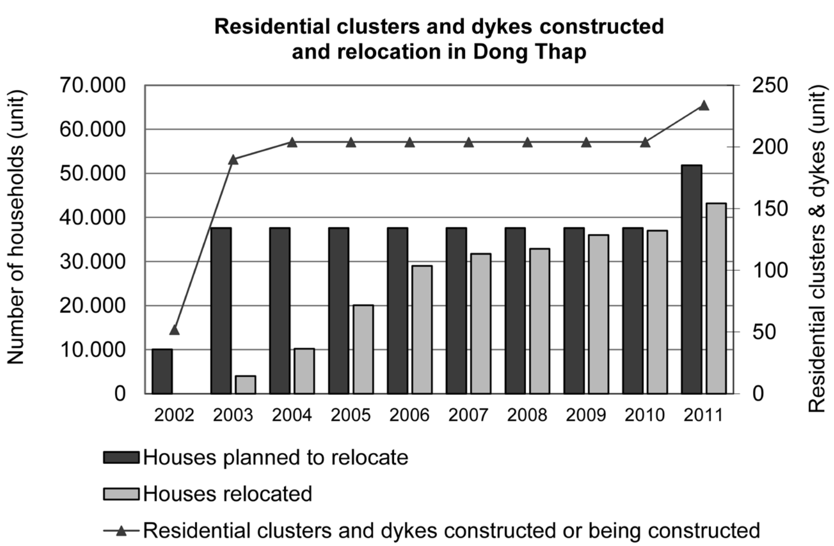


Figure 21.8 Timeline of relocation, dyke construction and new residential clusters, Dong Thap
Source: Commitee for Flood and Storm Control, Dong Thab (CFSC), 2002–2007.

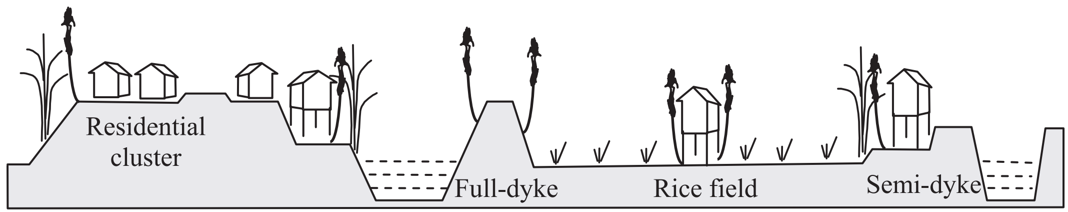
Exposure – before relocation

In the rural VMD, people usually live in floodplains, along canals, low dykes, high dykes or high places as residential clusters (see Figure 21.9). These patterns of settlement depend on residents' settlement periods, wealth, land ownership or relocation. Many people, particularly the poor, who settled in the flood-prone areas for livelihood opportunities were selected to be relocated in the residential clusters (relocation sites). Exposure levels to floods varied due to development conditions and human livelihoods. Relocated households who previously lived in the floodplains had been strongly exposed to flood impacts. Living far from high roads and densely populated areas, they lacked access to basic infrastructure, means of transportation, neighbours' support and had to evacuate when their houses were destroyed or damaged by flooding and strong winds. In the flooding season, they usually travelled by boat which constrained their children from accessing basic services like schooling and healthcare during the high flood season. Of so-called poor households in the region, 61 per cent still live in fragile (temporary) houses which are easily destroyed or damaged due to the long duration of flooding and high flood peaks. In past flood disasters, children under six suffered the highest fatalities, accounting for 74 per cent of total victims (Neefjes, 2002).

Exposure to floods differs particularly along the lines of land ownership. Landless people usually earn their main income from off-farm activities (for example, fishing) which normally cover their daily costs of living. During flooding events, children in these households are not well protected by adults since their parents and other adult members are usually working in the floodplains. Recently, as flood-related resources decline, and off-farm activities become more seasonal, landless people have tried to shift into other income-earning activities – remittance as the main household income has increased by 15 per cent in the last decade (own household survey, 2009).

Susceptibility to floods before relocation

Most of relocated people prone to floods lived in fragile as well as temporary houses far from the densely populated regions. During big floods, children could not access child daycare centres or more safe places since these infrastructures were not available in the rural areas. These households also lacked access to social networks and formal support (for example, local (Committees for Storm and Flood Control (CFSC), relief (see for example, CFSC Dong Thap, 2002) when facing severe flood damages and losses. A large rural population relies on agriculture, but much



Settlement periods	Relocated in 2003 from the floodplains, forced by the government	Resettled in the 1960s, forced by the former government	Informally resettled in the 1980–1990s, attracted by obtaining agricultural land and flood-related resources	Informally resettled in the 1980s–1990s, attracted by obtaining agricultural land
Flood impacts	Escaped direct flood impacts	Little affected by flooding	Severely affected by flooding	Moderately influenced by floods
Access to basic infrastructure	Electricity, tap water, schools, market, roads	Electricity, tap water, schools, market, roads	Lacks of access to basic infrastructure	Electricity, primary schools

Figure 21.9 Transect map of the inland site, Phu Hiep Commune (west–east direction)
Source: Vo Van Tuan, Transect Walk and interviews in Phu Hiep commune, 2008.

of this population lost its access to agricultural land in the context of economic reforms and changing production patterns. Landlessness among rural farmer households can be seen as a key factor of susceptibility in the VMD. Consequently, almost all poor people who had no residential land accepted relocation in residential complexes, while the others wanted to stay and live with floods given the flood-related and homestead-based benefits. Although most relocated people were landless, they heavily relied on rice production as a main source of income (off-farm activity). Moreover, households relocated and affected severely by floods were constrained in accessing formal loans and implementing livelihood diversification due to their chronic poverty and limited access to alternative job markets. Rural poor, particularly landless households, earn their main income during the flood season through flood-related resources such as fishing. Hence, floods were not only perceived as destructive hazards but also as livelihood opportunities. This explains why many resettled households still thrived on the rural floodplains. However, recently, flood-related resources have declined through an increase in embankments, agro-chemical use and illegal exploitation. Particularly, in fully protected areas, inundation periods have been shortened; therefore, access to flood-based resources is continuously declining. Although inhabitants in these relocation sites are gradually shifting into other livelihood activities, it is still difficult, particularly for very poor households, to access new livelihood activities.

Coping and adaptation – before relocation

During slow-onset floods, people in flood-prone areas applied a series of coping measures just before and during flooding in order to secure their housing or livestock. For example, they increased the stability of their houses by installing supportive wires just before floods. Many households also gradually lifted their house floor as the flood depth increased. However, floods provided both advantages and disadvantages; thus, people conducted flood-based activities, particularly fishing, during flooding to cope with the lack of access to other farming activities. That means shifting to other temporary livelihood activities can also be seen as a form of adaptation, since it is long term and allows livelihood diversification. In this regard flood-related products provided food not only during the flooding season but also for the dry season through processed products. In addition, adults of exposed households sent their children to childcare houses that are more safe in times of high floods. This coping process was a lesson learned due the high number of fatalities of children in the 2000, 2001 and 2002 floods.

Table 21.2 Overview of major changes for households before and after relocation in Phu Hiep residential cluster, Dong Thap

Items	Before relocation	After relocation
Natural hazard impacts	– Located in the floodplains annually exposed to flooding – House, physical household assets and people exposed to flood risks	– Located in the residential cluster higher than the highest flood peaks – House, physical household assets and people shifted out of flood impact zones
Social relations	– Rely on old socio-economic relations, neighbours' support	– Initially influenced by drinking & gambling impacts, quarrels, lack of neighbours' help
Housing	– Temporary houses	– Semi-permanent houses
Access to public infrastructure	– Use canal water polluted by agrochemicals and wastes – Go by boats in flooding duration	– Access to tap-water systems, electricity line, roads/transportation, schools and local markets
Land ownership	– Usually have no residential land, and no cultivated land	– Have residential land after paying costs for residential land, but no cultivated land
Income-earning activities	– Rely on fishing and natural resources and off-farm activities – Gain home-based agricultural income	– Non-farm activities far from home,[1] off-farm activities and home non-farm activities – Gain no homestead-based agricultural income
Daily expenditure	– Moderate costs for living due to natural resources and home-based production – Lack of product supply service	– Higher costs of living due to buying many items – An increase in consumption demand

Source: Vo Van Tuan, interviews with the relocated people in Phu Hiep residential cluster, 2010.

[1]Approximately 10% in 2008 and 24% in 2010 of the relocated households with all members have left their houses for an urban area for non-farm income.

Post-resettlement vulnerability

Exposure to floods after relocation

The relocation projects have significantly reduced the direct flood impacts on people living in these new locations. Also children are no longer at risk of drowning, and physical household assets are protected due to the reduction of exposure. In the Phu Hiep residential cluster, relocated people have in general also gained an improved access to basic public infrastructures and services. However, many households are still exposed to floods, particularly due to their place of work in the flood-prone areas.

Susceptibility to floods after relocation

Relocated households have access to subsidized houses together with residential land funded by the government. These subsidies and grants provided by the government are required to be repaid in installments within 10 years by the relocated households. In addition, households were told that they would get residential land certificates, which help them to access loans from financial institutions. Although relocated people are no longer affected by floods, they were initially confronted with new socioeconomic shocks and stresses, such as a decrease in off-farm income and small-scale agriculture in their homesteads, an increase in daily expenses (Hoi, 2005), social violence and debts because they bought their houses using credits. Also, other studies in flood-prone areas in the VMD (see Danh, 2007; Danh and Mushtaq, 2011) indicate that relocated households have been confronted with a loss in income sources due to the resettlement process. In the initial stage of the relocation, relocated labourers lost their old economic base such as off-farm activity and exchanges in food, finance and labour. Hence, they had to compete for off-farm activities with labourers both inside and outside residential complexes. Relocated households were also not allowed to keep small livestock, as they had previously done in the rural flood-prone areas. Hence, their daily expenses increased. The shift towards an urban lifestyle and the concentration of urban poor created new insecurities that increased the susceptibility of relocated people. In addition, relocated households were confronted with an incomplete infrastructure and incomplete houses. Thus, many households had to finance the third phase of resettlement (coping and adjustment see Scudder, 1985 and 2005) on their own. Although relocated households received subsidized houses and house foundations purchased with credit, they have not yet received their property rights and thus could also not use them for getting new loans.

Coping and adaptation – after relocation

While relocated people have reduced their exposure to floods; they have had to cope with new insecurities, especially the increased likelihood of livelihood disruption and the risk of financial problems due to the need to take loans. In the light of high competition for employment in off-farm activities, relocated people join and work as informal off-farm labour teams that can help them to establish informal contracts with large landowners to undertake off-farm activities. However, embankments have shifted the seasonality of off-farm activities, thereby affecting the income of relocated households. In general, most of the relocated households have not found a sufficient livelihood basis in the relocation site. Most of the relocated households – if possible – cope and adapt to this situation with a temporal or long-term migration to urban centres. Temporal migration to urban areas for income-earning activities increased from 10 per cent in 2004 to 25 per cent in 2011 according to the household survey. Thus the relocation process seemingly increases the pressure of households to migrate from rural to urban areas. Another adaptation strategy applied was the shift in occupation towards small-scale businesses; however, these have faced severe challenges due to lack of financial capital and high competition in this area. Although the relocated households expected to gain benefits from getting access to their own residential land, so far they have not received residential land titles and have experienced severe difficulties in repaying the loans they have taken. The limited access to a land title after the relocation process is similar to the relocation processes in Sri Lanka and Vietnam, but in Vietnam many rural poor have had to finance the third phase of the resettlement process, the construction of an appropriate house, by themselves, clearly implying an increased socio-economic susceptibility.

Case Study Vietnam II: Resettlement in the context of urban upgrading in Can Tho City

Introduction

Located about 150 km south-west of Ho Chi Minh City, Can Tho City is the demographic and economic centre of the Mekong Delta, hosting around 450,000 people in its urban and peri-urban districts. The city is located in the centre of the Mekong Delta. It therefore shares the general environmental settings with the Dong Thap case study presented above. Yet hazards vary considerably. While the influence of regular inundations lasting for several months during the rainy season is not as strong as in the upper parts of the Delta, Can Tho is exposed to tidal and rain-fed flooding in the wet season as well as to extreme flood events that can potentially occur in years with above average flood levels or concurrently with typhoons. Located around 50 km from the coast, and hence within tidal influence, tidal flooding implies that some parts of the city are inundated up to a depth of 1 m for several hours at high tide. These flooding events are stronger the closer they occur to the peak of the rainy season, hence coinciding with increased overall water levels in the rivers and canals. Besides flooding, river bank erosion is an important hazard in Can Tho.

In contrast to the case study presented above, resettlement in the urban areas of the Mekong Delta occurs as an important component within modernization projects in Vietnam's cities. In the context of rapid economic growth, the government of Vietnam, as well as international donors, strives for upgrading the country's large share of urban neighbourhoods with substandard living conditions and insufficient infrastructure. These slum-like areas are often characterized by increased vulnerability to natural hazards, notably urban flooding and river bank erosion, due to high levels of exposure and susceptibility as well as difficulties in coping and adapting.

The majority of such programmes concentrate on improving the situation in existing settlements which are maintained. However, other components of upgrading require resettling considerable numbers of households. Three modes of resettlement and compensation can in general be differentiated. First, households receive monetary compensation for their land and other assets. This money is supposed to be used for acquiring appropriate replacements elsewhere ("money for land"). Second, households receive a new house or apartment in a resettlement site developed by the implementing upgrading agency. Third, hybrid types exist where evicted households receive monetary compensation and have pre-emptive title to purchase standardized land slots under subsidized conditions.

Empirical research was conducted in 2009 and 2010 in Can Tho City (see sites in Figure 21.10(c)) to analyse the vulnerability effects of such resettlement programmes within urban upgrading initiatives. Two household survey campaigns, based on explorative qualitative household interviews and expert interviews, were conducted in 2009 and 2010.[2]

Pre-resettlement vulnerability

Exposure – before resettlement

The settlements targeted by urban upgrading and resettlement programmes in Can Tho feature high overall levels of exposure to flooding and river bank erosion. The dwellings in such settlements are often built on low-lying waste lands or along the numerous rivers and canals. More than 70 per cent of households interviewed in the resettlement sites had been living on or directly next to the water prior to the resettlement and over 40 per cent of them had their dwellings entirely or partly built on stilts onto the water in order to extend the living space and utilize the water for washing, sanitation and transportation. Accordingly, more than

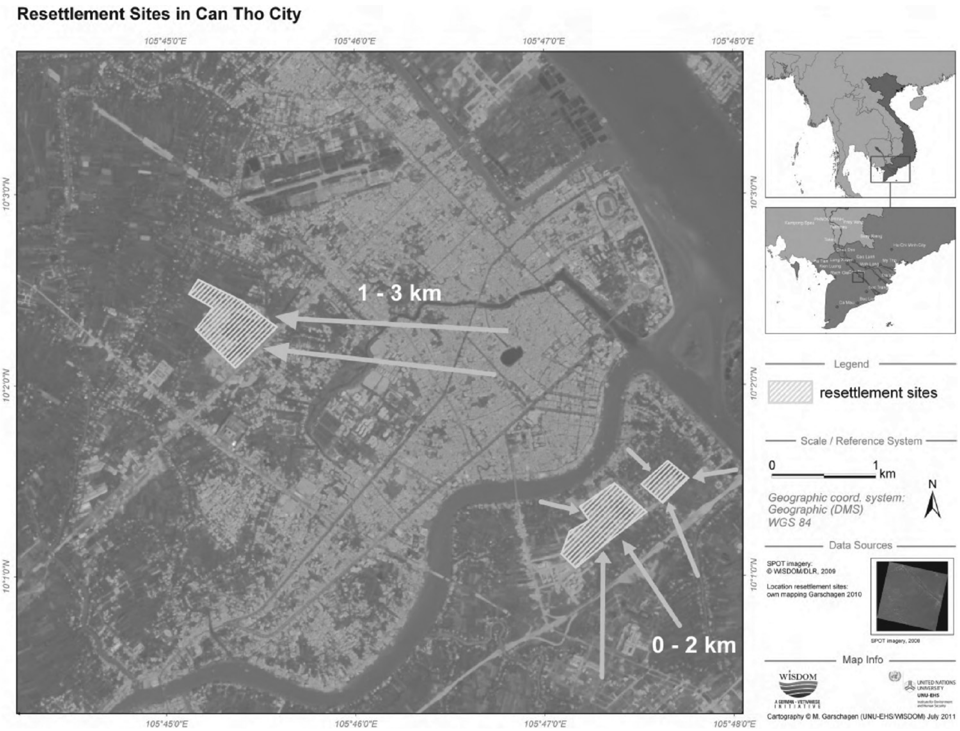


Figure 21.10 Resettlement sites in Can Tho City
Source: Draft Garschagen 2011.

Please see page 686 for a colour version of this figure.

half of the interviewed households reported that their old house had been flooded entirely or partly during high tides or heavy precipitation events. Depending on the location, typical flooding durations ranged from one to five hours. Such flooding occurs two times per day, particularly during the rainy season and with a peak at the middle and end of each lunar month. In addition, most of the households living right at the riverfront reported experiencing river bank erosion as a hazard.

Next to damage potential regarding physical assets, exposure to flooding poses in particular health-related risks. Water-borne and vector-borne diseases, as well as infectious diseases, can spread easily under flooding conditions due to stagnating wastewater and contaminated drinking water supply, coupled with monsoon climate conditions, high population density and low hygienic standards. Around 60 per cent of the households reported that one or more family members suffer from some sort of health impact during severe flooding, with fever and skin disease being the most important impact, followed by diarrhoea, coughing and injuries.

Susceptibility – before relocation

Living in such exposed settlements is often coupled with increased susceptibility to natural hazards, resulting from poor livelihood conditions and limited access to social security networks in both the public and private domain. Physical susceptibility prior to resettlement was strongly influenced by the physical nature of the dwelling. Only 14 per cent of the resettled households interviewed stated that they had the foundation of their house predominantly made of concrete prior to resettlement. Instead, more than 50 per cent of the interviewed households had the foundation of their former house built primarily with stilts, with the poorer people (around 50 per cent) having more fragile wooden stilts and the remainder having concrete stilts. Similarly, prior to resettlement, more than 30 per cent of the resettled households had dwellings with the walls primarily built of leaves, wooden planks or corrugated iron sheets. Almost 10 per cent had roofs made of leaves and improvised wooden planks. The poor housing conditions pose multiple burdens. First, such dwellings provide less protection against floods and storms, making the household members more susceptible to damage in case of flooding or storm events as well as suffering from erosion. Second, the poor quality of the construction materials and structures implies the need for recurrent repair and maintenance work.

The research has shown that the interviewed households had indeed faced an increased susceptibility prior to resettlement. In accordance with their proximity to water, their often informal land title status and their high levels of poverty, a considerable percentage of these households used river or canal water daily. The same water body was used for washing and the cleaning of food stuffs as well as for depositing waste and faecal matter. An increased overall level of susceptibility with regard to deteriorating health was the result.

Examining the institutional susceptibility of the households prior to resettlement also revealed substantial differences when compared with other households in middle- and upper-class settlements. Most of the interviewed households were lacking official titles for their land and dwelling prior to resettlement. Given this lack, they faced difficulties in, for example, acquiring bank loans needed for business activities or for house renovations since, in most cases, such loans would require a land use certificate for mortgaging. Loans from the government banks target reconstruction (for example, after a house has been destroyed by river bank erosion) but are less tailored towards precautionary renovation measures without as yet substantial observable damage. Support from other organizations, such as the Fatherland Front, is often restricted to holders of a poverty certificate. Many households who in fact live in dire poverty are nevertheless not considered eligible for a poverty certificate and, hence, for special assistance, for example for precautionary house improvements.

The assessment showed that the resettled households have on average quite low income levels. Of the 154 interviewed households, 6 per cent were holding a poverty certificate prior to resettlement, giving them access to special governmental support schemes. Yet, eligibility thresholds for obtaining a poverty certificate are often criticized as being too high, meaning that the actual levels of poverty are much higher (for example, Satterthwaite, 2004). In general, the resettled households had, for example, below-average access to healthcare prior to resettlement. In almost one quarter of the interviewed households, none of the household members had been covered by any governmental or private health insurance.

Access to information

Most of the households complained about insufficient levels of information given to them about the resettlement procedure. General information that some sort of resettlement would be carried out was provided a few years prior to the implementation of the project, which is quite a different situation compared to the other two case study areas presented above, particularly the case of Sri Lanka. Detailed information on the timing as well as the type of compensation and resettlement were not communicated until much later. Given this uncertainty, many households reported that they refrained from putting any more investment into renovating or maintaining their homes, thereby increasing the physical susceptibility of their dwellings even further.

Economic susceptibility

Economic susceptibility resulted from a number of different reasons but was mostly related to the exposure situation. The income of the majority of households had entirely or partly been based on activities in or around their houses. Next to the living space, such houses host, for example, workshops for small-scale businesses such as motor bike repair, hair dressing, tailoring, small-scale manufacturing, transport or waste recycling. This functional coupling means that not only the private spheres of life are affected in case of flooding but also economic activities. The resulting income loss can turn into serious economic pressure, depending on the frequency and duration of flooding.

Coping and adaptation

Coping and adaptation have been differentiated into the sub-components (a) capacity to anticipate, (b) capacity to cope and (c) capacity to recover (see also Fig. 21.1). The issue of anticipation is closely related to risk awareness and early warning. The household survey has revealed that risk awareness is tightly linked to previously experienced hazards, with potential climate change-induced hazards being underrepresented. Almost 80 per cent of the interviewees, for example, held the opinion that Typhoon Linda in 1997 was the worst possible storm that could hit the Mekong Delta – despite the fact that all major climate change models predict stronger storms there in the future. On a similar note, more than 50 per cent of the interviewees stated that severe storms and floods are primarily an issue for rural areas and do not play a great role in cities. Given the comparatively regular timing of the tidal flooding, early warning to this hazard is not considered a big issue.

Protecting goods and evacuation

The majority of inhabitants in the prior makeshift settlements had developed various mechanisms to cope with flooding and erosion. Residents have developed a certain routine for elevating important household appliances and furniture as soon as they observe rising water levels or heavy rain. The research has revealed quite sophisticated mechanisms for temporarily evacuating vulnerable household members such as infants or invalids. Yet, a number of limits remain with respect to coping. Given the poor housing status, for example, elevation and evacuation into higher floors was not possible in most cases, simply due to the fact that most of the makeshift housings only have one floor – in contrast to the majority of the middle- and upper-class buildings. Given the relatively low damage profile caused by flooding, questions about recovery have been of minor importance for the households.

Adaptation

Despite the discussed capacity to cope with regular flooding, the potential for sufficient long-term adaptation was much more limited among the households prior to resettlement. In fact, the adaptive capacity was often even undermined through the recurrent pressure to cope with hazardous conditions and the need to constantly reinvest in piecemeal repair of housing elements battered by monsoon rains, heat, flooding and erosion. The survey results show that these households mostly do not have the capacity to move to a more elevated location or to a neighbourhood with better drainage infrastructure due to the high land prices and increased costs of living there. Even within the same location, not all the households had resources to sufficiently elevate the floor of their houses where necessary – as can be observed widely among better-off households. The household interviews further suggest that most of the households would not be able to buffer extreme shocks caused, for example, by multiple hazard events or prolonged crises situations. Only one out of the 154 interviewed households had purchased insurance for the physical assets in the house.

Post-resettlement vulnerability

Exposure – after relocation

The exposure and physical susceptibility related to housing conditions could in general be decreased substantially. The resettlement sites are not located next to waterways and most parts of the resettlement clusters have been elevated with land fill of several decimetres prior to construction. In addition, almost 100 per cent of the house walls were entirely built with bricks in the resettlement site – while the majority of households had them at least partly built of thatched elements, wood planks or corrugated iron sheets prior to relocation. Similar improvements could be observed with respect to the roof and particularly the floor and foundation of the houses, especially for those houses that had previously been built on stilt constructions in the water (compare Figure 21.1). Due to the fact that the resettlement plots are situated inland and on plots elevated between 1 m and 2 m by land infill, the exposure to erosion and flooding is reduced substantially. In combination with basic sanitary infrastructure, the risk of disease spreading was also reduced.

Infrastructure and public amenities

As far as public infrastructure and amenities are concerned, the timely and affordable provisioning of water supply, electricity, transportation, schools and kindergartens was reported to be of high importance to the interviewed households. In the largest resettlement site, around one third of the respondents experienced delays in the provisioning particularly of water and electricity supplies. These delays amounted to up to several months or even more than one year in some cases. They resulted mostly from the delayed issuance of, or ambiguities with, the official land and housing certificates without which the infrastructure services cannot be obtained. A number of schools and kindergartens have been implemented in a timely fashion in the resettlement site. Yet, more than 85 per cent of the households interviewed stated that they had not transferred their children to the new facilities but had kept them in the old school or kindergarten. The reasons given were shortages of places in the new location, issues of reputation or administrative hurdles relating to transferring the official residency in the new ward. Resulting from this are increased amounts of driving since most children have to be carried to and from the schools or kindergartens by motorbike. Furthermore, the majority of households reported that they need to drive to the city centre to do their shopping, again resulting in increased opportunity costs. Public bus lines to the resettlement sites were not yet in place at the time of research, despite the fact that the resettlement had already occurred two to four years prior. Hence, geographical access to markets, shops or other service facilities became not entirely impossible but much more tedious and costly in direct and indirect terms. Of the respondents, therefore, 67 per cent considered the resettlement cluster too far away from the original home site.

Income effects and economic dimension of vulnerability

Similar to the two other case study areas presented here, effects on social relations and income-generating activities were of great concern to the households interviewed – despite the quite different resettlement context. In the largest resettlement site of the urban upgrading project in Can Tho, almost all of the respondents stated that one or more members of the household had to change their job due to the resettlement. In most of these cases, income generation had previously been linked to activities using their houses, for example as workshops, shops, offices or warehouses. Others had worked as mobile or semi-mobile vendors. In addition, some households had run a transportation or trading business utilizing their interface-location with direct access to waterways as well as streets. All these activities not only depended on the physical assets and location but also on large groups of customers and established business relationships in the old location. The vast majority of households having worked in such types of activity prior to resettlement have therefore stated that they had to find new income-earning activities after relocation. This is a clear example of second-order adaptation (see frame work Birkmann 2011a). In this context most households reported a reduction in income levels following resettlement, mainly ranging between 5 and 40 per cent. Hence, it can be observed that those households featuring increased economic vulnerability before the resettlement also experienced the strongest negative income effects after the resettlement. This is because those who had been working in rather informal small-scale businesses (mostly at the household level) with high economic and institutional insecurities and personal risk-bearing before the resettlement, suffer the most from the physical relocation and detachment from waterways or place-specific trading and customer networks. Hence, 50 per cent of the respondents stated that they were “strongly concerned” about the economic situation with respect to their business or income earning after relocation, with 21 per cent merely “concerned”. Apart from the hard economic facts, such figures hint at new or increasing psychological harm and pressure induced by resettlement.

Social dimensions of vulnerability

Impacts on social networks were reported quite differently. Thirty per cent of the respondents reported that they were “concerned” (or “strongly concerned” – 13 per cent) about negative effects on their social networks as a result of resettlement, yet the remaining 57 per cent were unconcerned. These differences can be explained mainly by the household profile and, hence, the mobility to travel to the old location in order to maintain periodic social relationships with former neighbours, family and friends. Elderly people and small children were reported to face the greatest challenges in maintaining social relationships outside the household. In addition, significant differences were reported with respect to whether or not former neighbours were assigned to neighbouring land plots in the resettlement area.

Drivers of economic vulnerability and institutional shortcomings

Besides infrastructure shortcomings and difficulties for social relations, particularly negative financial implications were incurred by resettlement. Financial deficits have to be explained with the detailed political economy behind compensation and land pricing or building costs. The following major disputes surfaced in the household survey (see in detail Garschagen, 2010):

1. Compensation rates for land as well as building materials were well below the actual market prices and substantially below the costs for the land plots in the new resettlement site.
2. Households lacking the official land use certificate prior to resettlement received considerably reduced amounts of compensation.
3. Those parts of houses built on stilts in the water have not been fully compensated.
4. Loss of income has not been adequately compensated, nor vocational training provided sufficiently.

As a result, 60 per cent of the interviewed households in the largest resettlement site experienced a financial loss due to relocation. Of these, three quarters experienced deficits of up to VND200 million (around US$10,350 at the time of interviews). The remaining quarter even re-

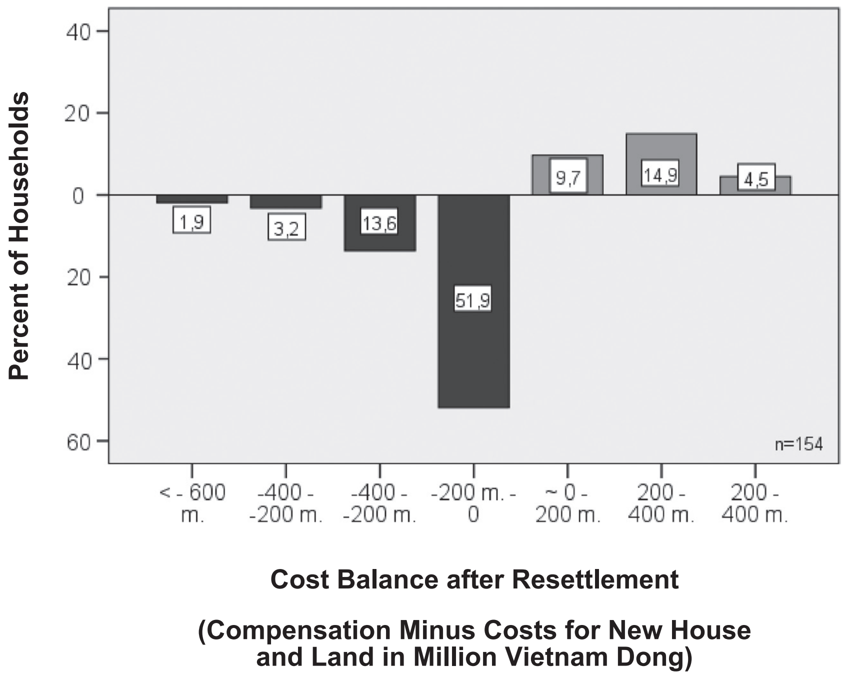


Figure 21.11 Cost balance after relocation in Can Tho
Source: Own draft based on household survey, 2010.

ported deficits of between VND200 and VND400 million. The majority of households had to revert to borrowing money from relatives and friends for negotiating these costs. The lack of access to official bank loans was stated to be a major problem, particularly for those households that had not yet received an official land use certificate for a new land lot.

Many of the households shared significant concerns about sustaining the new land lot and house in the long run. Cases were repeatedly reported of neighbours and friends who did not succeed in paying back debts and who eventually had to sell their land and house in the resettlement site and move out to cheaper grounds. Staff members, neighbourhood spokesmen and local officers of the People's Committees estimated that between 40 to 50 per cent of resettled people no longer lived in the resettlement site at the time of the household survey, i.e. only two to four years after resettlement. These findings suggest that future vulnerability research in the context of resettlement has to broaden its focus to consider those households who cannot be found in resettlement clusters anymore but have moved on.

Lessons learned and outlook

The three case studies of resettlement after natural hazards and disasters show that resettled households do not constitute a homogeneous group. Therefore, the question about whether relocation from hazard-prone areas to other areas increases or reduces risks has to be evaluated with micro studies. All case studies show that the relocation process has reduced the exposure to natural hazards, although some of the relocated people still had their place of work in the exposed coastal zone (in the case of Galle, Sri Lanka) or in the flood-prone areas (in the case of Dong Thap, Vietnam).

In contrast to the positive exposure reduction, the socio-economic situation, and especially the financial susceptibility, of relocated households has often not been improved. New physical infrastructures and services, although generally appreciated, also imply additional costs to the households budget. Particularly in Sri Lanka the limited ability of relocated households to pay electricity and water bills has in some cases led to these households losing these services. In addition, the case studies in Vietnam reveal that relocated households often have to take out loans to cope with the additional expenses, for example in building a robust house or in accessing public infrastructures. Seemingly the government, which is generally responsible for relocation, and in some cases private donors (for example, in some locations in Galle), did not provide sufficient resources or appropriate institutional framework conditions to the relocated households in order to move them from the second to the third phase of resettlement in Scudders' phase framework (see Scudder, 2005).

In addition, the new socio-economic setting after resettlement is likely to produce new vulnerabilities and the need for second-order adaptation (see Birkmann, 2011a) to the new situation and its implied challenges. For example, new expenses and the risk of livelihood disruption holds true for fishing households active in Galle that were relocated far from the city centre and the coastal zone. However, since households have different livelihoods, the need and the actual burden of commuting are not the same for all. For example, the relocated households in Sri Lanka at the site "Katupolwaththa" contain a particularly high number of people engaged in small-scale business, while in the "Tea Garden" site the percentage of people working in the fishery sector is significantly higher than in other relocation sites examined. Therefore, the impact of an increased distance to the coast or the city also depends on the livelihood activities a household undertakes.

Furthermore, multiple changes in environmental and socio-economic conditions were revealed in the rural parts of the northern Mekong Delta

(Dong Thap case study). The lack of employment opportunities at the relocation site have contributed to increases in social and economic vulnerability of resettled people. The Dong Thap case study also showed that many relocated household members temporarily migrated to urban centres to find employment. Hence, relocation might have functioned as a catalyst in the sense that it increases the pressure on households to migrate from rural to urban areas. It is important also to note that the situation of poor farmers in flood-prone areas worsened. The construction of flood protection measures (for example, dyke systems) and agricultural intensification with a strong increase in the use of agro-chemicals have severely affected the ability of farmers to gain an income from fishing in the flooding season. Thus, the more general changes in flood-exposed rural communities have to be assessed as well.

Overall, the case studies indicate that resettled people will face less exposure to natural hazards but experience additional socio-economic threats. Despite the general challenges of adapting to the new environments (for example, a semi-urban lifestyle in the case of Dong Thap or the change to rather rural surroundings from Galle inland for households resettled after the tsunami), the research also revealed that some of the households in both areas of Vietnam were able to stabilize their economic situation and income-earning activities relatively quickly after the spatial move. For some households the new location offered access to new employment opportunities or reduced expenses by avoiding the need to invest in flood and river bank erosion protection measures (Can Tho case study).

However, in combination with the above analysed effects, we conclude that the assessment of changes in vulnerability and its core components through the different stages of the resettlement process should not focus solely on the housing or infrastructure standards before and after relocation but should also evaluate the financial consequences of these infrastructures for the respective households and their ability to maintain these services and infrastructures in the long run.

In terms of institutional vulnerability, the analysis showed that in all three cases relocated households did not receive sufficient information about the resettlement process and the new risks to which the households might be exposed. Moreover, some governmental agencies were also not functioning well after the disaster, and severe coordination deficits occurred. In addition, the insufficient coordination between governmental and private stakeholders in the reconstruction and relocation process in Sri Lanka contributed to on-going problems with public infrastructure provision. Lastly, the case study of Can Tho shows that the type of compensation scheme combined with the type and amount of governmental and private support determine whether these households face a higher level of financial susceptibility and income depth. Hence, assessing institutional vulnerability is key, particularly since post-disaster situations, compared to other development-oriented relocation projects, are characterized by extraordinary circumstances where the normal functioning of governmental institutions is not secure and various external stakeholders may operate and implement such relocation processes.

Cultural aspects of vulnerability have been identified in the relocation processes analysed. For example, in the case of Sri Lanka conflicts in lifestyles between the host and guest communities are culturally based.

Although it is nearly impossible to capture all the changes in vulnerability observed and linked to different thematic dimensions (social, ecological, physical, cultural, institutional etc.), Figure 21.12 illustrates selected vulnerability characteristics and indicators that change within different phases of the relocation process. These indicators also differ in terms of the specific sub-groups of relocated households, since they are not homogenous.

The figure shows that issues of institutional vulnerability and uncertainty often generate specific context problems for households that face relocation or are relocated. Even the expectation that households are going to be relocated may reduce interest in investing in protection measures at the current place of residence. Additionally, the limited functioning of governmental institutions in Sri Lanka and the lack of transparency about the relocation process created insecurity that also increased vulnerability.

Further research needs

While the research of Scudder and other researchers dealing with development-induced resettlement mainly focus on the resettlement projects that end up on the resettlement site, the studies in Vietnam reminded us that in many cases people evicted by relocation projects do not stay in the resettlement sites but move to other places. Whether this secondary adaptation process (migration) leads to a further destabilization or stabilization process of households is still under-researched, particularly with regard to hazard-prone households. In addition, the research in Vietnam has shown that some households that have not been relocated in the past now wish to relocate because the environmental and economic situation in the rural flood-prone areas is increasingly deteriorating. This problem might also arise for coastal environments in the Vietnamese Mekong Delta due to the expected impacts of sea-level rise (see Carew-Reid, 2007).

The longitudinal changes in the vulnerability effects of resettled households are highly contested. Due to a lack of land titles and financial

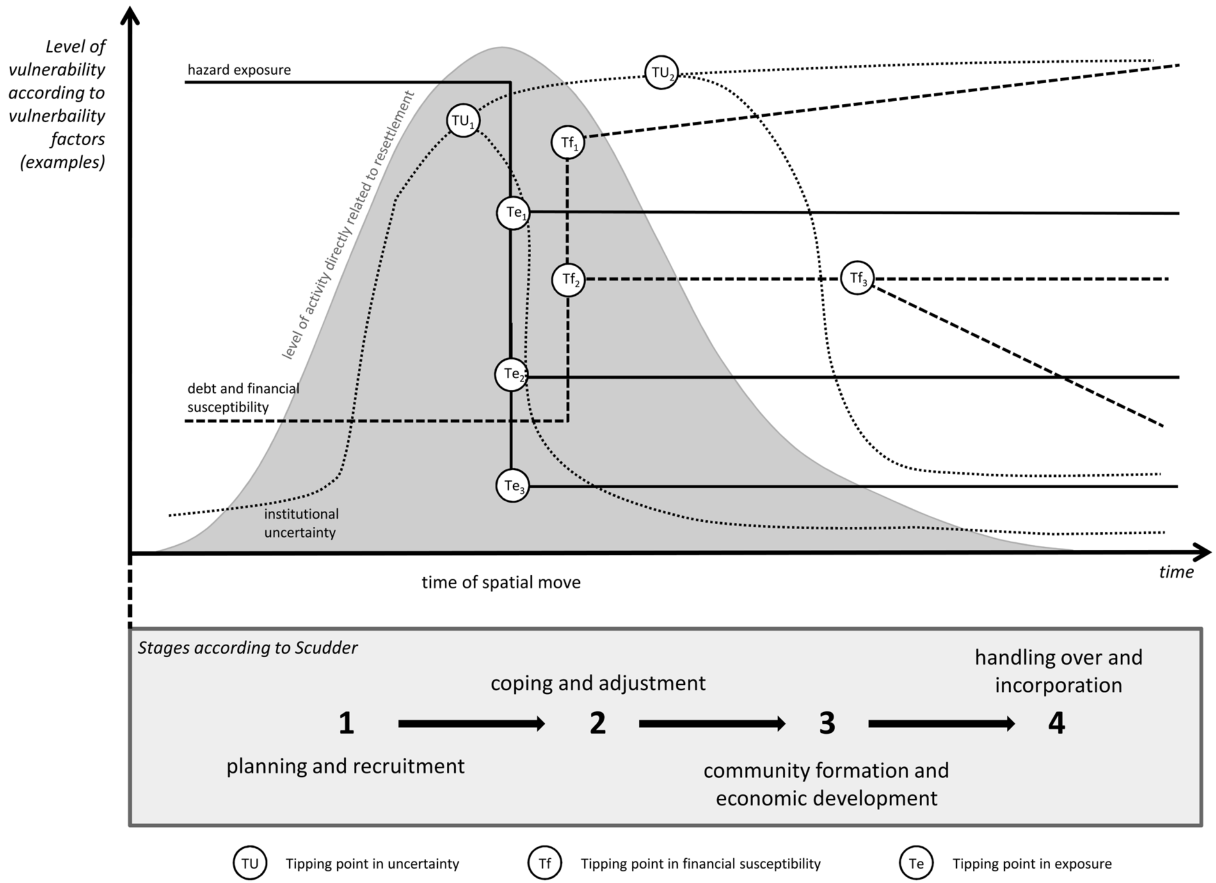


Figure 21.12 Dynamics of vulnerability related to resettlement
Source: Own draft, 2012.

resources they are in many cases forced again to squat on marginal lands, often with the same high exposure to natural hazards and without formal legal status. In addition, the majority of these households have to face disruption with respect to income generation and the maintenance of private social networks and business networks.

The findings also highlight that the differences in vulnerability dynamics between households within the same resettlement project are often underemphasized and deserve increased attention. In particular. in countries undergoing political and socio-economic transformation (for example, Vietnam), the factors underlying such disparities need to be understood in more detail. Also disasters, recovery processes and local as well as general development pathways modify vulnerability and risk profiles of different households as illustrated in the three case studies. The complex nexus between disaster impacts, recovery strategies and the socio-economic development pathways of a country and its consequences for vulnerability and risk require more research. The above assessment of changes in vulnerability in the context of forced relocation related to natural hazards and disasters provides a few ideas on how to tackle these future research questions.

Notes

1. Pseudonymous names were used for selected research locations as a precautionary measure to protect the participants' identities.
2. The research was carried out within the framework of the German-Vietnamese WISDOM-Project (Water Related Information Systems for the Sustainable Development of the Mekong Delta in Vietnam). The first campaign covered 588 households spread over three districts in Can Tho City in areas currently exposed to urban flooding and river bank erosion. Households interviewed in these areas are due for upgrading and most of them for resettlement in the near future. The second survey campaign captured 154 households that were resettled between 2007 and 2009 within the framework of pilot projects on canal upgrading.

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22

Conclusion

Jörn Birkmann

Introduction

In this book, more than 35 authors have presented approaches for measuring and assessing vulnerability and risk. The chapters have described different concepts, methodologies and procedures for measuring vulnerability, coping and adaptive capacities as well as resilience, ranging from quantitative loss and mortality assessment, macro trend analysis, identification of archetypes and patterns of vulnerability to self-assessment and participatory tools. This diversity shows that it is not possible to draw a universal conclusion that fits all concepts and methodologies. Rather, the following summary will focus on selected key aspects for measuring vulnerability and discuss some findings of the approaches presented in the volume. In addition, recommendations for future research will be made.

Looking forward: key aspects for future research

A major conclusion from the review of the various approaches presented in this volume is that more comparative assessments of existing methodologies and approaches in similar locations and situations are required; without them, it will be difficult to assess and judge the feasibility and range of the different approaches, including their potential limitations, overlaps and possible combinations. Thus, there is an urgent need to strengthen collaborative research into vulnerability assessment, using

Measuring vulnerability to natural hazards: Towards disaster resilient societies (2nd edn), Birkmann (ed.), United Nations University Press, 2013, ISBN 978-92-808-1202-2

different tools in similar case studies in order to explore and expand the collective expertise of different methodologies. The Intergovernmental Panel on Climate Change's (IPCC) *Special Report Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC, 2012) was a prime example of such cooperation between researchers in the domains of disaster risk reduction/management and climate change adaptation; however, this cooperation has to be further strengthened at all levels, particularly in the context of joint work and research on the ground.

The analysis of different conceptual frameworks and assessment methodologies has shown that no single conceptual approach can capture and explain vulnerability comprehensively; individual frameworks and methods imply specific perspectives and research lenses (epistemologies and ontologies) that need to be taken into consideration when applying them. The various approaches presented here combine and simultaneously use more than one method to capture vulnerability. A key challenge for future research is to respond to the need for integrated, cross-disciplinary vulnerability assessment using quantitative and qualitative, expert and participatory methods at different scales in order to provide a more comprehensive identification and understanding of vulnerability and resilience to natural hazards and climate change.

For example, the need to systematically combine different data, gathered with a diverse set of methods, is particularly evident when dealing with the dynamics of vulnerability and the different temporal and spatial scales that have to be considered.

Hence a major task for future research with regard to measuring vulnerability lies in combining different quantitative and qualitative methodologies.

In this regard, the questions of qualitative versus quantitative assessment methods, hazard-specific versus hazard-independent measurement are key. Furthermore, whether to prioritize snapshot or longitudal vulnerability analysis and whether to use simple or complex assessment methods have emerged as important topics in the discourse on how to assess vulnerability and resilience.

Quantitative versus qualitative

A decision about whether to use qualitative or quantitative assessment tools depends both on the level of the approach (global, national, subnational or local) and on its focus (macroeconomic, nation-state or individual actors and groups). The three global index projects presented by Peduzzi, Dilley and Welle et al. and discussed by Pelling (Chapters 6 to 9), as well as the approaches to measuring vulnerability and risk in the Americas by Cardona and Carreño (Chapter 10), the approach of assessing vulnerability to droughts in Tanzania (Chapter 13) and the assessment of social vulnerability presented by Cutter and Morath (Chapter 12) represent primarily quantitative approaches. These approaches assess vulnerability by comparing different levels of vulnerability at the national and/or sub-national level. In contrast, the example presented by Wisner of "self-assessment" at local level (Chapter 18) demonstrates a qualitative and participatory assessment methodology, while approaches presented by Kienberger (Chapter 16) and Birkmann et al. (Chapter 21) are based on quantitative and qualitative methodologies; thus qualitative and quantitative data are triangulated at the local and provincial level.

Conclusions and recommendations

While quantitative approaches based, for example, on global data, have a high potential for measuring vulnerability by comparing selected socio-economic, demographic characteristics of countries and their exposure to natural hazards and to climate change stressors, the abilities of these tools to measure context-dependent features and spatially specific characteristics of vulnerability, such as coping capacity, institutional vulnerabilities and intangible assets, are limited. Despite these limits, newer global assessments, such as the WorldRiskIndex, also account for governance failure and corruption, providing a first lens and overview of institutional vulnerabilities next to socio-economic, demographic and environmental aspects of vulnerability on a global scale. Global approaches for assessing vulnerability range from concepts that mainly focus on mortality risks and the risk of economic loss (see Hotspots project, Chapter 8) to indicator approaches that capture broader context conditions, institutional vulnerabilities and societal response capacities, such as coping capacities in terms of insurance policies that might help to compensate for economic loss due to an extreme event (see WorldRiskIndex, Chapter 9).

Qualitative methodologies to capture vulnerability are particularly applicable and useful at the local and community level. Qualitative methods are often able to capture local-specific characteristics of people's vulnerability, such as local perceptions, enabling them to explore the role and function of social networks. Social networks, for example, drive and determine important features of the vulnerability of different social groups and their coping and adaptation strategies. In many cases, these approaches – particularly qualitative-participatory approaches – aim to empower vulnerable or disadvantaged people. However, it might be difficult to compare different results of qualitative assessments conducted in different regions and over different time periods. In addition, people might be constrained to fully reveal the structures in which they are embedded or the governance failures to which they are exposed. In some communities, local (power) structures might even be a root cause of vulnerability. That means that participatory-qualitative methods might also face severe constraints if people that have been made vulnerable are still not able to articulate and address their problems openly.

Based on the approaches presented in this volume and research conducted in the last seven years, there is a clear need for balancing and combining qualitative and quantitative, expert and participatory methods for measuring vulnerability. The triangulation of different methods, concepts and theoretical approaches is essential, since a single method alone does not allow for capturing the multifaceted nature of vulnerability. Deficits of one method might be overcome by applying and combining it with another. Hence, developing and testing more integrated assessment approaches, which capture vulnerability to natural hazards and climate change more comprehensively, combining quantitative, semi-quantitative, qualitative and participatory methods are, therefore, key research challenges for the future. Particularly in the field of climate-change-related vulnerability, it will be essential to evaluate and assess different types of knowledge and their validity with different methods: for example, the validity of local knowledge for coping and adaptation that is mainly based on experiences in the past. Climate change might fundamentally challenge these strategies due to shifts in hazards, seasonality or frequency of hazard events. Thus, there is a need to improve assessment of the validity of existing knowledge (expert and local as well as indigenous knowledge) for coping and adaptation in the light of climate change. Furthermore, it is important for quantitative and qualitative, as well as reflective and action-oriented methodologies, to be transformed into continuous monitoring programmes in order to capture dynamics and changes within vulnerability patterns over time.

Different functions of various vulnerability assessments have to be considered carefully when applying specific methods and approaches. While some assessments mainly deal with the generation of knowledge, other approaches also aim to improve the application of vulnerability and risk assessment to risk reduction and adaptation planning (for example, emergency management and disaster risk reduction plans, national adaptation plans [NAPAs] or community development strategies). In this regard, we can observe an expansion of the focus of vulnerability assessments from the generation of knowledge towards the improvement of practices. This can, for example, be seen in assessments that also account for risk management performance (see Cardona and Carreño, Chapter 10) or that evaluate specific intervention tools that aim to reduce risk, such as early warning systems (see Pulwarty and Verdin, Chapter 4) or resettlement programmes (see Birkmann et al., Chapter 21).

On the other hand, we need to acknowledge the limitations of measurability. Especially with regard to risk management capacities, coping and adaption processes, research into appropriate indicators, criteria and data will come up against profound limitations, such as the difficulties of measuring the robustness of social networks, institutions, trust and other intangible factors (see Chapters 11 and 18). In addition, adaptive capacities in some assessment concepts refer to capacities that might be developed in the future (see Schneiderbauer et al., Chapter 14); capturing and assessing the ability to build such adaptive capacities is an additional challenge when measuring vulnerability. Likewise, methodologies for assessing institutional or cultural vulnerability are in their initial phase and need to be examined further.

The hazard-specific versus hazard-independent focus

While some approaches presented in the book measure vulnerability with regard to a single hazard, such as the one developed in Tanzania by Kiunsi and Minoris (Chapter 13) and Villagrán de León's sector approach (Chapter 17), others encompass a multihazard approach to assessing vulnerability and risk. Greiving, for example, shows an approach to multirisk assessment encompassing vulnerability indicators that are relevant for different hazard types (Chapter 11). He argues that, especially for policy interventions and spatial-planning strategies, the identification of regions at risk should be based on methodologies that consider vulnerability to multiple hazards in an aggregated manner. Kok and Jäger argue that more comprehensive vulnerability assessment should focus on multiple stresses. Within the framework of the GEO-3 approach, they identified three critical areas (human health, food security and economic losses) as being closely related to vulnerability (Chapter 5). By contrast, Villagrán de León emphasizes that vulnerabilities depend on the specific type of hazard in question. This means he clearly defines vulnerability in relation to a specific hazard.

Overall, there are advantages and disadvantages to assessing vulnerability within a multihazard versus a single-hazard context. An argument for a single-hazard-oriented vulnerability assessment is that susceptibilities, coping strategies and adaptive capacities differ from hazard to hazard: for example, the vulnerability of a community to floods might differ from their vulnerability to an earthquake or storms. In contrast, a multihazard-oriented vulnerability assessment focuses on situations where exposure and susceptibililty are not merely to one hazard but to a variety of hazards that might even occur simultaneously.

Snapshot versus longitudal vulnerability assessment

At present various concepts that aim to measure vulnerability focus on a rather limited timeframe to examine vulnerability. While this approach allows for generating knowledge about present conditions of vulnerability, the dynamics and changes within vulnerability over time are often not sufficiently captured within these assessment types. Consequently, approaches that assess present vulnerability with a snapshot focus need to be complemented by vulnerability assessments that are capable of examining the dynamics of vulnerability over time, encompassing changes in exposure, susceptibility, coping and adaptive capacities. Longitudal studies seem to be a prerequisite for such approaches, but these may be constrained by short-term funding regimes or the need in crisis or disaster situations to conduct rapid assessments for informing risk reduction and adaptation programmes. Overall, both snapshot and longitudal approaches are important and needed in order to inform decision-making processes at various scales and different actors involved.

Scenarios for vulnerability

Various approaches at present for assessing vulnerability to natural hazards and climate change focus on structures and socio-economic configurations for analysing the vulnerability of different groups or countries. Climate-change-related risk assessments often combine scenarios of climate change and respective changes in hazard patterns (for example, changes in heat stress, sea level or flood regimes), focusing on future conditions in 30, 50 or 100 years with the socio-economic vulnerability data of today. Hence, these assessments often lack appropriate data for socio-economic or environmental scenarios. That means these assessments combine potential future changes in extreme weather or climate conditions with present vulnerability conditions. This is a clear mismatch, since not only will the climate conditions change over time but so will socio-economic, demographic and spatial patterns. Furthermore, the exposure of people at risk is very likely to change significantly within time frames of 30, 50 or 100 years. Consequently, there is a need for research to address how vulnerability and risk assessments can be informed by scenarios about socio-economic changes and even scenarios for vulnerability (exposure to hazards, susceptibility, coping and adaptation). Such approaches would emphasize that not only are climate conditions dynamic but societal structures and conditions are also likely to change and might take different development pathways. In contrast, if vulnerability characteristics were to be defined as static, these assessments of climate-change-related risks would prioritize changes in physical conditions (such as hazards, climate change) as key drivers of risk. At present, we face major constraints in terms of available vulnerability data for such scenarios; however, developing scenarios for vulnerability remains an important task. Discussion and research about new scenarios for climate change adaptation and mitigation in the context of the IPCC has also stimulated more interest on the part of the integrated assessment and modelling community (IAM) in examining, together with vulnerability researchers, how these new socio-economic development pathways and scenarios could also inform scenarios for vulnerability (van Ruijven et al., 2013 and Birkmann et al., 2013). At the moment, most scenarios at global level account solely for so-called hard measures, while issues and scenarios for governance or adaptation are still rare or missing. Overall, it will be important to translate existing scenarios and new scenarios that are underway into core categories of risk and vulnerability research, such as exposure, susceptibility, coping and adaptation.

Conclusions and recommendations

- Future research should explore more precisely how to combine hazard-dependent and hazard-independent indicators.
- Hazard-independent indicators of vulnerability tend to focus on general and indirect features of vulnerability, such as income, poverty or education. In contrast, hazard-dependent indicators generally capture potential direct and hazard-specific impacts, such as the possibility of a building being flooded, based on the assessment of the height of a building. In this regard, it is important to combine hazard-independent and hazard-dependent variables within vulnerability assessments. While vulnerability assessments show that the consequences of natural hazards and climate change cannot be derived sufficiently by focusing on hazards alone, impact assessments focus mainly on actual damages and losses. Vulnerability assessments should be checked and tested against past impact patterns, although it is important to acknowledge that most vulnerability assessments are not designed to explain specific disaster impacts of single events.
- Bollin and Hidajat (Chapter 15) point out that indicators have different meanings for specific hazards; as a consequence, hazard-specific weighting factors should be used in order to combine the different figures into one index or final result. This underlines the need to investigate different methodologies of weighting with regard to the combination of different indicators and criteria. The approaches presented by Cardona and Carreño, Bollin and Hidajat, Villagrán de León and Greiving provide examples of potential ways of using weighting factors to combine different indicators in a quantitative fashion (Chapters 10, 15, 17 and 11).

- In terms of future scenarios for vulnerability, it is important to note that some approaches for measuring vulnerability are using scenarios for demographic development trends, but comprehensive applications of scenarios for vulnerability are still lacking. This is a clear deficit, since comparing climate change scenarios for the year 2050 with present day socio-economic vulnerability is misleading. Consequently, the Disaster Risk Reduction (DRR) or Disaster Risk Management (DRM) and Climate Change Adaptation (CCA) research communities need to develop more comprehensive approaches for integrating scenarios for vulnerability into vulnerability and risk assessments. In this regard the usefulness and applicability as well as the limitations of quantitative and qualitative scenario approaches for vulnerability assessments at different scales need to be addressed. Emphasis should be given to the development of scenarios for different exposure trends to natural hazards and climate change stressors in the future (combining future population, urbanization and migration trends) and scenarios for socio-economic transformations and changes in governance conditions. These scenarios might become an important tool for indicating the importance for risk of changes and dynamics in societal conditions for risk and vulnerability. At present it is evident that, for example, adaptation strategies for large delta regions might be obsolete if they fail to consider potential changes in population exposure, also those resulting from migration trends into low-lying coastal zones. Costs and benefits of different adaptation and risk reduction measures often differ significantly in terms of the socio-economic and governance scenario used within vulnerability and risk assessment.

The ongoing discussion on how to construct scenarios linked to different Shared Socio-economic Pathways (SSPs) in the climate change arena might offer an opportunity to also establish a research field on scenarios for vulnerability. A more intensive and continued cooperation between the integrated modelling community, climate change researchers and the vulnerability and risk research community has still to be enhanced.

Linking global and local

While global index projects allow a first visualization and comparison of vulnerability and risk worldwide, the situational context-specific approaches (place- and time-specific), such as self-assessment, explore place or spatially specific features and patterns of vulnerability of selected communities. The question of how to integrate these “spatial” and “time” dependencies of vulnerability is yet to be answered adequately.

Global indexing approaches such as the Hotspots project have revealed that, on a global scale, one can observe an inverse relationship between those countries with the highest number of people killed and those countries with the highest absolute economic losses (Chapter 8). Although it is evident that countries with heavy human losses have to be viewed as priority countries for humanitarian aid, the high economic losses in developed countries may point out the need to analyse vulnerability differently in different countries or with regard to the different degree of development of a country. That means the focus on mortality as the main characteristic of revealed vulnerability in developed countries is problematic, particularly since in many regions floods, for example, occur regularly and catastrophically without significant loss of life but with very significant loss of property and livelihoods. In addition, vulnerability assessments also need to consider the broader consequences for susceptibility to non-extreme events and the issue of risk accumulation, particularly in terms of different spatial and temporal scales regarding coping and adaptive capacities.

For example, the Fukushima disaster revealed that specific types of modernization and societal development pathways, such as a high dependency of the society and economy on critical infrastructures (particularly electricity supply), might create additional vulnerabilities at various spatial scales. Particularly, if these critical infrastructure systems are impacted by natural hazards (earthquake and tsunami) but few coping capacities exist and additional, cascading risks emerge that go far beyond the spatial extent of the nuclear power plant (long-distance impact); vulnerability is also high in developed countries. Interestingly, cascading risks, such as were seen in the Fukushima crisis in Japan, are often manifested over more than one spatial scale and involve massive indirect losses that are difficult to capture or that are at present not sufficiently considered within global data bases on disasters or losses (EM-DAT, NatCat etc.), making assessment even more difficult.

Conclusions and recommendations

- We still have only a limited understanding of how changing place-based socio-economic, environmental and governance conditions affect vulnerability to specific hazards and climate change stressors. While there is general evidence that corruption and state failure, for example, often decrease the abilities of people to cope and adapt to adverse consequences (for example, drought disaster in Somalia, the earthquake in Haiti), there are still limited data on how these context conditions correlate with specific coping and adaptation. In addition, the environmental degradation, particularly of coastal wetlands and coral reefs and mangroves might increase the exposure of people to coastal hazards and erode coping and adaptive capacities. Although these phenomena are examined within local case studies, there are still very few data that really allow these linkages at national or global scale to be established. Consequently, improved up-scaling methods are needed to further strengthen this research. Global indexing projects and national vulnerability and risk profiling are often too general (or operate at a core scale) to permit the full exploration of these issues. In this context, we have to acknowledge that the global index projects – Hotspots, WorldRiskIndex and the system of indicators for disaster risk management in the Americas – are not intended to be verifiable against specific disaster-related outcomes, which might even be very difficult for place- and time-specific approaches.

- Global indexing projects, which do not account for spatially specific features of vulnerability, are very useful for identifying regions and countries with high levels of risk and vulnerability – compared to other regions or countries. Although these global approaches do not lead to an identical list of highly vulnerable countries and countries at risk, they could serve as a first screening for hotspots or priority countries, while local and sub-national approaches might also consider spatially specific aspects of vulnerability. Particularly, the Social Vulnerability Index (SoVie) introduced by Cutter and Morath shows that quantitative tools provide a lens for examining spatial-specific configurations of vulnerability by examining the driving factors that are responsible for the specific SoVie score (see in detail, Chapter 12). Nevertheless, compared to quantitative global and national assessments of vulnerability, local assessments (based on quantitative and qualitative data) can also reflect local specific socio-economic, environmental or cultural context conditions, including specific value and norm systems in their assessment. This might be relevant for the identification of appropriate intervention and risk reduction tools, such as presented by Pulwarty and Verdin in Chapter 4. They point out that early warning systems for droughts, for example, can also to be linked to vulnerability assessments but have to consider different types of knowledge, such as expert and local as well as indigenous knowledge.
- Overall, further analysis on how to combine and link global indexing methodologies with local and sub-national assessment methodologies is needed. For example, local approaches that allow the assessment of coping and adaptation might need to be up-scaled in order to provide relevant information about these processes at a higher scale. Emphasis should be given to the question of how these approaches can be used to stimulate future actions that will be undertaken to reduce vulnerability and risk. Hence, global indexing and locally specific assessment tools, as well as combined approaches, need to be strengthened in terms of their applicability in formal or governmental decision-making processes (for example, urban planning, disaster emergency plans) as well as in informal or non-governmental decision-making processes

(i.e. at the individual household level). Up to now, much research on vulnerability in the context of climate change adaptation and disaster risk has either focused on governmental planning strategies and formal decision-making processes or on non-governmental strategies and actors. These spheres need to be bridged in order to ensure that conflicts between risk reduction strategies and adaptation plans of governmental and non-governmental actors are considered. In this regard, vulnerability assessments might even serve as a tool to bridge these worlds.

- More emphasis should be given to the links between vulnerabilities of various elements at different scales. Lebel et al. (Chapter 19) point out that institutions operating at the scale of basins or regions might influence the vulnerabilities of individuals and households. Therefore, future research should address more precisely such links of vulnerability between different scales. In this context, challenges of vulnerability reduction and adaptation across administrative boundaries need to be identified and integrated into respective assessments. That means transboundary shifts in vulnerability and risk, due to specific adaptation measures taken in one region or community and their consequences, for example on downstream communities, still have not been sufficiently captured in vulnerability and risk assessments that deal with transboundary hazards.

Reliable loss estimation versus fuzzy context interpretation

The review of current approaches shows the divergence between reliable loss data (implying a retrospective focus) and forward-looking assessment based on broader and general development and context indicators such as population growth, poverty levels and literacy rates. These differences can be illustrated, for example, by comparing the Hotspot approach (Chapter 8) with the community-based disaster-risk indicators of Bollin and Hidajat (Chapter 15). In the community-based disaster-risk indicators project, vulnerability is measured with context variables such as population density, demographic pressure (population growth), poverty levels, literacy rates, decentralization, community participation and economic diversification. These indicators represent important factors that can influence or determine the vulnerability of communities; however, they are not necessarily able to explain the vulnerabilities revealed (linked to loss and damage patterns) in the past. In contrast, assessments based on experienced events, known damage and revealed vulnerabilities often appeal to decision-makers and the general public; they seem to have statistical rigour since they include actual losses and fatalities experienced due to a hazard event.

However, the losses experienced in the past are not necessarily a reliable indicator for estimating present and future vulnerabilities, particularly in the light of climate and socio-economic changes (Birkmann, Chapters 1 and 2). The calculation of future vulnerability based on previously experienced losses is particularly difficult for low-frequency hazards, such as tsunamis, or of hazards that have not yet occurred in a specific region, such as sea-level rise. Nevertheless, estimating vulnerability in areas where a hazardous event took place recently is often important in order to understand the various vulnerability profiles and to estimate the unusual difficulties different groups experience in the recovery process (see Birkmann et al., 2006).

Conclusions and recommendations

- Vulnerability assessment must go beyond retrospective loss estimation and mortality assessment. However, the analysis of specific cases of severe hazardous events and disasters that have taken place (such as the Indian Ocean tsunami, Hurricane Katrina, earthquake disaster in Haiti, floods in Pakistan, Fukushima disaster in Japan) is often crucial for understanding the divergence between general contexts, such as poverty or theoretical rules and capacities on "paper", and the reality of the actual vulnerabilities revealed as well as the actions undertaken during an extreme event or disaster. This is particularly important in terms of assessing institutional capacities to reduce risk and vulnerability, clearly revealed by the lack of effective and reliable institutional capacities during the Hurricane Katrina catastrophe or the difficulties in dealing with cascading risks in Japan between governmental and private actors in the case of the accident within the nuclear power plant in Fukushima.
- Additional research is needed to examine those factors and characteristics contributing to vulnerability (e.g. root causes of vulnerability) that can be measured quantitatively and those that can only be captured through qualitative assessment tools, such as the various influences of armed conflicts on the vulnerability of the people exposed. In addition, the assessment of the effectiveness of the cooperation and coordination of private and public stakeholders in the context of risk management needs to be improved, particularly against the experiences in the crises in Fukushima, where a private company was not in the position to undertake risk reduction actions and supply appropriate information to the public during the crises and thereafter.
- Furthermore, approaches that combine forward-looking context analysis with retrospective loss estimation should be applied. An example is the Human Security Index proposed by Plate (Plate, 2006), which as-

sesses the vulnerability of individuals or households on the basis of their income above the minimum subsistence level compared with the economic losses experienced by the respective entity.

- Finally, more research is needed with regard to sub-national and local approaches for addressing spatially specific root causes of vulnerability and exploring potential intervention tools to reduce vulnerability and promote the disaster resilience of communities. This is especially important for the development of policy recommendations, as is shown implicitly in the Tanzania case study (Chapter 13) and the research that deals with changes in vulnerability due to resettlement (see Chapter 21). In this context, the evaluation of disaster risk management performance is also important but has only been captured by a few approaches in a quantitative fashion: for example, within the Americas Programme (Chapter 10).

Complexity versus simplification

All the approaches presented in this volume deal explicitly or implicitly with the question of how to simplify the complex concept of vulnerability in order to be able to measure it. Once a quantitative assessment is required, it is necessary to simplify the notion of vulnerability in terms of measurable components. Quantitative as well as qualitative approaches to measuring vulnerability at different levels are based on a selection of specific features and characteristics in order to estimate different levels of vulnerability of a nation, community, group or economic sector (Chapter 2). Complexity and simplification often depend on the scale of the approach selected; normally, global measurement tools need to be limited to a small set of data that is available for all analytical units around the globe. Local approaches, in contrast, are generally more open to a large number of input variables available for specific and relatively small-sized locations. Another option to simplify complex processes is the archetype approach presented by Kok and Jäger (Chapter 5) which shows new ways of generalizing processes and trends through the development of blueprint scenarios that help to provide a better understanding of basic processes leading to vulnerability, with a special focus on human–environmental interaction. Regarding this interaction, Renaud (Chapter 3) also calls for a stronger focus on the impact that environmental degradation has on societies and their vulnerability. There seems to be increasing evidence that environmental degradation will particularly affect the vulnerability and adaptive capacity of rather poor population groups that depend heavily on ecosystem services and ecosystem goods. However, the assumption that improved environmental conditions will directly reduce disaster risk is still to be verified for various hazards. Crises and disasters that reveal the vulnerability of societies and communities are often not attributable to a single-causal relationship, since these crises and disasters that are a materialization of vulnerability and risk are triggered by a set of factors and processes that are rather complex.

Overall, the degree of complexity or simplification is linked to the thematic scope of the approach: that is, whether the approach accounts for susceptibility alone, or whether it also encompasses coping capacity, exposure and adaptive capacities (for example, see Turner et al., 2003). According to Villagrán de León, if many elements are included within vulnerability – such as coping capacity, resilience and exposure – major complications arise, first regarding decisions about how to assess each of these components (identification and quantification) and, second, with respect to how to combine the different figures in order to arrive at a final result (Chapter 17).

In this context, a careful balance is required between broad measurement approaches encompassing various characteristics of vulnerability – implying a large number of input variables or characteristics – and the alternative of focusing only on a very few indicators to describe the complex processes behind vulnerability that might produce greater transparency. This balancing act can be seen in various approaches presented in this volume, such as in the overview given by Pelling regarding the global index projects (Chapter 6), the approach proposed by Cardona and Carreño (Chapter 10), the research on dynamics of vulnerability in Sri Lanka and Vietnam in the context of resettlement (Chapter 21), the vulnerability assessment conducted by Kiunsi and Minoris in Tanzania (Chapter 13) and the discussion on how to measure coping capacity with participatory self-assessment methodologies, presented by Wisner (Chapter 18).

Conclusions and recommendations

- Although vulnerability assessment can be either simple or complex, it invariably deals with complex phenomena and multidimensional problems. In this regard, it is important to explore the added value of very precise and specific assessment methodologies compared to general overviews that can be provided by highly aggregated approaches or those concepts that use only a very limited number of quantitative key indicators or qualitative criteria.
- Simplification of the complex interactions that determine and drive vulnerability is necessary in any approach to measure or describe vulnerability. In this context, it is useful to promote a more harmonized and comprehensive use of the terminology within vulnerability research. Differing interpretations of the same term (see glossary in this volume) hamper efforts to derive appropriate indicators and criteria to measure the different facets of vulnerability. The promotion of a com-

mon language to describe key components of vulnerability is therefore an important task, although it is vital to acknowledge the different schools of thinking and their justifications.

- This volume itself shows that it seems futile to try to develop a single methodology to assess complex phenomena and processes that shape vulnerability. In contrast to a standardization of a single approach, future research should encompass the formulation of procedural requirements for the development of appropriate tools to measure vulnerability. Currently, many approaches do not provide a transparent procedure or sufficient information regarding their selection choices for the indicators and criteria used. This reflective element is underdeveloped in various approaches.
- Furthermore, the appropriate degree of simplification is also determined by the function and nature of the target group on which the approach focuses. Although one can agree with Bollin and Hidajat (Chapter 15) that indices are often appealing because of their ability to summarize a great deal of information in a way that is easy for non-experts to visualize and understand, one has to acknowledge that a single number is often not sufficient for making policy recommendations.
- There is often too little understanding of the close link between the definition or assigned function of the approach and the target group, on the one hand, and the level of complexity and simplification on the other. Research is needed to explore how different target groups deal with, understand and respond to the differing levels of complexity of the information reaching them with regard to vulnerability and risk.
- Arguments for or against a specific level of simplification and aggregation should also be based on considerations of the target group and functions that the approach has. However, this is not an easy task either, since some approaches focus on a range of target groups; examples include the Americas Indicator Programme.
- Not enough has been done to exploit the opportunities of a combined and modular approach to measuring vulnerability that takes into account different levels of aggregation, different datasets and assessment methodologies. A prerequisite for improving such comprehensive and combined approaches is another issue, particularly the need for enhanced cooperation between different disciplines, especially the cooperation between schools of thought such as sociology, disaster risk research, climate change adaptation science, environmental research and space technology. In many cases we still organize research according to traditional disciplinary foci, although interdisciplinary and multidisciplinary approaches are imperative for understanding complex and non-linear problems linked to vulnerability and adaptation that cross different disciplines. Interestingly, the IPCC special report SREX (IPCC, 2012) can be seen as a prime example of such cooperation;

however, continued and more in-depth cooperation between different disciplines in the area of vulnerability and risk assessment needs to be strengthened.

Measuring without goals?

The majority of current approaches are functioning without precise goals; a review of the approaches presented shows indirectly that the measuring of vulnerability, coping capacity and performance in risk reduction would benefit from having more clearly defined targets for vulnerability reduction. Although some approaches were able to establish indicators and evaluation tools without setting specific goals – examples include the comprehensive approach of the system of indicators for disaster risk management in the Americas (Chapter 10) or the assessment of institutionalized capacities (Chapter 21) – it is increasingly evident that a benchmarking and assessment of vulnerability, and particularly vulnerability reduction strategies, require precise goals and standards of risk and vulnerability reduction and/or adaptation at various scales.

Conclusions and recommendations

- The systematized and logical development of the measurement of vulnerability should be based on goals. These goals are still either missing or, at best, available solely for a few regions and communities. Therefore, vulnerability assessment and measurement should also inform and promote the formulation of specific goals for vulnerability reduction, which could themselves serve as a basis for measurement. Especially if the aim is to promote more proactive efforts towards vulnerability reduction and resilience building, we need to define the goals of vulnerability reduction beforehand in order to get away from the reactive focus on disaster relief and rescue operations. The review of the Hyogo Framework for Action, the analysis of the implementation of the Millennium Development Goals, the post-Kyoto Protocol as well as the Rio+20 process are four areas in which such goals could be implemented.
- Finally, one of the most important goals in developing indicators to measure vulnerability and adaptive capacity is to help bridge the gaps between the theoretical concepts and day-to-day decision-making. For example, Weichselgartner and Obersteiner (2002) argue that insufficient progress has been made in converting theoretical research findings into concrete actions in practical disaster risk management.

  This publication offers various examples of methodologies and approaches to measuring vulnerability, adaptative capacities and reslience, and of ways to derive practical recommendations from these

approaches that are useful for decision-making processes. For example, the case study of early warning provided by Pulwarty and Verdin (Chapter 3) indicates that even rather technical systems, such as early warning systems, need to be based on a good understanding of the vulnerability of the communities exposed and their capacities to cope and adapt to, for example, drought problems.
- While more research and development is required for the improvement of data regarding the various vulnerabilities of the social, economic and environmental systems, we also need to address the current lack of clearly defined goals for vulnerability and risk reduction as well as climate change adaptation.
- The question of whether or not tools for measuring vulnerability will have an impact on vulnerability reduction depends not only on their structure, data and thematic focus but also on the willingness of (political) decision-makers to define precise targets and goals for vulnerability reduction or resilience building in the future. The methodologies shown in this book are an important prerequisite for such a standard and goal-setting.

This chapter, and indeed this volume, illustrates that many questions concerning the identification, measurement and assessment of vulnerability (adaptation or resilience) are still subject to discussions within the scientific and professional community worldwide. We have to acknowledge that a range of approaches is needed to capture the multifaceted nature of vulnerability and to serve the specific needs of different end-user groups. However, the various approaches presented in the book show some clear trends pointing at the priorities set within the discussion. An example is the intention to focus more precisely on the governance and institutional dimensions of vulnerability as well as on evaluation tools that help to assess the performance and effects of risk reduction strategies (for example, resettlement) on people's vulnerability.

Overall, it became evident that a stronger exchange between ideas from the various disciplines as well as from very different regions is essential not only in order to achieve a better overview of the various approaches but also to promote a stronger inter- and transdisciplinary cooperation and combination of different techniques to measure vulnerability. With the continued work of the Expert Working Group on Measuring Vulnerability, UNU-EHS intends to contribute further to the above-mentioned goals and to move the scientific debate towards policy-relevant goals and impacts. The recent meeting of the Expert Working Group in Indonesia, for example, brought together different experts from South East Asia, the USA, Japan and Europe to discuss scenarios for vulnerability, limits of adaptation and challenges in addressing the root causes of vulnerability.

Moreover, the IPCC special report on managing the risk of extreme events and disasters to advance climate change adaptation (IPCC, 2012), as well as the ongoing work on the IPCC fifth assessment report, also offer opportunities for collaborative research and for strengthening the understanding that disasters, disaster risk as well as adaptation needs can not sufficiently be defined by looking at only natural processes., Rather, vulnerability research in various fields in the last 40 years reveals that key determinates of risk are socially constructed and can be influenced or even changed. The dual consideration of climate change stressors on the one hand (vulnerability *to* what) and the influences of development pathways on vulnerability and risk on the other (vulnerability *due to* what) are important key messages of the IPCC SREX report (IPCC, 2012). In this regard, cooperation between scientists from the DRR or DRM and CCA communities has resulted in an improved framing on how to view extreme events and extreme impacts in the context of climate change and human development (see also Chapter 1 of this volume). Finally, new research initiatives under the umbrella of the Integrated Research on Disaster Risk (IRDR) will also provide the opportunity for collaborative research on how to enhance data on vulnerability, risk and resilience, as well as on how to improve vulnerability and risk assessment procedures.

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23

Components of risk: A comparative glossary

Katharina Marre

Introduction

For this second edition of *Measuring Vulnerability to Natural Hazards,* the glossary that was published in the first edition has been revised and updated. The glossary provides an overview of different definitions of key terms used in disaster risk reduction, vulnerability and adaptation as well as resilience research.

Today, the science around disaster, risk and vulnerabilities is usually multidisciplinary. A shared language and shared concepts are crucial stepping stones in widening the understanding and effectiveness of disaster reduction. Definitions of the same terms were developed simultaneously and separately in multiple disciplines, often resulting in the same term being defined in different ways. Consequently, communication within the disaster reduction community is often encumbered and misunderstandings are common. (Thywissen, 2006)

The ongoing debate about terminology and concepts even leads some experts to doubt the usefulness of the debate, claiming that too much time and energy is spent on academic discussions rather than on getting the actual (disaster risk reduction) work done. However, discussion and exchange of methodologies, experiences and concepts are necessities where professionals want to widen the application and implementation of their specific approaches in disaster risk reduction, disaster relief, hazard mitigation etc. This becomes difficult where the partners involved do not use the same technical language. The expectation should not be a total

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agreement on the definition of a specific term or concept, at least not in the short run. But it is very important to be informed about existing – and sometimes contradictory – definitions.

Moreover, terms and concepts are not just an academic exercise but have real importance in the practical world. The language used by workers in the disaster field frames, focuses, and limits the kinds of questions they ask (Handmer and Wisner, 1998).

Common, coordinated, and consequent approaches to risk reduction can only be achieved if there is a common agreement as to the structure of the problem and as to the basic notions, concepts, and terms used in its definition (Lavell, 2003). That means, before working on disaster risk reduction differing perceptions, interests, and methodologies have to be recognized and a broad consensus on targets, strategies and methodologies has to be reached (Yodmani, 2001). Clearly, definitions and concepts are needed at every level of disaster risk and vulnerability reduction as well as climate change adaptation.

This comparative glossary does not claim to be exhaustive; rather it focuses on a selection of terms that typically are used across multiple disciplines and that are central to the cause-and-effect chain of disaster risk reduction and are components of risk. The listing of definitions concludes with a concept that attempts to show the relationship between the main terms while keeping the concept as concise as possible and as diverse and elaborate as necessary. These terms and definitions have been collected from the literature, including several reports that already offer glossaries of disaster reduction terms. Disciplines and sectors represented include: insurance industry, United Nations, natural, social, and multidisciplinary sciences, economics, engineering, governance/policy, civil society and disaster relief.

The first collection of terms and definitions was exposed to an online peer review process. For that purpose, the glossary was hosted by the RADIX website and the ECIE (Electronic Communication and Information Exchange) website. In this context the impeccable support by Maureen Fordham, Ben Wisner and Alberto Delgado was greatly appreciated. The feedback provided by international experts in the course of this peer review process has been incorporated into this glossary and we thank all experts who contributed with their comments. It also became quite obvious that the development in the field of disaster reduction is gaining momentum.

Comparative glossary
Listing of terms

Adaptation

Adjustment in natural or human systems in response to actual or expected [climatic] stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC, 2001)

Adaptation

(1) Evolutionary adaptation – a genetically based characteristic expressed by a living organism. Particular adaptations found in populations become frequent and dominant if they enhance an individual's ability to survive in the environment.
(2) Physiological adaptation – change in an organism's physiology as a result of exposure to some environmental condition. (Pidwirny, 1999)

Adaptation

- Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation:
- Anticipatory Adaptation – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
- Autonomous Adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
- Planned Adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state.
- Private Adaptation – Adaptation that is initiated and implemented by individuals, households or private companies. Private adaptation is usually in the actor's rational self-interest.
- Public Adaptation – Adaptation that is initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs.

- Reactive Adaptation – Adaptation that takes place after impacts of climate change have been observed. (IPCC TAR, 2001)

Capacity

[Is] "The maximum amount of risk [in monetary terms] that can be accepted in insurance. One factor in determining capacity is government regulations that define minimum solvency requirements. Capacity also refers to the amount of insurance coverage allocated to a particular policyholder or in the marketplace in general." (Swiss Re, 2005)

Capacity

"A combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster. Capacity may include physical, institutional, social or economic means as well as skilled personal or collective attributes such as leadership and management. Capacity may also be described as capability." (UN/ISDR, 2004)

Capacity, adaptive

". . . defines adaptive capacity as a combination of a society's ex ante vulnerability to damages from natural hazards and its ex post resilience or ability to cope with the damages that result." (Dayton-Johnson, 2004)

Capacity, coping

"Refers to the manner in which people and organisations use existing resources to achieve various beneficial ends during unusual, abnormal, and adverse conditions of a disaster event or process. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and other hazards." (European Spatial Planning Observation Network, 2003)

Capacity, coping

"Is a function of: perception (of risk and potential avenues of action – the ability to cope is information contingent); possibilities (options ranging from avoidance and insurance, prevention, mitigation, coping); private action (degree to which special capital can be invoked); and public action" (for example, Webb and Harinarayan, 1999, Sharma et al., 2000) quoted in IPCC (2001).

Capacity, coping

"The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. In general, this involves managing resources, both in normal times as well as during crises or adverse conditions. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and human-induced hazards." (UN/ISDR, 2004)

Capacity, coping

"The manner in which people and organisations use existing resources to achieve various beneficial ends during unusual, abnormal and adverse conditions of a disaster phenomenon or process." (UNDP, 2004)

Capacity, coping

"The ability to cope with threats includes the ability to absorb impacts by guarding against or adapting to them. It also includes provisions made in advance to pay for potential damages, for instance by mobilizing insurance repayments, savings or contingency reserves." (UNEP, 2002)

Capacity, coping and adaptive

"While the concept of coping capacity is more directly related to an extreme event (e.g. a flood or a winter storm), the concept of adaptive capacity refers to a longer time frame and implies that some learning either before or after an extreme event is happening. The higher the coping capacity and adaptive capacity, the lower the vulnerability of a system, region, community or household. Enhancement of adaptive capacity is a necessary condition for reducing vulnerability, particularly for the most vulnerable regions and socioeconomic groups." (Peltonen, 2006)

Catastrophe

"An event in which a society incurs, or is threatened to incur, such losses to persons and/or property that the entire society is affected and extraordinary resources and skills are required, some of which must come from other nations.

An example would be the 1985 Earthquakes in Mexico City and other Mexican cities. Thousands of people – estimates vary markedly – died and tens of thousands were injured. At least 100,000 building units were damaged; reconstruction costs exceeded five billion dollars (with some estimates running as high as $10 billion). Over sixty donor nations contributed to the recovery through programs coordinated by the League of Red Cross and Red Crescent Societies." (Drabek, 1996 quoted in Blanchard, 2005)

Catastrophe

"... an event that causes $25 million or more in insured property losses and affects a significant number of property-casualty policyholders and insurers." (Insurance Services Office, 2005)

Catastrophe

"In the English speaking world a differentiation is sometimes made between disaster and catastrophes. In the latter, most or all people living in a community are affected, as are the basic supply centers, so that help from neighbours is largely impossible (the affected people helping each other is a general phenomenon in disasters with a lower degree of severity)." (Quarantelli, 1998)

Catastrophe

"In a catastrophe compared to a disaster:
1. Most or all of the community built structure is heavily impacted. [...] In addition, in catastrophes, the facilities and operational bases of most emergency organizations are themselves usually hit. [...] While in a major disaster some such facilities may be directly impacted, the great majority typically survive with little or no damage.
2. Local officials are unable to undertake their usual work role, and this often extends into the recovery period. [...] One overall consequence is that because local personnel are casualties and/or usual community resources are not available, many leadership roles may have to be taken by outsiders to the community.
3. Help from nearby communities cannot be provided. [...] In short, catastrophes tend to affect multiple communities, and often have a regional character. [...] In a disaster there is usually only one major target for the convergence after a disaster. In a catastrophe many nearby communities not only cannot contribute to the inflow, but they themselves can become competing sources for an eventual unequal inflow of goods, personnel, supplies and communication.
4. Most, if not all, of the everyday community functions are sharply and concurrently interrupted. Even in major disasters, there is no such

massive-across the board disruption of community life even if particular neighbourhoods may be devastated [...].

5. The mass media system especially in recent times socially constructs catastrophes even more than they do disasters.
6. Finally, because of the previous five processes, the political arena becomes even more important." (Quarantelli, 2005)

Catastrophe

"... for a given society might be defined as an event leading to 500 deaths or $10 million in damages. These figures, however, are arbitrary since levels of impact mean different things to different people in different situations. Furthermore, we cannot ignore the element of scale. It would be a catastrophe for a small community if every building were totally destroyed by flooding (as occurred in 1993 in Valmeyer, Illinois), but at the global scale, it would be an insignificant event if only 350 houses were involved. Similarly, $10 million in damage to some communities would be devastating, especially in less wealthy societies, but others would be able to cope relatively easily."

"... a catastrophe not only disrupts society, but may cause a total breakdown in day-to-day functioning. One aspect of catastrophes, is that most community functions disappear; there is no immediate leadership, hospitals may be damaged or destroyed, and the damage may be so great and so extensive that survivors have nowhere to turn for help (Quarantelli, 1994). In disaster situations, it is not unusual for survivors to seek help from friends and neighbors, but this cannot happen in catastrophes. In a disaster, society continues to operate and it is common to see scheduled events continue." (Tobin and Montz, 1997, quoted in Blanchard, 2005)

Disaster

"A disaster is an unusually severe and/or extensive event that usually occurs unexpectedly and has such a severe impact on life and health of many people and/or causes considerable material damage and/or impairs or endangers the life of a large number of people for a long period of time to such an extent that resources and funding available at local or regional level cannot cope without outside help. The disaster qualifies as such when it becomes apparent that the available resources and funding are inadequate for the necessary and prompt relief. Relief provision systems that are capable of evolving from every day use and which integrate all the necessary components are required for effectively managing disasters." From: 30.11.1998 Report of the working group of the Permanent Conference on Disaster Reduction and Disaster Protection, DKKV Handbuch. (DKKV, 2002)

Disaster

"External danger, the loss of development potential and the helplessness of the affected population; a serious disruption of the functioning of a society causing widespread human, material or environmental losses which exceed the ability of the affected society to cope using only its own resources." (DKKV, 2002)

Disaster

"A serious disruption of the functioning of society, causing widespread human, material or environmental losses, which exceed the ability of affected society to cope using only its own resources. Disasters are often classified according to their cause (natural or man-made)." (EEA, 2005)

Disaster

"A hazard might lead to a disaster. A disaster by itself is an impact of a hazard on a community or area – usually defined as an event that overwhelms the capacity to cope with it." (European Spatial Planning Observation Network, 2003)

Disaster

"Disasters combine two elements: events and vulnerable people. A disaster occurs when a disaster agent (the event) exposes the vulnerability of individuals and communities in such a way that their lives are directly threatened or sufficient harm has been done to their community's economic and social structures to undermine their ability to survive. A disaster is fundamentally a socio-economic phenomenon. It is an extreme but not necessarily abnormal state of everyday life in which the continuity of community structures and processes temporarily fails. Social disruption may typify a disaster but not social disintegration" (IFRC, 1993)

Disaster

"For a disaster to be entered into the database of the UN's International Strategy for Disaster Reduction (ISDR), at least one of the following criteria must be met:

- a report of 10 or more people killed
- a report of 100 people affected
- a declaration of a state of emergency by the relevant government
- a request by the national government for international assistance" (IRIN news service, 2005)

Disaster

"The result of a vast ecological breakdown in the relations between man and his environment, a serious and sudden event (or slow, as in drought) on such a scale that the stricken community need extraordinary efforts to cope with it, often with outside help or international aid." (*Journal of Prehospital and Disaster Medicine*, 2004)

Disaster

". . . a disaster is at some basic level a social construction, its essence to be found in the organization of communities, rather than in an environmental phenomenon with destructive or disruptive effects for a society."

". . . a process involving the combination of a potentially destructive agent(s) from the natural, modified and/or constructed environment and a population in a socially and economically produced condition of vulnerability, resulting in a perceived disruption of the customary relative satisfactions of individual and social needs for physical survival, social order and meaning."

"A disaster is made inevitable by the historically produced pattern of vulnerability, evidenced in the location, infrastructure, sociopolitical structure, production patterns, and ideology, that characterize a society. The society's pattern of vulnerability is an essential element of a disaster." (Oliver-Smith, 1998)

Disaster

"Disaster is defined as the set of adverse effects caused by social-natural and natural phenomena on human life, properties and infrastructure within a specific geographic unit during a given period of time." (Serje, 2002)

Disaster, remarks on

"In summary, it can be determined that there is a problem of definition which affects the interpretation of vulnerability to disasters. Therefore, a list of important questions often cannot be answered clearly: When does a disaster begin? Who decides about shortcomings in the coping capacity of a society? When does the disaster end? What are the appropriate indicators for disasters? In addition, many definitions do not take differing vulnerabilities of population groups into account." (Feldbrügge and von Braun, 2002)

Disaster risk

The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery. (IPCC, 2012)

Disaster risk management

The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. (UN/ISDR, 2009)

Disaster risk management

A development approach to disaster management, this focuses on underlying conditions of the risks which lead to disaster occurrence. The objective is to increase capacities to effectively manage and reduce risks, thereby reducing the occurrence and magnitude of disasters.

Institute for Disaster Risk Management (IDRM, N.D.)

Disaster risk reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events. (UN/ISDR, 2009)

Disaster risk reduction

"The systematic development and application of policies, strategies and practices to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) adverse impact of hazards, within the broad context of sustainable development." (Cited in FEMA Higher Education Project UN/ISDR 2002, 25) (ICDRM, 2007)

Exposure

The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected. (IPCC, 2012)

Exposure

"Exposure is another component of disaster risk, and refers to that which is affected by natural disasters, such as people and property." (ADRC, 2005)

Exposure

"Exposure describes the number of people, and the value of structures and activities that will experience hurricane hazards and may be adversely impacted by them." (Davidson and Lambert, 2001, quoted in Blanchard, 2005)

Exposure

"The process of estimating or measuring the intensity, frequency, and duration of exposure to an agent. Ideally, it describes the sources, pathways, routes, magnitude, duration, and patters of exposure; the characteristics of the population exposed; and the uncertainties in the assessment." (EEA, 2005)

Exposure

"The economic value or the set of units related to each of the hazards for a given area. The exposed value is a function of the type of hazard." (European Spatial Planning Observation Network, 2003)

Exposure

"People, property, systems, or functions at risk of loss exposed to hazards." (Multihazard Mitigation Council, 2002)

Exposure

"The degree to which a risk or portfolio of risks is subject to the possibility of loss; basis for calculating premiums in (re)insurance." (MunichRe, 2002)

Exposure

"Elements at risk, an inventory of those people or artefacts that are exposed to a hazard." (UNDP, 2004)

Hazard

"A Hazard is an extreme geophysical event that is capable of causing a disaster. 'Extreme' in this case signifies a substantial departure in either the positive or the negative direction from a mean or a trend [...]. The fundamental determinants of hazards are location, timing, magnitude and frequency. Many hazardous phenomena are recurrent in time and predictable in terms of location. (...) we define natural hazards as extreme events that originate in the biosphere, lithosphere, hydrosphere or atmosphere." (Alexander, 2000)

Hazard

"... natural and social systems interact to produce a hazard ..."

Hazards always result from interaction of physical and human systems. To treat them as though they were wholly climatic or geologic or political or economic is to risk omission of components that must be taken into account if sound solutions for them are to be found."

... nature is neutral, and ... the environment event becomes hazardous only when it intersects with man. The event leads to disaster when (1) it is extreme in magnitude, (2) the population is very great, or (3) the human-use system is particularly vulnerable" (Burton, 1993, quoted in Blanchard, 2005)

Hazard

"Natural hazard: the probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon."

"In general, the concept of hazard is now used to refer to latent danger or an external risk factor of a system or exposed subject. Hazard can be expressed mathematically as the probability of occurrence of an event of certain intensity, in a specific site and during a determined period of exposure time." (Cardona, 2003)

Hazard

"A hazard, in the broadest term, is a threat to people and the things they value. Hazards have a potentiality to them (they could happen), but they also include the actual impact of an event on people or places. Hazards arise from the interaction between social, technological, and natural systems." (Cutter, 2001, quoted in Blanchard, 2005)

Hazard

"A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period and area." (EEA, 2005)

Hazard

"Hazard reflects a potential threat to humans as well as the impact of an event on society and the environment. Hazards are in part socially constructed by people's perceptions and their experiences. Moreover, people contribute to, exacerbate, and modify hazards. Thus, hazards can vary by culture, gender, race, socioeconomic status, and political structure as well." (Mitchell and Cutter, 1997)

Hazard

"An act or phenomenon that has the potential to produce harm or other undesirable consequences to some person or thing". (Multihazard Mitigation Council, 2002)

Hazard

"The term 'risk' is often confused with 'hazard'. A high voltage power supply, a sample of radioactive metal, or a toxic chemical may present a hazard, meaning that they present the potential for harm. Concentrated acids, for example, clearly present the hazard to the user of serious burns if they are handled incorrectly.

The risk is the probability or chance that the hazard posed by the chemical will lead to injury. Thus, concentrated sulfuric acid is a hazardous chemical; because it is very corrosive and reactive. However, provided it is handled in an appropriate way the risks it poses may be small.

It is thus evident that hazards are something we can do little about. The hazards posed by a carcinogen, a concentrated acid or an explosive substance are inherent properties of the material. The risks they pose, however, can be (and should be!) minimised by initially preparing a suitable risk assessment, and then following the procedures laid down in that assessment." (Oxford University, 2005)

Hazard

"The probability of occurrence associated with an extreme event that can cause a failure." (from: UNDRO). (Plate, 2002)

Hazard

"... there is a distinction between an event, a hazard, and a disaster. A natural event, whether geological, climatological, etc., is simply a natural occurrence, whereas a hazard, geological or otherwise, is the potential danger to human life or property." (Rahn, 1996)

Hazard

"Hazards are defined as threats to a system, comprised of perturbations and stress (and stressors), and the consequences they produce. A perturbation is a major spike in pressure (e.g., a tidal wave or hurricane) beyond the normal range of variability in which the system operates. Perturbations commonly originate beyond the system or location in question. Stress is a continuous or slowly increasing pressure (e.g., soil degradation), commonly within the range of normal variability. Stress often originates and stressors (the source of stress) often reside within the system. Risk is the probability and magnitude of consequences after a hazard (perturbation or stress)." (Turner et al., 2003)

Hazard

"A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability." (UN/ISDR, 2004)

Hazard, natural

"Natural hazards are dynamic phenomena that involve people not only as victims but also as contributors and modifiers." (Kates, 1996, quoted in Rashed and Weeks, 2002)

Hazard, natural

"Natural processes or phenomena occurring in the biosphere that may constitute a damaging event." (UNDP, 2004)

Human Security

"Human Security can no longer be understood in purely military terms. Rather, it must encompass economic development, social justice, environmental protection, democratization, disarmament, and respect for human rights and the rule of law." (Annan, 2005)

Human Security

"The Commission on Human Security's definition of human security: to protect the vital core of all human lives in ways that enhance human freedoms and human fulfilment. Human security means protecting fundamental freedoms – freedoms that are the essence of life. It means protecting people from critical (severe) and pervasive (widespread) threats and situations. It means using processes that build on people's strengths and aspirations. It means creating political, social, environmental, economic, military and cultural systems that together give people the building blocks of survival, livelihood and dignity." (Commission on Human Security, 2003)

Human Security

"In policy terms, human security is an integrated, sustainable, comprehensive security from fear, conflict, ignorance, poverty, social and cultural deprivation and hunger, resting upon positive and negative freedoms." (van Ginkel and Newman, 2000)

Human Security

"Human Security is about attaining the social, political, environmental and economic conditions conducive to a life in freedom and dignity for the individual." (Hammerstad, 2000)

Human Security

[To achieve] ". . . human security, recognizing the inter linkages of environment and society, and acknowledging that that our perceptions of our environment and the way we interact with our environment are historically, socially, and politically constructed. In this context human security is achieved when and where individuals and communities:

→ have the options necessary to end, mitigate, or adapt to threats to their human, environmental, and social rights;

→ have the capacity and the freedom to exercise these options; and

→ actively participate in attaining these options.

Human security embodies the notion that problems must always be addressed from a broader perspective that encompasses both poverty and issues of equity (social, economic, environmental, or institutional) as it is these issues that often lead to insecurity and conflict." (Lonergan et al., 2000)

Mitigation

Structural and non-structural measures undertaken to limit the adverse impact of natural hazards. (UN/ISDR, 2004)

Mitigation

Measures, structural and non-structural, taken to reduce the impact of disasters. (IDRM, undated)

Mitigation

Any action taken to reduce or permanently eliminate the long-term risk to life and property from natural hazards. (NOAA Coastal Services Center, undated)

Mitigation

A proactive strategy to gear immediate actions to long-term goals and objectives. (European Spatial Planning Observation Network, 2003)

Mitigation

- The phase of Comprehensive Emergency Management that encompasses all activities that reduce or eliminate the probability of a hazard occurrence, or eliminate or reduce the impact from the hazard if it should occur. In comprehensive emergency management, mitigation activities are undertaken during the time period prior to an imminent or actual hazard impact. Once an imminent or actual hazard impact is recognized, subsequent actions are considered response actions and are not called "mitigation" – this avoids the confusion that occurs with

the HAZMAT discipline's use of mitigation, which applies to response actions that reduce the impact of a hazardous materials spill.
- Activities taken to eliminate or reduce the probability of the event, or reduce its severity or consequences, either prior to or following a disaster/emergency. (after NFPA 1600, 2004)
- The activities designed to reduce or eliminate risks to persons or property or to lessen the actual or potential effects or consequences of an incident. Mitigation measures may be implemented prior to, during, or after an incident. Mitigation measures are often informed by lessons learned from prior incidents. Mitigation involves ongoing actions to reduce exposure to, probability of, or potential loss from hazards. Measures may include zoning and building codes, floodplain buyouts, and analysis of hazard-related data to determine where it is safe to build or locate temporary facilities. Mitigation can include efforts to educate governments, businesses, and the public on measures they can take to reduce loss and injury. (after NIMS, 2004) (ICDRM, 2007)

Precautionary approach/principle

"Responsibility towards future generations commands that the natural foundations of life are preserved and that irreversible types of damage, such as the decline of forests, must be avoided. [Thus:] The principle of precaution commands that the damages done to the natural world (which surrounds us all) should be avoided in advance and in accordance with opportunity and possibility. Vorsorge further means the early detection of dangers to health and environment by comprehensive, synchronized (harmonized) research, in particular about cause and effect relationships . . . , it also means acting when conclusively ascertained understanding by science is not yet available. Precaution means to develop, in all sectors of the economy, technological processes that significantly reduce environmental burdens, especially those brought about by the introduction of harmful substances." (Bundesministerium des Innern, 1984).

"The precautionary principle applies where scientific evidence is insufficient, inconclusive or uncertain, and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the high level of protection chosen by the EU." (EU, 2000)

Resilience

"The ability to resist downward pressures and to recover from a shock. From the ecology literature: property that allows a system to absorb and use (even benefit from) change. Where resilience is high, it requires a major disturbance to overcome the limits to qualitative change in a system and allow it to be transformed rapidly into another condition. From the sociology literature: ability to exploit opportunities, and resist and recover from negative shocks." (Alwang et al., 2001)

Resilience

"The capacity that people or groups may possess to withstand or recover from emergencies and which can stand as a counterbalance to vulnerability." (Buckle, 1998)

Resilience

"Qualities of people, communities, agencies, infrastructure that reduce vulnerability. Not just the absence of vulnerability rather the capacity to 1) prevent, mitigate losses and then if damage occurs 2) to maintain normal living conditions and to 3) manage recovery from the impact." (Buckle et al., 2000)

"A measure of how quickly a system recovers from failures." (Emergency Management. Australia, 1998, quoted in Buckle et al., 2000)

"Not just the absence of vulnerability. Rather it is the capacity, in the first place, to prevent or mitigate losses and then, secondly, if damage does occur to maintain normal living conditions as far as possible, and thirdly, to manage recovery from the impact." (Buckle et al., 2000)

Resilience

"Resilience is a measure of the recovery time of a system." (Correira et al., 1987)

Resilience

"The capacity of a group or organization to withstand loss or damage or to recover from the impact of an emergency or disaster. The higher the resilience, the less likely damage may be, and the faster and more effective recovery is likely to be." (Department of Human Services, 2000)

Resilience

"The ability of an organization to absorb the impact of a business interruption, and continue to provide a minimum acceptable level of service." (*Disaster Recovery Journal*, 2005)

Resilience

"Details of Resilience might be inherently unknowable – especially in the case of complex communities undergoing constant change." (Handmer, 2002)

Resilience

"Resilience is the flip side of vulnerability – a resilient system or population is not sensitive to climate variability and change and has the capacity to adapt." (IPCC, 2001)

Resilience

"The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters and improving risk-reduction measures." (IRIN news service, 2005)

Resilience

"The concept [of resilience] has been used to characterize a system's ability to bounce back to a reference state after a disturbance and the capacity of a system to maintain certain structures and functions despite disturbance. [. . .] resilience of the system is often evaluated in terms of the amount of change a given system can undergo (e.g., how much disturbance or stress it can handle) and still remain within the set of natural or desirable states (i.e., remain within the same 'configuration' of states, rather than maintain a single state)." (Turner et al., 2003)

Resilience

"The capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures." (UN/ISDR, 2004)

Resilience

"[. . .] determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling, 1973 quoted in Folke, 2006)

Resilience (engineering)

"[. . .] how fast a variable that has been displaced from equilibrium returns to it. Resilience could be estimated by a return time, the amount of time taken for the displacement to decay to some specified fraction of its initial value." (Pimm, 1991 quoted in Folke, 2006)

Resilience (social ecological)

[. . .] social ecological resilience is interpreted as:
(1) The amount of disturbance a system can absorb and still remain within the same state or domain of attraction,
(2) The degree to which the system is capable of self-organization (versus lack of organizations, or organizations forced by external factors), and
(3) The degree to which the system can build and increase the capacity for learning and adaptation. (Carpenter et al., 2001 quoted in Folke, 2006)

Resilience (in a framework)

"A vulnerable social-ecological system has lost resilience. Losing resilience implies loss of adaptability. Adaptability in a resilience framework does not only imply adaptive capacity to respond within a social domain, but also to respond to and shape ecosystem dynamics and change in an informed manner." (Folke, 2006 after Berkes et al., 2003)

Resiliency

"Pliability, flexibility, or elasticity to absorb the event. Resiliency is offered by types of construction, barriers, composition of the land (geological base), geography, bomb shelters, location of dwelling, etc. As resiliency increases, so does the absorbing capacity of the society and/or the environment. Resiliency is the inverse of vulnerability." (*Journal of Prehospital and Disaster Medicine*, 2004)

Resiliency

"Resiliency to disasters means a locale can withstand an extreme natural event with a tolerable level of losses. It takes mitigation actions consistent with achieving that level of protection." (Mileti, 1999)

Resiliency

"Resiliency is thought of as a characteristic of systems that offers flexibility and scope for adaptation whilst maintaining certain core functions (for example, access to basic needs and social stability)." (Pelling, 2003)

Risk

"The combination of the probability of an event and its negative consequences" (UN/ISDR, 2009)

Risk

"In general, 'risk' is defined as the expectation value of losses (deaths, injuries, property, etc.) that would be caused by a hazard. Disaster risk can be seen as a function of the hazard, exposure and vulnerability as follows; Disaster Risk = function (Hazard, Exposure, Vulnerability)" (ADRC, 2005)

Risk

"Risk can be defined as the likelihood, or more formally the probability, that a particular level of loss will be sustained by a given series of elements as a result of a given level of hazard. The elements at risk consist of populations, communities, the built environment, the natural environment, economic activities and services, which are under threat of disaster in a given area." (Alexander, 2000)

Risk

[In this definition risk and hazard are used as synonyms] "Risk is characterized by a known or unknown probability distribution of events. These events are themselves characterized by their magnitude (including size and spread), their frequency and duration, and their history." (Alwang et al., 2001)

Risk

"Risk: the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk.

The capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure. This is determined by the degree to which the social system is capable of organising itself, and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster." (Cardona, 2003)

Risk

"... risk is when you know the possible range of things that may happen following a choice; uncertainty is when you don't ... Risk in its general form is when it is possible, at least in principle, to estimate the likelihood that an event (or set of events) will occur; the specific forms of those estimates are the probabilities of adverse consequences." (Clarke, 1999, quoted in Blanchard, 2005)

Risk

"'Risk' is the probability of a loss, and this depends on three elements, hazard, vulnerability, and exposure. If any of these three elements in risk increases or decreases, then the risk increases or decreases respectively." (Crichton, 1999)

Risk

"Potential for exposure to loss. Risks, either man-made or natural, are constant. The potential is usually measured by its probability in years." (*Disaster Recovery Journal*, 2005)

Risk

Risk is "the probability of an event multiplied by the consequences if the event occurs." (Einstein, 1988)

Risk

"A combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. More specific, a risk is defined as the probability of harmful consequences, or expected loss (of lives, people, injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards." (European Spatial Planning Observation Network, 2003)

Risk

"The following formula is used to calculate disaster risk: Disaster Risk = Hazard × Vulnerability. In this equation risk is the product of the two factors, hazard and vulnerability. Therefore, it is clear that a risk exists only if there is vulnerability to the hazard posed by a natural event." (Garatwa and Bollin, 2002)

Risk

"The risk associated with flood disaster for any region is a product of both the region's exposure to the hazard (natural event) and the vulnerability of objects (society) to the hazard. It suggests that three main factors contribute to a region's flood disaster risk: hazard, exposure, and vulnerability." (Hori et al., 2002)

Risk

"The objective (mathematical) or subjective (inductive) probability that the hazard will become an event. Factors (risk factors) can be identified that modify this probability. Such risk factors are constituted by personal behaviours, life-styles, cultures, environmental factors, and inherited characteristics that are known to be associated with health-related questions. Risk is the probability of loss to the elements at risk as the result of the occurrence, physical and societal consequences of a natural or technological hazard, and the mitigation and preparedness measures in place in the community. Risk is the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk. – UNDRO." (*Journal of Prehospital and Disaster Medicine*, 2004)

Risk

"Risk and uncertainty relate to situations where there is more than one possible outcome.

F. Knight (1921) first formally distinguished between risk and uncertainty:

Risk: We can identify the probability of each possible outcome.

Uncertainty: We can identify the outcome, but not the corresponding probabilities" (Knight, 1921, quoted in Bieri, 2006)

Risk

"[. . .] the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood. (In disaster risk management – a concept used to describe the likelihood of harmful consequences arising from the interaction of hazards, communities and the environment.)" (Natural Disaster Risk Management, 2001)

Risk

"Risk indicates the degree of potential losses in urban places due to their exposure to hazards and can be thought of as a product of the probability of hazards occurrence and the degree of vulnerability." (Rashed and Weeks, 2002)

Risk

"The probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril over a specified time period." (Schneiderbauer and Ehrlich, 2004)

Risk

"Risk of a system may be defined simply as the possibility of an adverse and unwanted event. Risk may be due solely to physical phenomenon such as health hazards or to the interaction between man-made systems and natural events, e.g. a flood loss due to an overtopped levee. Engineering risk for water resources systems in general has also been described in terms of a figure of merit which is a function of performance indices, say for example, reliability, incident period, and reparability . . . ." (Shrestha, 2002)

Risk

"Risk is an integral part of life. Indeed, the Chinese word for risk 'weij-ji' combines the characters meaning 'opportunity/chance' and 'danger' to imply that uncertainty always involves some balance between profit and loss. Since risk cannot be completely eliminated, the only option is to manage it." (Smith, 1996, quoted in Blanchard, 2005)

Risk

"Used in an abstract sense to indicate a condition of the real world in which there is a possibility of loss; also used by insurance practitioners to indicate the property insured or the peril insured against." (Swiss Re, 2005)

Risk

"The expected number of lives lost, persons injured, damage to property and disruption of economic activities due to a particular natural phenomenon, and consequently the product of specific risk and element at risk. Specific risk: The expected degree of loss due to a particular natural phenomenon and as a function of both, natural hazard and vulnerability." (Tiedemann, 1992)

Risk

"The probability of harmful consequences, or expected loss of lives, people injured, property, livelihoods, economic activity disrupted (or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions. Risk is conventionally expressed by the equation: Risk = Hazard × Vulnerability." (UNDP, 2004)

Risk

"The probability of exposure to an event, which can occur with varying severity at different geographical scales, suddenly and expectedly or gradually and predictably, and to the degree of exposure." (UNEP, 2002)

Risk, acceptable

"One definition of acceptable risk that has been widely accepted in environmental regulation, although is not relevant to microbiological parameters, is if lifetime exposure to a substance increases a person's chance of developing cancer by one chance in a million or less."

"A risk is acceptable when:

- it falls below an arbitrary defined probability
- it falls below some level that is already tolerated
- it falls below an arbitrary defined attributable fraction of total disease burden in the community
- the cost of reducing the risk would exceed the costs saved
- the cost of reducing the risk would exceed the costs saved when the 'costs of suffering' are also factored in
- the opportunity costs would be better spent on other, more pressing, public health problems
- public health professionals say it is acceptable
- the general public say it is acceptable (or more likely, do not say it is not)
- politicians say it is acceptable."

"In the strict economic sense a risk is acceptable if the economic savings arising out of action to reduce a risk outweigh the cost of such action. This approach is, in effect, a simple cost-benefit analysis (Sloman 1994)."

"This approach to determining acceptable risk is based on what is acceptable to the general public. In other words, a risk is acceptable when it is acceptable to the general public." (Hunter and Fewtrell, 2001)

Risk, acceptable

"The probability of occurrences of physical, social, or economic consequences of an earthquake that is considered by authorities to be sufficiently low in comparison with the risks from other natural or technological hazards that these occurrences are accepted as realistic reference points for determining design requirements for structures, or for taking social, political, legal, and economic actions in the community to protect people and property." (*Journal of Prehospital and Disaster Medicine*, 2004)

Risk, acceptable

"Degree of humans and material loss that is perceived as tolerable in actions to minimize disaster risk." (Nimpuno, 1998, quoted in Blanchard, 2005)

Risk, acceptable

"The concept of acceptable risk is not particularly easy to define. It is essentially a measure of the risk of harm, injury or disease arising from a chemical or process that will be tolerated by a person or group."

"Whether a risk is 'acceptable' will depend upon the advantages that the person or group perceives to be obtainable in return for taking the risk, whether they accept whatever scientific and other advice is offered about the magnitude of the risk, and numerous other factors, both political and social." (Oxford University, 2005)

Risk, acceptable

"Risk tolerance.

Given that the provision of absolute safety is impossible, there is great sense in trying to determine the level of risk which is acceptable for any activity or situation. Thus, when a hazard is being managed, the financial and other resources allocated to the task should theoretically match the degree of threat posed by the hazard, as indicated by the rank of the risk.

One must always specify acceptable to whom and that implies a conscious decision based on all the available information.

The 1993 floods in the upper Mississippi river basin had an estimated return period of more than one in 200 years, yet some people who were flooded asserted that this event should now be regarded as an unacceptable risk. Such arguments ignore both the economic and social benefits derived by those communities from their floodplain location over the previous 100 years or so, when few flood losses occurred, and the cost to the taxpayer implied in protecting floodplain basins against a flood of the 1993 magnitude." (Smith, 1996)

Risk, acceptable

"The level of loss a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess structural and non-structural measures undertaken to reduce possible damage at a level which does not harm people and property, according to codes or 'accepted practice' based, among other issues, on a known probability of hazard." (UN/ISDR, 2004)

Risk, acceptable

"The acceptable probability of losing one's life from an action or an event based on equation:

$$PE_j\left(xd\right) \leq PAcc = (10-6/year)/v_{ij},$$

with PE_j being the exceedance probability at location *j*, *xd* is the design event PA*cc* is the acceptable probability, and v_{ij} is the vulnerability of an individual *i* at location *j*." (Vrijling et al., 1995)

Risk, seismic

"Seismic risk consists of the components seismic hazard, seismic vulnerability, and value of elements at risk (both, in human and economic terms)." (Wahlström et al., 2004)

Vulnerability

"The propensity or predisposition to be adversely affected." (IPCC, 2012)

Vulnerability

"Vulnerability should be recognized as a key indicator of the seriousness of environmental problems such as global warning." (Adger et al., 2001)

Vulnerability

"[...] 'vulnerability' to the natural phenomenon must be present for an event to constitute a natural disaster. Vulnerability is defined as a condition resulting from physical, social, economic, and environmental factors or processes, which increases the susceptibility of a community to the impact of a hazard." (ADRC, 2005)

Vulnerability

"If risk is one side of the coin, its other side is vulnerability, which we may loosely define as potential for losses or other adverse impacts. People, buildings, ecosystems or human activities threatened with disaster are vulnerable. [...] Essentially, vulnerability refers to the potential for casualty, destruction, damage, disruption or other form of loss with respect to a particular element. Risk combines this with the probable size of impact to be expected from a known magnitude of hazard. [...] Many authors [...] have confused vulnerability with exposure: in reality they are two complementary components of risk." (Alexander, 2000)

Vulnerability

"The insecurity of the well-being of individuals, households or communities in the face of a changing environment." (Moser and Holland, 1989, quoted in Alwang et al., 2001).

Vulnerability

"Summarizing livelihood and environmental literature: vulnerability is the exposure of individuals or groups to livelihood stress as a result of environmental change." (Alwang et al., 2001)

Vulnerability

"The characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete or identifiable event in nature or society."

"Vulnerability concept consists of two opposing forces: On one hand, the processes that cause vulnerability that can be observed; on the other hand, the physical exposure to hazards (earthquakes, storms, floods, etc.). Vulnerability develops then from underlying reasons in the economic, demographic and political spheres into insecure conditions (fragile physical environment, instable local economy, vulnerable groups, lack of state or private precautions) through the so-called dynamic processes (e.g., lack of local institutions, under-developed markets, population growth, and urbanization)." (Blaikie et al., 1994)

Vulnerability

"Vulnerability concerns the complex social, economic, and political considerations in which peoples' everyday lives are embedded and that structure the choices and options they have in the face of environmental hazards. The most vulnerable are typically those with the fewest choices, those whose lives are constrained, for example, by discrimination, political powerlessness, physical disability, lack of education and employment, illness, the absence of legal rights, and other historically grounded practices of domination and marginalization." (Bolin and Stanford, 1998)

Vulnerability

"The degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss) or in per cent of the new replacement value in the case of damage to property." (Buckle et al., 2000)

Vulnerability

"Vulnerability (in contrast to poverty which is a measure of current status) should involve a predictive quality: it is supposedly a way of conceptualizing what may happen to an identifiable population under conditions of particular risk and hazards. It the complex set of characteristics that include a person's:
- initial well-being (health, morale, etc.);
- self-protection (asset pattern, income, qualifications, etc.);
- social protection (hazard preparedness by society, building codes, shelters, etc.);

- social and political networks and institutions (social capital, institutional environment, etc.)" (Cannon et al., 2003)

Vulnerability

"Vulnerability: the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss)."

"On the other hand, vulnerability may be understood, in general terms, as an internal risk factor, mathematically expressed in terms of the feasibility that the exposed subject or system will be affected by the phenomenon that characterizes the hazard." (Cardona, 2003)

Vulnerability

"Vulnerability, therefore, is a human-induced situation that results from public policy and resource availability/distribution, and it is the root cause of many disaster impacts. Indeed, research demonstrates that marginalized groups invariably suffer most in disasters. Higher levels of vulnerability are correlated with higher levels of poverty, with the politically disenfranchised, and with those excluded from the mainstream of society." (Chakraborty et al., 2005)

Vulnerability

"Vulnerability expresses the severity of failure in terms of its consequences. The concern is not how long the failure lasts but how costly it is." (Correira et al., 1987)

Vulnerability

"Is a broad measure of the susceptibility to suffer loss or damage. The higher the vulnerability, the more exposure there is to loss and damage." (Department of Human Services, 2000)

Vulnerability

"The degree of loss to a given element at risk (or set of elements) resulting from a given hazard at a given severity level. In contrast to the concept of risk, here the probability of the occurrence of a hazard is not considered" (from UNDP/UNDHA, 1994, pp. 38–39; see also UNDHA, 1992). "Vulnerability has process character and is not static." (Feldbrügge and von Braun, 2002)

Vulnerability

"Vulnerability (V) = Hazard – Coping,
with Hazard = H (Probability of the hazard or process; shock value; predictability; prevalence; intensity/strength); and
Coping = C (Perception of risk and potential of an activity; possibilities for trade; private trade, open trade)."

"Determinants of disaster vulnerability:

- demographic factors: population growth, urbanization, settlements near coastal areas, etc.,
- the state of economic development: poverty, modernization processes,
- environmental changes: climate changes, degradation and depletion of resources (straightening the courses of rivers, deforestation, etc.);
- political factors,
- an increase in tangible assets, which leads to an increase in damages,
- effects of disaster protection structures and research, and
- the interactions of the causes of disasters." (Feldbrügge and von Braun, 2002)

Vulnerability

"Vulnerability denotes the inadequate means or ability to protect oneself against the adverse impacts of natural events and, on the other hand, to recover quickly from their effects." (Garatwa and Bollin, 2002)

Vulnerability

"The likelihood that some socially defined group in society will suffer disproportionate death, injury, loss or disruption of livelihood in an extreme event, or face greater than normal difficulties in recovering from a disaster." (Handmer and Wisner, 1999)

Vulnerability

"The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard." (IFRC, 1999)

Vulnerability

"Vulnerability is defined 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." (IPCC, 2001)

Vulnerability

"The potential loss in value of an element at risk from the occurrence and consequences of natural and technological hazards. The factors that influence vulnerability include: demographics, the age and resilience of the built environment, technology, social differentiation and diversity, regional and global economies, and political arrangements. Vulnerability is a result of flaws in planning, siting, design, and construction. Vulnerability is the degree of loss to a given element at risk, or set of such elements, resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (= no damage) to 1 (= total loss)." – UNDRO (*Journal of Prehospital and Disaster Medicine*, 2004)

Vulnerability

"Vulnerability is provisionally defined as the degree to which a system is sensitive to and unable to cope with adverse impacts of global change stimuli. Vulnerability is therefore a function of a system's exposure to global change stimuli and its adaptive capacity, that is, its ability to cope with these stimuli." (Klein, 2003)

Vulnerability

"Vulnerability is a pervasive socio-economic condition; it is the reason why the poor and disadvantaged are the predominant victims of disaster." (Lewis, 1997, quoted in Musser, 2002)

Vulnerability

"Vulnerability defines the inherent weakness in certain aspects of the urban environment with are susceptible to harm due to social, biophysical, or design characteristics." (Rashed and Weeks, 2002)

Vulnerability

Is the predisposition of being susceptible to injuries, attacks or to have difficulties to reconstitute a compromised state of health. All depends on the vulnerable components placed at the centre of our system:

1. vulnerability of human beings to natural hazards of the planet, depending on their systems, behaviours and reactions of individuals.
2. formally more or less fragile natural environments that have been settled, often in excess, and that have become vulnerable due the increase human activity.
3. Nature itself.
4. vulnerabilities: man, goods, activities, and the environment. Translated from Reveau (2004).

Vulnerability

"We propose the term 'susceptibility' for 'vulnerability' in the pre-event phase and 'resilience' for 'vulnerability' in the post-event phase. [. . .] Susceptibility would be predominantly determined by physical features, 'resilience' by socio-economic characteristics." (Schneiderbauer and Ehrlich, 2004)

Vulnerability

"Vulnerability is usually defined as the capacity of a system to be wounded from a stress or perturbation. It is a function of the probability of occurrence of the perturbation and its magnitude, as well as of the ability of the system to absorb and recover from such perturbation." (Suarez, 2002)

Vulnerability

"The degree to which different classes in society are differentially at risk, both in terms of the probability of occurrence of an extreme event and the degree to which the community absorbs the effects of extreme physical events and helps different classes to recover." (Susman et al., 1983)

Vulnerability

"Vulnerability is the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to hazard, either a perturbation or stress/stressor." (Turner et al., 2003)

Vulnerability

"The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. For positive factors, which increase the ability of people to cope with hazards, see definition of capacity." (UN/ISDR, 2004)

Vulnerability

"A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard." (UNDP, 2004)

Vulnerability

"Vulnerability is expressed as the degree of expected damage (i.e., the cost of repair divided by the cost of replacement) given on a scale of 0 to 1, as a function of hazard intensity (or magnitude, depending on the convention used)." (UNDRO, 1991)

Vulnerability

"Represents the interface between exposure to the physical threats to human well-being and the capacity of people and communities to cope with those threats." (UNEP, 2002)

Vulnerability

Vulnerability is the intrinsic and dynamic feature of an element at risk (community, region, state, infrastructure, environment etc.) that determines the expected damage/harm resulting from a given hazardous event and is often even affected by the harmful event itself. V. changes continuously over time and is driven by physical, social, economic and environmental factors. (Thywissen, 2006)

Vulnerability

"The vulnerability increases with the number of people affected by the impact of a natural hazard, given by the formula: $v_{ij} = 10 - 3\ nj^2$, for $n \geq 10$ casualties", where v_{ij} is the vulnerability of an individual i at location j. (Vrijling et al., 1995)

Vulnerability

"This definition [by Chambers 1989] suggests three basic co-ordinates:
1. the risk of exposure to crises, stress and shocks
2. the risk of inadequate capacities to cope with stress, crises and shocks; and

3. the risk of severe consequences of, and the attendant risks of slow or limited poverty (resiliency) from, crises, risk and shocks." (Watts and Bohle, 1993, based on Chambers, 1989)

Vulnerability (Urban)

"Urban vulnerability to natural hazards such as earthquakes is a function of human behaviour. It describes the degree to which socioeconomic systems and physical assets in urban areas are either susceptible or resilient to the impact of natural hazards. Vulnerability is independent from any particular magnitude from a specific natural event but dependent on the context in which it occurs. The characteristic of the urban community that can be assessed through a combination of ecological factors associated with the physical conditions of the population in that place. The physical and social conditions are inextricably bound together in many disaster situations that we can use the former as indicative of the latter. V. is continuously modified by human actions and therefore it varies over space and time. V cannot be assessed in absolute terms; the performance of the urban place should be assessed with reference to specific spatial and temporal scales." (Rashed and Weeks, 2002).

"The adaptive and coping capacities that determine the extent to which a society can tolerate damage from extreme events without significant outside assistance." (Mileti, 1999)

Vulnerability, aggregate

"Aggregate vulnerability depends on a portfolio of risks and related portfolio and risk responses." (Alwang et al. 2001)

Vulnerability, aggregate

"Factors or determinants of vulnerability are selected and measures on these usually aggregate surrogates are obtained from available secondary data. By means of an aggregation function over the selected measures (usually summation) an overall vulnerability value is calculated." (Smit and Wandel, 2006)

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Conclusions

This comparative glossary demonstrates just how widely the definitions of a single term can range. Many terms are tightly interwoven and are even used interchangeably. The listing informs the reader about the multiple definitions in use across various disciplines and sectors, which is an important stepping stone to dispelling the often lamented misunderstandings that arise in discussions of disaster reduction. What the above listing fails to offer is a harmonized concept of core terms that is precise enough to delineate the terms from each other, yet flexible and broad enough so as to be applicable across sectors, disciplines, and scales on which disaster reduction operates.

Terms such as "vulnerability" and "risk" are envelopes for complex and interconnected parameters and processes. A paradigm shift has taken place that puts more and more emphasis on non-natural science issues. These are harder to conceptualize since they are often not tangible, or of qualitative nature, e.g. coping capacity, resilience, institutional frameworks, cultural and social aspects.

Terms of such complexity are not easily defined in an exhaustive way. No matter – it is more important to agree on their key characteristics. That way, it is possible to create a conceptual frame whose content will vary with context, geographic scale, and time scale. Here the author describes the characteristics of some central terms in such a way that they all fit into a logically coherent framework. Once the basic framework is established, each term can always be defined more precisely to fit the specific context, use and scale.

Hazard

Every disaster starts with a hazard – known or unknown. There are many ways to characterize hazards, e.g. natural, technical, man-made, nuclear, ecological. The categories are probably as diverse as the disciplines and sectors involved. But they all have in common the potential to cause the severe adverse effects that lie at the bottom of every emergency, disaster, and catastrophe.

A hazard can be as general as "flood" or "storm" and, as such, stand for groups of potentially harmful events of variable severity. In other words, the hazard "storm" refers to all potential wind speeds that can be expected in a given region. A hazard can also be formulated more specifically as a magnitude 7.2 earthquake in Los Angeles or a category 5 Hurricane hitting the Philippines. In that case we are dealing with a specific hazard scenario. One important feature of hazard is that it has the notion of probability, or a likelihood of occurring. A hazard is a threat, not the actual event. Any hazard can manifest itself in an actual harmful event. In other words, if it can be measured in terms of real damage or harm, it is no longer a hazard but has become an event, disaster or catastrophe.

Every specific hazard magnitude is attached to a usually empirically derived return period, which is site-specific. The return period of a category 5 hurricane is different for New Orleans compared to the Philippines. If hazard is pegged out more broadly such as "epidemic", "drought", or "flood", it is characterized by all possible magnitudes. In order to quantify hazard each magnitude is tied to a specific return period or its inverse, frequency. The latter ensemble is the magnitude–frequency relationship of a particular hazard and it is always an inherent characteristic of a specific locality or region.

Vulnerability

Another prerequisite for a disaster besides hazard is vulnerability. Vulnerability is a dynamic, intrinsic feature of any community (or household,

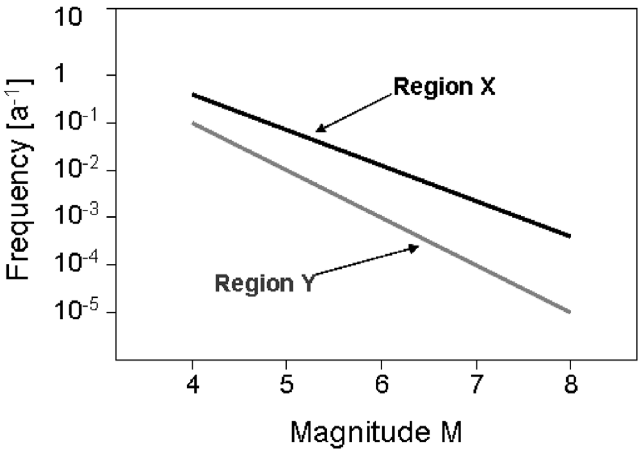

Figure 23.1 For earthquake hazard, the two lines represent the different magnitude–frequency relationships for two different fictitious regions, region x and region y. The two lines are region-specific.

region, state, infrastructure or any other element at risk) that comprises a multitude of components. The extent to which it is revealed is determined by the severity of the event.

Vulnerability indicates a damage potential and is a forward-looking variable. Or as Cannon et al. (2003) characterized it, "vulnerability (in contrast to poverty, which is a measure of current status,) should involve a predictive quality: it is supposedly a way of conceptualizing what may happen to an identifiable population under conditions of particular risk and hazards." Determining vulnerability means asking what would happen if certain event(s) impacted particular elements at risk (e.g. a community).

Vulnerability is an intrinsic characteristic of a community that is always there even in quiescent times between events. It is not switched on and off with the coming and going of events; rather, it is a permanent and dynamic feature that is revealed during an event to an extent that depends on the magnitude of the harmful event. This means that vulnerability can often only be measured indirectly and retrospectively, and the dimension normally used for this indirect measure is damage or more general harm.

What is normally seen in the aftermath of a disaster is not the vulnerability per se, but the harm done. Seeing the damage pattern of a community without knowing the magnitude of the event does not allow conclusions regarding the community's vulnerability. In that sense the

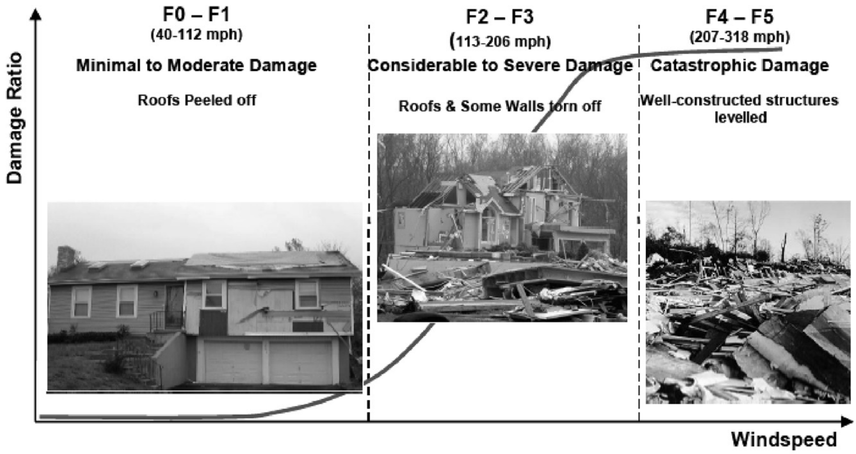

Figure 23.2 Sample residential damage function for the hazard of tornado illustrates the progression of wind damage.
Source: Doggett (2003). Tornado intensities are marked from F0 to F5 on the Fujita Scale. The full relationship between windspeed and damage characterizes the physical vulnerability of a certain building type.

magnitude–damage relationship reflects the vulnerability of an element at risk (community, household, nation, infrastructure, etc.).

Vulnerability changes continuously over time and is usually even affected by the harmful event itself. It can increase, for example, if poverty has been heightened by a disaster, so that the next disaster will have an even more devastating effect on the impoverished community. A small event, however, can raise the awareness of the community and in that way decrease its vulnerability.

Vulnerability is a function of the sensitivity or susceptibility of a system (community, household, building, infrastructure, nation etc.). It is "independent from any particular magnitude from a specific natural event but dependent on the context in which it occurs. Vulnerability cannot be assessed in absolute terms; the performance of the urban place should be assessed with reference to specific spatial and temporal scales" (Rashed and Weeks, 2002).

For practical reasons a vulnerability analysis will often limit itself to a certain scenario, i.e. event magnitude, for which an analysis is carried out. This is usually an appropriate approach to assessing vulnerability, but the choice of the event scenario is a subjective one. What scenario should be chosen: the 100-year event, 200-year event, the largest event that has occurred in the living memory, or the 5 m flood level?

In earthquake engineering this susceptibility is often quantified by means of a damage ratio that can vary between no damage (0 per cent) and total destruction (100 per cent). But vulnerability has many dimensions – physical (built environment), social, economic, environmental, institutional and human – and many of them are not easily quantifiable.

The complexity of vulnerability is not only given by its multiple dimensions but also by the fact that it is site-specific and that its parameters change with geographic scale. The parameters that determine vulnerability are different on the household, community and country levels. In the economic dimension of the household level, parameters such as the amount and diversity of income of single persons are relevant, whereas on a country level, inflation rate and GDP are more appropriate.

The limitations of vulnerability theory in addressing complex and dynamic reality are noted in Duryog Nivaran's book, *Understanding Vulnerability*. He says that "vulnerability is too complicated to be captured by models and frameworks. There are so many dimensions to it: economic, demographic, political, and psychological. There are so many factors making people vulnerable: not just a range of immediate causes but – if one analyses the subject fully – a host of root causes too . . . investigations of vulnerability are investigations into the workings of human society, and human societies are complex – so complex and diverse that they easily break out of any attempts to confine them within the neatly drawn frameworks, categories, and definitions. They are also dynamic, in a state of constant change, and, because they are complex and diverse, all the elements within societies are moving, so that these changes occur in different parts of society, in different ways and at different times" (Twigg, 1998). On a more optimistic note, every vulnerability analysis requires adaptation to its specific objectives and scales. Professionals in that field must be aware that there are many answers to the question of vulnerability. One potential answer to the question of vulnerability is given in Birkmann (2006), who defines vulnerability in a more encompassing way so that it includes exposure and coping capacities of a community.

Exposure

Together with vulnerability and hazard exposure is another prerequisite of risk and disaster. Here, exposure is understood as the number of people and/or other elements at risk that can be affected by a particular event. In an uninhabited area the human exposure is zero. No matter how many hurricanes will affect an uninhabited island, the human exposure, and hence the risk of human loss, remains zero. While the vulnerability determines the severity of the impact an event will have on the elements at risk, it is the exposure that drives the final tally of damage or harm. So in its economic dimension, vulnerability is depicted by the projection that in a given event a family will probably lose 50 per cent of its assets. How many families will be affected and lose 50 per cent of their assets is captured by the exposure. In an overly simplified example, the poverty of a community will determine the degree to which it will be affected by an event of a certain magnitude (→ susceptibility) and the number of the community members represents the exposure. In that sense a densely populated area is at higher risk then a sparsely populated one, all other conditions being equal.

Coping capacity and resilience

In real life the harm done does not only depend on hazard, vulnerability and exposure but also on the coping capacity and the resilience of the element at risk. In the literature, most definitions show a large overlap between coping capacity and resilience and are often used as synonyms. These two dimensions of a harmful event are not easily separated from each other.

Here, coping capacity encompasses those strategies and measures that act directly upon damage during the event by alleviating or containing the impact or by bringing about efficient relief, as well as those adaptive strategies that modify behaviour or activities in order to circumvent or avoid damaging effects.

Resilience is all of these things, plus the capability to remain functional during an event and to completely recover from it. So resilience includes coping capacity but at the same time goes beyond it.

The difficult question that arises from this definition is: does vulnerability already account for coping capacity and resilience or are they separate and counteracting parameters? The answer depends on how we define the damage or harm caused. If the extent of the damage or harm is defined also by the duration of the adverse effects and by its repercussions on people's poverty, economy or awareness, then vulnerability has to include coping capacity and resilience. This conclusion follows from the postulation that vulnerability describes susceptibility to damage or harm.

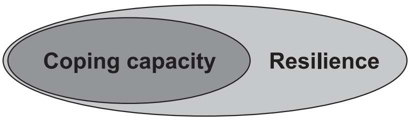

Figure 23.3 Coping capacity and resilience are hard to delineate. Resilience is understood to be the more encompassing term.

Risk

Vulnerability is measured in terms of expected harm/damage and so is risk. How can those terms be delineated from each other?

Risk always involves the notion of probability of occurrence. So information on "when" or on "how often" indicates we are talking about risk. That could be captured in a continuous damage–frequency relationship or just the definition of the return period for a particular event scenario. While vulnerability informs about the consequences of possible adverse events, risk also provides information on how often or with what probability those scenarios have to be expected.

For example: information on expected losses for an event during which the water level reaches 5 m above normal refers to hazard and vulnerability. Information on expected losses for a 200-year event during which the water level reaches 5 m above normal refers to risk. In another context: projecting the consequences of a 15 m tsunami is important, but in order to make informed disaster management decisions it is necessary to know how often such an event can be expected. Disaster management decisions are based on risk and not only on hazard.

Despite all the known shortcomings of databases of historic events, they do provide some means to create a magnitude–frequency relationship over a range of event magnitudes. This magnitude–frequency relationship can be an important tool for supporting the decision-making process with respect to the level of acceptable risk. Responsible disaster managers have to decide for what type of event a community should be prepared. To get prepared for the biggest possible event would be the safest way to go, but it is rarely economically feasible; such high levels of protection are simply unaffordable and the benefits would not justify the costs. In addition, maintenance and alertness would be unmanageable over such long periods of time because the largest events can only be expected to occur after many years of quiescence.

To summarize, risk is understood as a function of hazard, vulnerability, exposure and resilience (see also the figure below):

$$\text{Risk} = f(\text{hazard, vulnerability, exposure, resilience})$$

The frequency or return period of adverse effects allows the individual or official decision-maker to define a level of acceptable consequences. This is only possible if the decision-maker understands what events to expect over time. Decisions will be different for a 10-year event as compared to a 5,000-year event. For decision-making, information on the probability of occurrence is crucial.

Figure 23.4 Risk seen as a function of hazard, vulnerability, exposure and resilience, while the mathematical relationship between the variables is unknown.

Often the historical record is too short to provide reliable magnitude–frequency relationships for particular hazards and regions. In addition, climate change has started to alter those relationships. This can be seen in Germany where the return period of the 100-year event for the Rhine and the Danube had to be revised as a 20-year or even a 10-year event (Alt, 2002). Or in the US where the Missouri River has had six 100-year floods since 1946 (Albright Seed Company, 1998). Fluke of nature or real trend? It is hard to decide. But many scientists agree that the trend is strongly supported by data. In situations of uncertainty it would be most appropriate to heed the precautionary principle. After all, if we are not even prepared to deal with the current risk situation, how shall we cope with and adapt to a deteriorating situation due to climate change?

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