

Risk and vulnerability analysis to coastal hazards – an approach to integrated assessment

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Vorwort

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Abbreviations

AIACC	Assessments of Impacts and Adaptations to Climate Change
ASLR	Accelerated Sea Level Rise
CCC	Climate Change Community
COP	Conference of Parties
CM	Common Methodology
CRED	Centre for Research on the Epidemiology of Disasters
DEWA	UNEP Division of Early Warning and Assessment
DIVA	Dynamic Interactive Vulnerability Assessment
DKKV	Deutsches Komitee für Katastrophenvorsorge
DPSIR	Driving forces – Pressures – States – Impacts – Responses Framework
DRI	Disaster Risk Index
DRMC	Disaster Risk Management Community
DSS	Decision Support System
EEA	European Environmental Agency
GCM	Global Circulation Models
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIS	Geographical Information System
GNP	Gross National Product
GVA	Global Vulnerability Assessment
GVA	Gross Value Added
HDI	Human Development Index
HPI	Human Poverty Index
IA	Integrated Assessment
ICZM	Integrated Coastal Zone Management
IDNDR	International Decade for Natural Disaster Reduction
IFRC	International Federation of Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
MERK	Micro scale risk evaluation of the flood prone areas
NSR	North Sea Region
NOAA	National Oceanic and Atmospheric Administration
SIDS	Small island developing states
SLR	Sea Level Rise
SMP	Shoreline Management Plan

SRES	Special Report on Emission Scenarios
SST	Sea Surface Temperature
SURVAS	Synthesis and Upscaling of Vulnerability Assessment Studies
TAR	Third Assessment Report
UNCSD	United Nations Commission on Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USCSP	US Country Studies Program
VA	Vulnerability Assessment
VCA	Vulnerability and Capacity Assessment
WB	World Bank
WCDR	World Conference on Disaster Reduction

Summary

The recent flood disaster in South East Asia as well as the tremendous impacts of hurricane *Katrina* in the U.S. have pointed out the special vulnerability of coastal zones, their inhabitants, economics, and ecological systems. These events are far from being singular. Rather, an increase in damages caused by natural disasters is clearly discernible. Global warming, an accelerating sea level rise and an increase of extreme events are assumed to aggravate flood risk in the future. Consequently, coastal zones are ever more threatened by land loss, flooding of coastal lowlands, erosion, salinization of soils and ground water and not at least by the loss of lives.

These novel threats force scientists and decision makers to rethink hazard response and adaptation strategies in order to be prepared for future changes. To develop adequate risk management strategies, knowledge about vulnerability is crucial to estimate the actual risks. Only with a concrete knowledge of the vulnerability, present and future risks can be managed adequately. In the last decades, numerous diverse methodologies and approaches to assess risk and vulnerability have been developed. Most of them were designed according to morphological or economic terms, whereas social and ecological vulnerability criteria as well as the systems' coping ability have been widely neglected. Yet, especially with regard to changing climate conditions, these criteria draw increasingly attention.

The superordinate goal of this thesis was to develop a framework of vulnerability assessment which integrates resilience in a broader sense in order to contribute to interdisciplinary efforts of improving risk management including disaster preparedness and adaptation to climate change.

In a first step, existing methods and approaches of vulnerability assessment were investigated, evaluated, and categorized. Two research communities dealing with coastal risks and vulnerability could be differentiated:

- On the one hand the climate change community, which is primarily concerned with the long-term consequences of a sea level rise and adaptation to it.
- On the other hand the natural hazard or disaster risk management community, which is concerned with the risk reduction of localized specific hazards (e.g. hurricanes or storm surges). It includes damage potential analyses for coastal defense planning as well as capacity building for disaster management.

The two communities differ in the spatial and temporal scale of the analysis. Climate impact assessments predominantly follow a scenario-based top-down approach which considers long

term changes and is primarily applied on global and regional scale. In the disaster risk management community, in contrast, the vulnerable region itself is the starting point of the bottom-up approaches. Here, future scenarios are only of secondary importance, as the hazard characteristics are derived from past events.

In a subsequent comparison of vulnerability assessment studies clear differences could be pointed out, especially regarding scale. Early studies conducted in the climate change community, such as the IPCC Country Studies (IPCC/ CZMS, 1992) which apply the *Common Methodology*, the IPCC Technical Guidelines (CARTER ET AL., 1994), or the U.S. Country Studies (BENIOFF ET AL., 1996) gave a first worldwide overview of coastal vulnerability to sea-level rise. These early investigations have some serious deficits, as they assumed consistent scenarios (e.g. a common sea-level rise) and focused on natural system changes such as flooding, erosion, and salinization as well as the assessment of the economic damage potential only. Social and ecological vulnerability factors and the resilience of coastal systems were by far the most neglected coefficients. Beyond that, the studies use strongly aggregated data, so that the outputs do not have the level of detail which is required by decision makers to implement management strategies on local level. Recent studies such as Dinas Coast (DE LA VEGA-LEINERT ET AL., 2005) took up these deficits by explicitly including social vulnerability indicators in their model. Yet, the resolution remains on a global to regional level and is therefore of limited use for decision makers. In contrast, in the disaster risk management community mostly local studies are conducted. They use data with a higher resolution, but they barely include future scenarios and are of limited use for comparison of regions, and for making future prognosis.

In this thesis an integrated framework for vulnerability assessment within which indicators for composite vulnerability and resilience could be developed was designed. This framework differs from the predominantly sectoral view of vulnerability in that it incorporates a diversified consideration of social, economic, and ecological vulnerability of the elements of risk due to hazard specific exposure. As every system has the ability to resist adverse impacts, this natural and socio-economic resilience reduces vulnerability in a relation of $1/x$.

More, the specific social, economic and ecological risks can be derived from the total vulnerability. In order to quantify composite vulnerability, an indicator set, which is applicable to coastal hazards was developed, allowing the creation of vulnerability profiles by including social, economic, and ecological indicators for coastal vulnerability as well as for socio-economic and ecological resilience on different scales.

These indicators reflect an integrative approach and were grouped into the following vulnerability categories:

Social vulnerability	Economic vulnerability	Ecological vulnerability	Resilience
Demography	Capital value at loss	Ecological value	Ecological Resilience
Health	Land loss	Environmental pressure	Socio-economic resilience
Education and work	Labor force		<ul style="list-style-type: none"> • Preparedness • Early warning capacity • Coping capacity • Adaptive capacity • Recovery
Governance	Economic activity		
Culture			
Personal wealth			

A special focus of this thesis is the investigation of risk perception. The risk perception and risk awareness of coastal hazards and climate change are of outstanding relevance for risk assessment and vulnerability. They indicate preparedness, coping capacity as well as adaptive capacity.

To investigate the relevance of risk perception of storm floods in coastal lowlands in the North Sea Region, the author conducted a transnational study in the framework of the Interreg IIB project COMRISK – *Common Strategies to Reduce the Risks in Coastal Lowlands* in the sub-project *Public Perception in Coastal Flood Defense and Participation in Coastal Flood Defense Planning*. With help of a household as well as an expert survey in selected municipalities in Belgium, Denmark, Germany, the Netherlands, and the United Kingdom, empirical data were gained. 2,000 households were asked to state their knowledge and opinion about flood risk, and personal prevention. From this survey, it could be concluded that the perception of flood risk is not well developed in the region, and there is a great information deficit concerning storm surge risks and possibilities for prevention. Almost one third of the respondents are not aware, that they live in a flood-prone area; more than 90% do not take any precautionary measures. About two third stated that they do not know what to do in case of an emergency. The international comparison showed only small differences in the perception and the awareness of risk. The analysis of the public survey as well as expert interviews lead to the assumption that risk perception decisively contributes to vulnerability and resilience, and can thus be seen as an indicator for resilience.

In a last step, it was investigated how a better connection can be established between vulnerability assessment and concrete actions taken in risk management and how indicator-based assessment can be operationalised in risk management.

Climate change and an increasing socio-economic pressure in coastal zones require a shift from current -primarily technical- adaptation strategies to integrative risk management in order to mitigate current and future risks. To face the problem of adaptation to uncertain long term climate changes, approaches from the disaster risk management community and the climate

change community should be combined. Strengthening resilience with technical measures, implementing early warning systems, and promoting capacity building programs as well as information dissemination and participation mitigate not only current disaster risk. Additionally, a society gets prepared for today's risks, and thus is also better able to cope with future changes.

It could be observed that vulnerability assessment is only useful if the results could be used to make adequate short- and long-term decisions. Thus a place-based assessment approach is suitable to derive the detailed data that are necessary for local planning. But at the same time cross scales linkages should be facilitated to reduce the effort of micro scale analysis. However, the uncertainty of climate impact prognoses requires that decision makers have to make decisions concerning adaptation today, even if the benefits lie in the far future. As this causes conflicts in coastal management, involving stakeholders and decision makers in early stages of risk and vulnerability assessment is crucial. Indicators can help to make the amount of data produced in vulnerability assessment more comprehensive to politicians. Indicators serve as an instrument for policy, showing trends of development which require adaptation. In so doing it is possible to bridge the gap between scientific-based vulnerability assessment and political-administrative decision making in risk management.

Zusammenfassung

Die Flutkatastrophe in Südostasien sowie die verheerenden Folgen des Hurrikans *Katrina* in den USA in jüngster Vergangenheit haben die hohe Vulnerabilität (Verletzlichkeit) von Küstenregionen, ihrer Wirtschafts- und Ökosysteme und nicht zuletzt ihrer Bewohner gezeigt. Dies sind bei Weitem keine einmaligen Ereignisse, vielmehr lässt sich seit Jahren eine Häufung von Naturkatastrophen und damit einhergehend ein immenser Zuwachs der Schäden verzeichnen. Es ist zu erwarten, dass die globale Erwärmung, der damit einhergehende beschleunigte Meeresspiegelanstieg sowie die Zunahme von Extremereignissen diese Überflutungsrisiken zukünftig noch verstärken. Folglich werden Küstenregionen zunehmend durch Landverlust, Überflutungen von Tiefländern, Erosion, Versalzung von Böden und Grundwasser, Schäden durch Extremereignisse und nicht zuletzt den Verlust von Menschenleben bedroht.

Wissenschaftler und Entscheidungsträger sehen sich darum verstärkt mit der Notwendigkeit konfrontiert, bisherige Methoden der Gefahrenabwehr zu überdenken, um adäquate Anpassungsstrategien für diese neuen Bedrohungen zu entwickeln. Der Abschätzung der Vulnerabilität kommt dabei eine zentrale Rolle zu, da sie maßgeblich das Ausmaß negativer Einwirkungen durch Naturgefahren bestimmt. Nur mit der genauen Kenntnis der Vulnerabilität lassen sich gegenwärtige und zukünftige Risiken effektiv bewältigen.

Zur Abschätzung des Risikos und der Vulnerabilität wurden in den vergangenen Jahrzehnten zahlreiche, mitunter sehr differierende, Methoden entwickelt. Diese Methoden stützen sich hauptsächlich auf morphologische und ökonomische Analysen, wobei soziale und ökologische Vulnerabilitätskriterien sowie die Betrachtung der Bewältigungsfähigkeit der Küstenbewohner weitestgehend vernachlässigt werden. Gerade unter dem Aspekt der sich ändernden klimatischen und sozioökonomischen Rahmenbedingungen wird diesen Kriterien jedoch steigende Bedeutung beigemessen.

Übergeordnetes Ziel der vorliegenden Arbeit war es daher, einen konzeptionellen Rahmen für eine integrative Risiko- und Vulnerabilitätsabschätzung zu schaffen, welcher – unter besonderer Berücksichtigung der Widerstandsfähigkeit (Resilienz) von Küstensystemen – zur Entwicklung eines effizienten Risikomanagements beiträgt.

Im ersten Schritt wurden bestehende Methoden und Ansätze zur Vulnerabilitätsabschätzung untersucht, bewertet und kategorisiert. Es ließen sich hierbei zwei Forschungsrichtungen unterscheiden:

- Zum einen die Klimafolgenforschung, die sich mit zunehmendem Erkenntnisstand über den Klimawandel und dessen Folgen entwickelt hat und sich im Küstenbereich vornehmlich mit den langzeitlichen Folgen eines Meeresspiegelanstiegs sowie Anpassungsmöglichkeiten daran beschäftigt.
- Zum anderen die Naturgefahrenforschung, die sich mit den Folgen und der Risikominde- rung lokal spezifischer Naturgefahren (z.B. Hurrikans oder Sturmfluten) befasst und dabei häufig eine konkrete Maßnahmenplanung im Küstenschutz oder Katastrophenmanage- ment verfolgt.

Die Ansätze der beiden Forschungsrichtungen unterscheiden sich im Wesentlichen in der räumlichen und zeitlichen Betrachtungsweise. Während Klimafolgenabschätzungen weitestge- hend einen Szenario-gestützten *top down*-Ansatz verfolgen, der vornehmlich auf globaler und regionaler Ebene angewendet wird, steht in der Naturgefahrenforschung der vulnerable Raum selbst im Mittelpunkt und bildet den Ausgangspunkt für Untersuchungen nach dem *bottom up*-Ansatz. Zukunftsszenarien spielen hier eine untergeordnete Rolle, vielmehr wird das Gefah- renpotential aus vergangenen Ereignissen generiert.

In einem anschließenden Vergleich von konkreten Vulnerabilitätsstudien konnten deutliche Unterschiede, insbesondere im Hinblick auf die Maßstabebene, aufgezeigt werden. Frühe Untersuchungen in der Klimafolgenforschung wie die IPCC Country Studies (IPCC/ CZMS, 1992), die die *Common Methodology* anwenden, die IPCC Technical Guidelines (CARTER ET AL., 1994) oder die US Country Studies (BENIOFF ET AL., 1996) gaben einen ersten weltweiten

Überblick über die Vulnerabilität von Küsten gegenüber einem Meeresspiegelanstieg. Diese frühen Untersuchungen weisen jedoch gravierende Schwächen auf, insbesondere im Hinblick auf die Annahme einheitlicher Szenarien wie beispielsweise einen einheitlichen Meeresspiegelanstieg. Außerdem befassen sie sich vorrangig mit den naturräumlichen Systemveränderungen wie Überflutungen, Erosion und Versalzung, sowie mit der Erfassung des ökonomischen Schadenspotentials. Soziale und ökologische Vulnerabilitätsfaktoren und die Einbeziehung der Resilienz bleiben weitgehend unberücksichtigt. Darüber hinaus werden in diesen Studien stark aggregierte Daten verwendet, so dass die generierten Ergebnisse nicht den Umfang und den von Entscheidungsträgern als notwendig erachteten Detailgrad haben, um daraus konkrete Maßnahmen auf lokaler Ebene abzuleiten. Jüngste Studien wie das Dinas Coast Projekt (DE LA VEGA-LEINERT ET AL., 2005) beziehen zwar soziale Vulnerabilitätskriterien mit ein, erreichen jedoch auch nur eine globale und regionale Auflösung und sind damit für das lokale Risikomanagement nur von begrenztem Nutzen.

Die Studien der Naturgefahrenforschung dagegen sind meist lokal spezifische Studien. Sie verwenden höher aufgelöste Daten, beziehen jedoch selten Szenarien mit ein und sind daher nur begrenzt geeignet, regionale Vergleichsmöglichkeiten zu liefern und Aussagen über zukünftige Entwicklungen zu treffen.

Im Mittelpunkt der Arbeit stand die methodische Entwicklung eines integrativen Konzepts für eine auf Indikatoren basierende Vulnerabilitätsanalyse. Der meist sektoralen Betrachtungsweise von Vulnerabilität wird hier eine diversifizierte Betrachtung sozialer, ökonomischer und ökologischer Vulnerabilität der durch eine gefahrenspezifische Exposition gefährdeten Elemente entgegen gestellt. Weil jedes System eine Fähigkeit zum Abpuffern von Einwirkungen besitzt, stellt diese sogenannte natürliche und sozio-ökonomische Resilienz eine die Vulnerabilität im Verhältnis 1/x abschwächende Komponente dar. Aus der Wechselwirkung von Vulnerabilität und Resilienz ergibt sich das jeweilige soziale, ökonomische und ökologische Risiko.

Zur Quantifizierung von Vulnerabilität und Resilienz wurde ein für Küstenrisiken spezifischer Indikatorensatz entwickelt, der die Ableitung von Vulnerabilitätsprofilen für soziale, ökonomische und ökologische Küstenvulnerabilität sowie für sozio-ökonomische und ökologische Resilienz auf verschiedenen Maßstabsebenen ermöglichen soll.

Diese Indikatoren ließen sich in übergeordnete Vulnerabilitätsklassen zusammenzufassen:

Soziale Vulnerabilität	Ökonomische Vulnerabilität	Ökologische Vulnerabilität	Resilienz (Widerstandsfähigkeit)
Demographie	Kapitalverlust	Ökologische Wertigkeit	Ökologische Resilienz
Gesundheit	Landverlust	Umweltbelastung	Sozio-ökonomische Resilienz
Bildung	Arbeitskräfte		Resilienz

Politische Struktur	Ökonomische Aktivität	• Bereitschaft
Kultur		• Frühwarnkapazität
Wohlstand		• Bewältigungsfähigkeit
		• Anpassungsfähigkeit
		• Wiederherstellung

Einen Schwerpunkt dieser Arbeit bildete die Evaluierung der Risikowahrnehmung.

Die Risikowahrnehmung und das Risikobewusstsein von Naturgefahren und Klimaveränderungen sind wesentliche Faktoren von Risikobewertung und damit von Vulnerabilität. Sie geben Aufschluss über die Bereitschaft, die Bewältigungsfähigkeit sowie die Anpassungsfähigkeit. Um die Bedeutung der Risikowahrnehmung von Sturmfluten zu untersuchen, wurde im Rahmen des Interreg IIIB Projektes COMRISK – *Common Strategies to Reduce the Risks in Coastal Lowlands in the North Sea Region* im Teilprojekt *Public Perception in Coastal Flood Defense and Participation in Coastal Flood Defense Planning* – erstmalig eine internationale Vergleichsstudie in den durch Sturmfluten gefährdeten Nordsee-Anrainerstaaten durchgeführt. Hierfür wurden mittels einer Haushalts- und einer Expertenbefragung in ausgewählten Gemeinden in Belgien, Dänemark, Deutschland, Großbritannien und den Niederlanden empirische Ergebnisse ermittelt. 2000 Haushalte wurden zu ihrer Meinung und ihrem Wissen über Überflutungsrisiken und Vorsorgemöglichkeiten befragt. Insgesamt konnte festgestellt werden, dass das Risikobewusstsein nur sehr schwach ausgeprägt ist und ein großes Informationsdefizit sowohl bezüglich des Sturmflutrisikos als auch der Präventionsmöglichkeiten herrscht. Knapp ein Drittel aller Befragten sind sich nicht darüber im Klaren, dass sie im überflutunggefährdeten Gebiet leben, über 90% treffen keine Vorsorgemaßnahmen. Rund zwei Drittel gaben an nicht zu wissen, wie sie sich im Katastrophenfall verhalten sollen. Der Ländervergleich bezüglich des Risikobewusstseins zeigte nur geringfügige Unterschiede. Aus der Studie wurde deutlich, dass das Risikobewusstsein der Betroffenen maßgeblich zur Vulnerabilität und zur Widerstandsfähigkeit einer Region sowie zum Umgang mit Katastrophen beiträgt und somit als ein Indikator für Resilienz angesehen werden kann.

In einem letzten Schritt wurde untersucht, wie eine bessere Verknüpfung zwischen Vulnerabilitätsabschätzungen und konkreten Handlungsweisen im Rahmen eines Risikomanagements hergestellt und wie ein Indikatoren-basierter Ansatz für das Risikomanagement operationalisiert werden kann. Klimatische Veränderungen sowie eine gleichzeitige Zunahme von Nutzungsansprüchen und Interessen im Küstenraum erfordern eine Änderung bisheriger Anpassungsstrategien in Form von überwiegend rein technischem Küstenschutz hin zu einem integrativen Managementansatz zur Minderung gegenwärtiger und zukünftiger Risiken. Die Stärkung der Resilienz und der Bewältigungsfähigkeit sollte elementarer Bestandteil des Risikomanagements sein und daher auch schon in die Vulnerabilitätsanalyse einfließen. Um dem

Problem der Anpassung an langfristige, mit Unsicherheiten behaftete Klimaprognosen zu begegnen, sollten die Ansätze aus der Naturgefahren- und Katastrophenforschung mit denen der Klimafolgenforschung kombiniert werden. Maßnahmen zur Stärkung der Bewältigungsfähigkeit, Frühwarnsysteme, Trainingsprogramme zur Informationsvermittlung und Bewusstseinsbildung, Partizipation sowie individuelle Präventionsmaßnahmen, wie sie im Katastrophenschutz praktiziert werden, helfen nicht nur im Umgang mit gegenwärtigen Risiken, sondern können auch langfristigen Risiken vorbeugen.

Es hat sich gezeigt, dass Vulnerabilitätsabschätzungen nur effizient nutzbar sind, wenn sie in konkrete Entscheidungen münden. Insbesondere die Evaluierung sozio-ökonomischer Faktoren ist auf globaler und regionaler Ebene nur schwer möglich und erfordert eine Betrachtung lokal spezifischer Gegebenheiten. Daher ist ein sogenannter *place-based* (lokal spezifischer) Vulnerabilitätsansatz am geeignetsten, um die mikroskalige Information zu erhalten, die für lokale Managementstrategien notwendig ist. Gleichzeitig sind jedoch maßstabsübergreifende Verknüpfungen herzustellen, um den Aufwand mikroskaliger Methoden zu reduzieren. Die Unsicherheiten in der Abschätzung langfristiger klimatischer und sozio-ökonomischer Veränderungen erfordern, dass Entscheidungsträger heute über Anpassungsmaßnahmen entscheiden müssen, deren Nutzen in ferner Zukunft liegt. Da dies mitunter zu Konflikten im Küstenmanagement führt, ist es notwendig, Interessenvertreter und Entscheidungsträger möglichst frühzeitig in die Risiko- und Vulnerabilitätsabschätzung einzubeziehen. Indikatoren helfen, die bei einer Vulnerabilitätsanalyse produzierten Datenmengen zu reduzieren und sie für Politiker verständlich zu machen. Indikatoren sind ein Instrumentarium für die Politik und das Küstenmanagement, welches Trends aufzeigt, die eine Anpassung erfordern. Es hat sich gezeigt, dass es mit Hilfe von Indikatoren möglich ist, eine Verbindung zwischen der auf wissenschaftlichen Methoden basierten Vulnerabilitätsanalyse und dem politisch-administrativen Risikomanagement herzustellen.

1 Introduction

Hazards only become disasters when people's lives and livelihoods are swept away. We can and must reduce the number and impact of disasters by building sustainable communities that have the long-term capacity to live with risk.

Kofi Annan, 2003

Recently the world was hit by two of the most devastating natural catastrophes and human disasters in history. In December 2004, an earthquake west of Sumatra in the Indian Ocean triggered a Tsunami which destroyed coastlines thousands of kilometres away, taking the lives of more than 200,000 people and leaving more than one million homeless. Only eight months later, the hurricane "Katrina" destroyed numerous stripes of the U.S. South Coast. Dikes were unable to withstand, leading to a total flooding of the town New Orleans. Hundreds of people were killed and one million lost their home. The total damage exceeded 175 billion €.

These events dramatically proved the power of nature, the special vulnerability of coastal zones and the need for risk management to protect human lives, their property and infrastructure. Threats caused by natural hazards and the massive impacts they have on societies are far from being singular events; rather, their frequency and intensity are increasing significantly (MUNICH RE, 2005). Furthermore the global climate change with an accelerating sea level rise is superimposing climatic hazards. The altercation with these risks has become a big challenge for the international community because our society more than ever is encroaching in natural processes and thus exposes itself to them.

1.1 Background and motivation

Coastal zones are among the most dynamic environments on earth. They are characterised by very sensitive ecosystems such as mangroves, reefs, beaches, dunes and wetlands as well as important socio-economic functions and values. Coeval the population density in the coastal zone is much higher than in the hinterland. About 21% of the world's population live within 30 km of the coast, with numbers growing rapidly (GOMMES ET AL., 1998). By 2100, 600 million people are expected to occupy coastal flood plain land below the 1000 year flood level (NICHOLLS & MIMURA, 1998). As the coastal population density, accompanied by dynamic eco

conomic activities, is increasing, the encroachment of coastal resources is boosted. More, wetlands and coastal ecosystems are stressed and economic values such as buildings, infrastructure, or industrial facilities are growing.

Building the boarder between land and ocean, coastlines are heavily exposed to impacts from hazards such as storms, waves, erosion, flooding and tectonic processes. Natural hazards have always occurred in history; yet, the MUNICH RE (2005) states a global increase in frequency and intensity of natural disasters, with the total figure three times higher and a tenfold increase in the amount of damages since 1950, a large number of them in coastal regions. An estimated global mean sea-level rise of 48 cm and an increase in extreme events for the 21st century are expected to seriously threaten the coastal zones (IPCC, 2001), especially regions with a reduced ability to cope with adverse impacts. People have always adapted to changes and risks - e.g. by migration, retreat, or coastal defense measures. However, global change hampers simple adaptation strategies.

Since the coastal zone is and in the future will even be more one of the most important human spheres of action, increasing efforts are necessary to handle these risks and to develop strategies and measures to protect life and property. To quantitatively and qualitatively assess the potential risks and to derive management strategies under local socio-economic terms and conditions, the knowledge of the vulnerability of a region is inevitable.

Efforts of developing methods to assess risks and vulnerability have become a broad field of interdisciplinary research. Especially on the fields of hazard and climate change research, numerous methods and tools for vulnerability assessment in coastal zones at global to national, regional and local scale have been developed and conducted since the beginning of the 1990s. These studies have contributed significantly to the awareness of coastal risks, identified vulnerable hot spots around the world, and helped to conduct cost-benefit analyses for coastal defense measures and coastal management.

In most of the earlier investigations, coastal risks have been examined in simple economic terms, whereas other aspects of vulnerability, such as social, cultural and ecological values, as well as the capacity of societies to cope have been neglected. However it has become increasingly clear that risks and disasters cannot be reduced in isolation but have to be part of an integrated social and political issue. In order to identify and quantify vulnerability - including anthropogenic and natural drivers - an analysis that crosses the interface between natural and social science to effectively manage coastal risks is needed though.

To date there is a need for estimates that allow a comparison between regions and for transferable and comprehensive methodologies for vulnerability assessment that bridges the gap between scientific scenario-based investigations and local manifestation of the results. It is neither economically feasible to neutralize hazards completely through technical measures nor

is it socially acceptable to exclude people from hazard zones. Therefore, many potential users - e.g. scientists, stakeholders and policy makers - could benefit from improved estimates of vulnerability to hazards and also from wide information about risks in order to successfully develop and implement risk management strategies.

1.2 Questions, objectives, and structure of this thesis

This work seeks to address the issue at stake by developing a methodological framework for an indicator-based holistic vulnerability assessment. To form the basis of this work, some key questions are formulated in the beginning:

- What is the hazard potential in coastal zones?
- Which approaches and methods exist to assess vulnerability?
- What results do international vulnerability assessment studies deliver on different scales?
- How can vulnerability be differentiated?
- What role does the resilience factor of coastal communities play?
- Which indicators can measure vulnerability and resilience?
- Can/should risk perception be integrated in risk and vulnerability assessment?
- How can vulnerability assessment contribute to risk management?

From these research questions the objectives of this thesis can be formulated.

The superior goal of this thesis is to develop a framework of integrated vulnerability assessment which integrates resilience in a broader sense in order to contribute to interdisciplinary efforts of improving risk management including disaster preparedness and adaptation to climate change.

Concretely this includes the following working steps:

First, an overview of the hazard and risk potential of the coastal zone is given. This comprises biophysical hazards, the impacts of future climate change, as well as the socio-economic development and environmental changes. It is outlined to which degree the functions of the coastal zone are at risk and what kind of hazard reduction strategies have been developed by societies.

Secondly, the concept of risk and vulnerability is defined, focusing on the evolution, purpose and approaches of vulnerability assessment in the climate change community and in the disaster risk management community. Relevant international research studies on coastal vulnerabil-

ity and risk assessment are evaluated and classified in order to assert their output on different scales.

The focus of this thesis lies on the development of a framework of vulnerability and resilience, In this framework indicators to assess vulnerability and resilience are developed.

Special meaning is given to the investigation of the role of risk perception. A case study comprising a public and an expert survey is conducted in the North Sea Region, to evaluate the role of risk awareness in the context of risk assessment and management.

Finally, challenges for future vulnerability assessment and integrated risk management are outlined as well as the possibilities for the application of an indicator-based vulnerability framework in coastal risk management.

Figure 1-1 gives a schematic overview of this thesis.

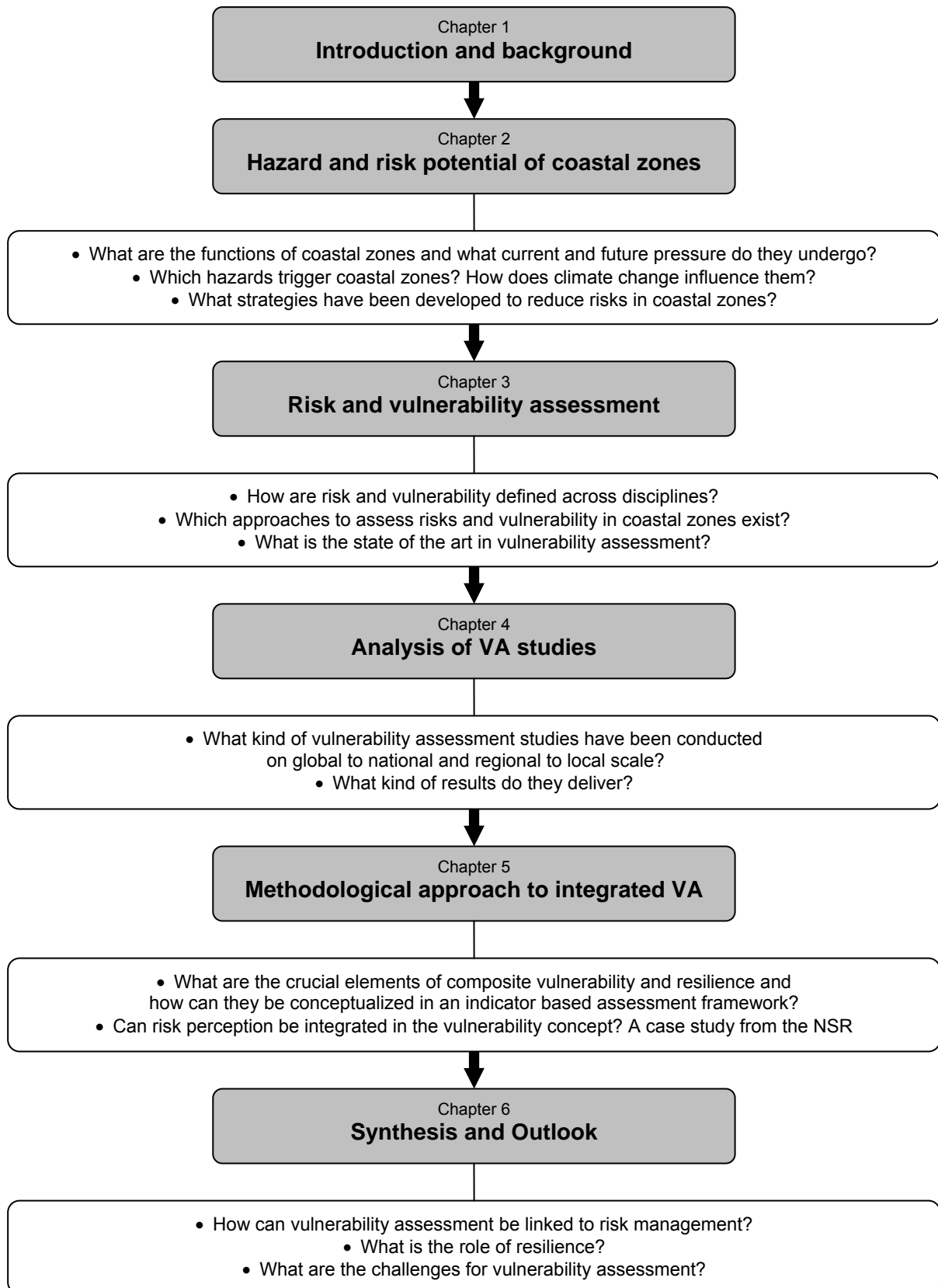


Figure 1-1: Schematic overview of the thesis

2 Hazard and risk potential of coastal zones

Earth's history has been characterised by many changes in climate conditions. But the extent and the rate of current climate change most likely exceeds all natural variation in the last thousand years and possibly further back in history.

EEA, 2004

Building a long narrow interface between land and ocean, the coastal zone consists of a biophysical system exposed to natural forces such as tides, storms, and sediment transport and a socio-economic system, which is determined by demographic and economic development (cf. figure 2-1). These two systems are interacting with and depending on each other. A disturbance in any part of the system will seriously threaten the equilibrium and harm society as well as the environment.

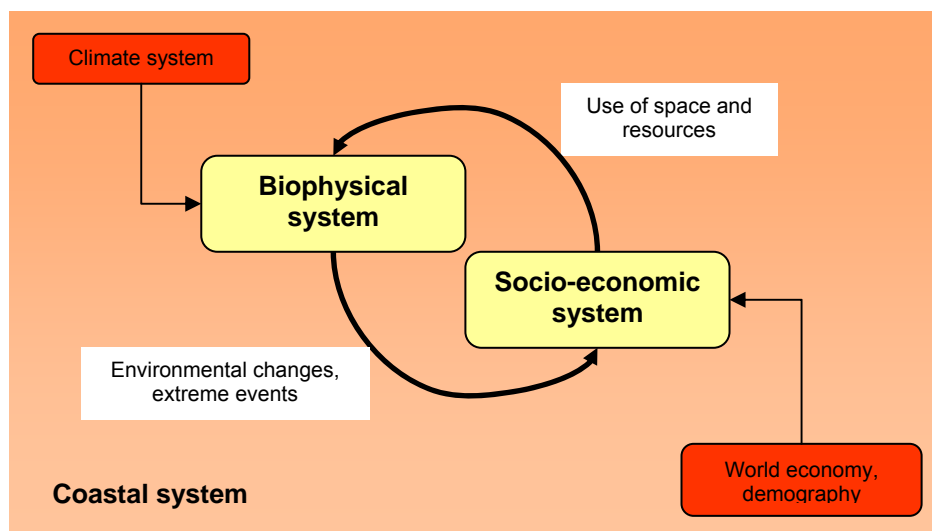


Figure 2-1: The coastal system

The coastal zone has always been intensively used and settled by humans. Yet, in the last century the pressure has increased significantly. This is partly due to an enormous population growth in developing countries including a migration towards the coast, followed by degradation of coastal habitats and overexploiting of coastal resources. It is also partly due to basic

changes in use, transport, and infrastructure as well as increasing values. This coastal squeeze is further boosted by the consequences of global warming.

2.1 Coastal zones – functions, development, and squeeze

As significant economic and ecological sphere the functions of the coastal system can be categorized in *regulation functions*, *user and production functions* and *information functions* (cf. table 2-1).

Table 2-1: Functions of the coastal system (Source: STERR & SIMMERING, 1997:5)

Regulation functions	User and production functions	Information functions
<ul style="list-style-type: none"> • Regulation of local energy balance • Regulation of the chemical composition of water and sediment • Regulation of water exchange between land and ocean • Storage and recycling of nutrients and organic matter • Regulation of biotic nutrition • Filtration of nutrients and toxic matters • Maintenance of migration and nursery habitats • Maintenance of biological and genetic diversity 	<ul style="list-style-type: none"> • Production of drink- and irrigation water • Production of food • Production of raw materials, and materials for building and construction • Production of biological and genetic resources • Providing space and resources for human habitation and settlement (fishery and aquaculture, energy conservation, tourism and recreation, nature protection) 	<ul style="list-style-type: none"> • Aesthetic information • Historic and cultural information • Educational and scientific function

Many of these functions have been subject to outstanding stress, creating an imbalance between the biophysical and the socio-economic system. A large number of regulation functions which are important for the environmental equilibrium are disturbed and thus make the coastal system susceptible to adverse impacts. The coastal zone is a habitat with unique ecological functions providing living space for a special biota. At the same time it is a sedimentological active zone and a source of energy. Coastal ecosystems consist mainly of wetlands, including salt marshes, mangroves, and associated unvegetated intertidal areas. These wetlands provide important functions, such as waste assimilation, nursery areas of fisheries, flood protection, and nature conservation. The coastal ecosystem faces pressure caused by economic impacts, including overexploitation of coastal resources, pollution, increasing nutrient fluxes, decreasing freshwater availability, sediment starvation, or urbanization. Hence, it is in mutual stress with the socio-economic system.

The user and production functions of the coastal system are essential for human activities and well being. A great part of the world's economy – transport, infrastructure, harbors, fishery, or tourism - is allocated to the coast. Tourism is one of the world's most important and fastest growing industries with a gross output of over US\$ 7 trillion. In 2004 the travel and tourism industry directly contributed 3.8% to the global GDP, and 3% to global employment. More, the tourism industry employs 8.3% of the global workforce and forms 10.6% of the global GDP. The number of international tourists has grown by a factor of 30 since 1950 (AMELUNG, 2006). In many regions the tourism industry ranks first in the local economy. Especially in developing countries international tourism contributes substantially to the GDP.

Around 70% of this global tourism takes place in coastal zones (AMELUNG, 2006), especially in low-lying areas with sandy beaches or islands (e.g. the Mediterranean, the Caribbean or South-East Asia). Although the world economy as well as the regional economy are jeopardizing by tourism, it also causes conflicts and coastal management problems due to its substantial contribution to environmental degradation and overexploitation of resources. Although there have been many approaches toward sustainable tourism in recent years, a massive expansion of tourism continues into areas that have not been accessible before. The interaction of tourism with coastal hazards is twofold. On the one hand, tourism exacerbates the risks in coastal zones by destroying ecosystems and building infrastructure in near shore areas where sediment movements and erosion are progressing. On the other hand tourism is affected by extreme events and beach loss due to sea-level rise. Already today many tourist resorts are urged to nourish their beaches and protect them through hard coastal protection structures. Other locations and tourist resorts, for example in the Caribbean, are exposed to reoccurring natural disasters caused by hurricanes.

The twentieth century has been characterized by massive changes in demographic development. The UN is projecting that the world's population will reach 7.2 billion by 2015, 7.9 billion by 2025, and 9.3 billion by 2050. All projected population growth until 2050 is expected to occur in the developing world (KLEIN ET AL., 2002). It will mainly take place in urbanized areas near the coast, as in general the population and (integrated) population density decrease with elevation and distance from the shoreline (cf. figure 2-2). The highest population density occurs below 20m.

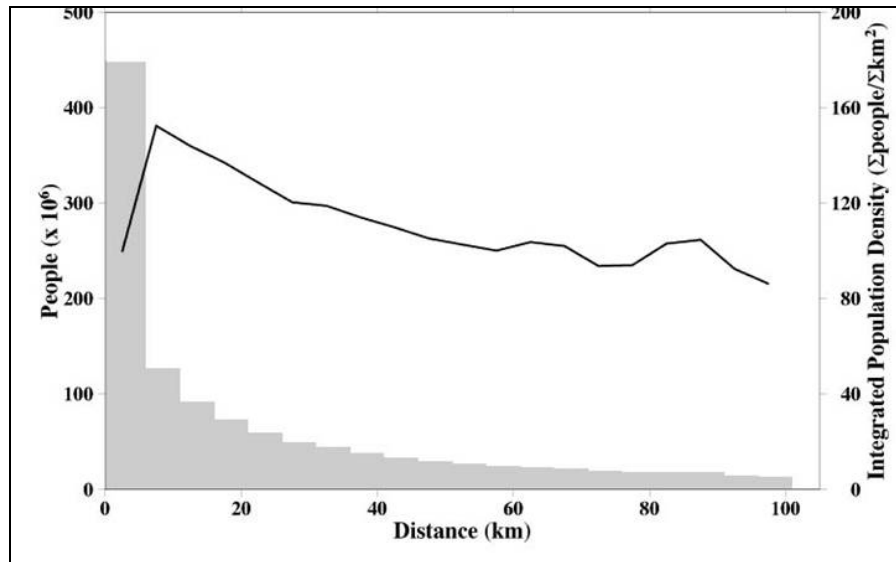


Figure 2-2: Population and population density vs. distance/km from the coast
(Source: NICHOLLS & SMALL, 2002:302)

Low-lying areas near coasts now have the largest concentration of people on earth (SMALL & COHEN, 1999). The population inhabiting the coastal zone 100km in distance/ 100m in elevation in 1990 was estimated about 1.2 billion people (112 people/km² - about three times the global average) or more than 23% of the global population, concentrating on hot spots in Europe or Asia (NICHOLLS & SMALL, 2002; GOMMES ET AL. 1998).

According to the World Population Progress Report 2001 (UN/DESA, 2001), there is a movement from rural locations to urban areas already taking place in developed countries and increasing significantly in developing countries. In these developing countries, the explosive population growth and the coastward migration lead to the rise, of the so called megacities - larger cities than have ever existed in coastal locations (KLEIN, 2003). It is projected that in 2015 there will be 33 megacities, 21 of them in coastal zones, all of them with a population of more than eight million. Table 2-2 shows that with the exception of Tokyo, New York, Los Angeles, Osaka, Paris, and Moscow, all projected megacities are situated in developing countries. From 2015 on, a continued growth is expected in Africa and Asia (KLEIN ET AL., 2002).

Megacities are extremely vulnerable to extreme weather events because of their high population density and capital values. The risk for loss of life is much higher in megacities in developing countries because they are not as protected by structural measures as in the developed world and thus more often subject to flooding.

Table 2-2: The world's largest cities, with projected populations in 2015 exceeding eight million (Source: KLEIN ET AL., 2002:114)¹

Rank	Agglomeration	Country	Population size (million)			Expected growth (%) 2000-2015	Rank in 1975	Rank in 2000
			1975	2000	2015			
» 1	Tokyo	Japan	19.771	26.444	26.444	0.00	1	1
» 2	Bombay	India	6.856	18.066	26.138	44.68	15	3
» 3	Lagos	Nigeria	3.300	13.427	23.173	72.59	33	6
» 4	Dhaka	Bangladesh	2.172	12.317	21.119	71.46	43	11
» 5	São Paulo	Brazil	10.047	17.755	20.397	14.88	5	4
» 6	Karachi	Pakistan	3.983	11.794	19.211	62.89	16	12
» 7	Mexico City	Mexico	11.236	18.131	19.180	5.79	4	2
» 8	New York	United States of America	15.880	16.640	17.432	4.76	2	5
» 9	Jakarta	Indonesia	4.814	11.018	17.256	56.62	22	14
» 10	Calcutta	India	7.888	12.918	17.252	33.55	12	8
» 11	Delhi	India	4.426	11.695	16.808	43.72	23	13
» 12	Metro Manila	Philippines	5.000	10.870	14.825	36.38	21	16
» 13	Shanghai	China	11.443	12.887	14.575	13.10	3	9
» 14	Los Angeles	United States of America	8.926	13.140	14.080	7.15	8	7
» 15	Buenos Aires	Argentina	9.144	12.560	14.076	12.07	7	10
» 16	Cairo	Egypt	6.079	10.552	13.751	30.32	20	19
» 17	Istanbul	Turkey	3.601	9.451	12.492	32.18	32	22
» 18	Beijing	China	8.545	10.839	12.299	13.47	10	17
» 19	Rio de Janeiro	Brazil	7.854	10.582	11.905	12.50	13	18
» 20	Osaka	Japan	9.844	11.013	11.013	0.00	6	15
» 21	Tianjin	China	6.160	9.156	10.713	17.01	19	24
» 22	Hyderabad	India	2.086	6.842	10.457	52.84	45	31
» 23	Bangkok	Thailand	3.842	7.281	10.143	39.31	28	27
» 24	Lahore	Pakistan	2.399	6.040	9.961	64.92	41	35
» 25	Seoul	Republic of Korea	6.808	9.888	9.923	0.35	16	20
» 26	Paris	France	8.885	9.624	9.677	0.55	9	21
» 27	Lima	Peru	3.651	7.443	9.388	26.13	30	25
» 28	Kinshasa	Dem. Rep. of the Congo	1.735	5.064	9.366	84.95	n/a	40
» 29	Moscow	Russian Federation	7.623	9.321	9.353	0.34	14	23
» 30	Madras	India	3.609	6.648	9.145	37.56	31	32
» 31	Chongqing	China	2.439	5.312	8.949	68.47	40	38
» 32	Teheran	Islamic Republic of Iran	4.274	7.225	8.709	20.54	25	28
» 33	Bogotá	Colombia	3.036	6.288	8.006	27.32	35	34
Total (coastal agglomerations)			150.6	254.1	324.1	27.53		
Total (all agglomerations)			217.4	368.2	467.2	26.88		

n/a: not available.

The user and production function of the coastal zone are under severe stress due to overstraining. The concentration of values and people on the small narrow stripe along the world's coastline is not only hampering environmental conditions, but is also making it vulnerable to external impacts.

2.2 Coastal hazards

The earth - a geologically active system with natural climate variability - is always facing natural anomalies or hazards. However, not every natural hazard leads to a catastrophe or disaster. Disasters actually do not exist in nature. Whether natural hazards cause a disaster or not depends on the magnitude of the hazard and the socio-economic or ecological vulnerabilities of the system being impacted.

Consequently, it has to be distinguished between *natural hazards* and *natural disasters*. Both terms have been defined in many different ways.

¹ the authors of table 2-2 made some subjective estimations concerning the definition of "coastal agglomeration", e.g. Sao Paulo is not defined coastal because it is situated at 800m above sea level, while Cairo, Dhaka, and Kalkutta (all not directly at the coast) are coastal because of their deltaic setting.

The International Strategy for Disaster Reduction, ISDR (2004) defines natural hazards as

“...natural processes or phenomena occurring in the biosphere that may constitute a damaging event”.

Natural hazards can be of hydro-meteorological, geological, or biological origin and can occur on a global, regional, or local scale. Geological hazards include earthquakes or volcano eruptions. Both of these can in turn trigger secondary hazards such as tsunamis and landslides. Hydro-meteorological (climatic) hazards include storms, droughts, precipitation, floods, fires, and oceanic hazards (BRYANT, 2005; ISDR, 2004).

Figure 2-3 gives an overview over the common hazard classification given by the ISDR (2004).

Natural disasters are the consequences or effects of natural hazards and are defined as

“...a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community/society to cope using its own resources” (ISDR, 2004).

However it must be stated that although hydro-meteorological and geological hazards underlie a natural occurrence and variability, there also exist natural hazards that are caused by human activity. Some natural forces may even be man-made from the beginning, when e.g. flooding is occurring because of deforestation or falsely planned infrastructure. While controversially discussed, there are also clear evidences that today's climate change is to a large part human induced and thus causing natural hazards such as storms or sea-level rise that are not only an inevitable force of nature.

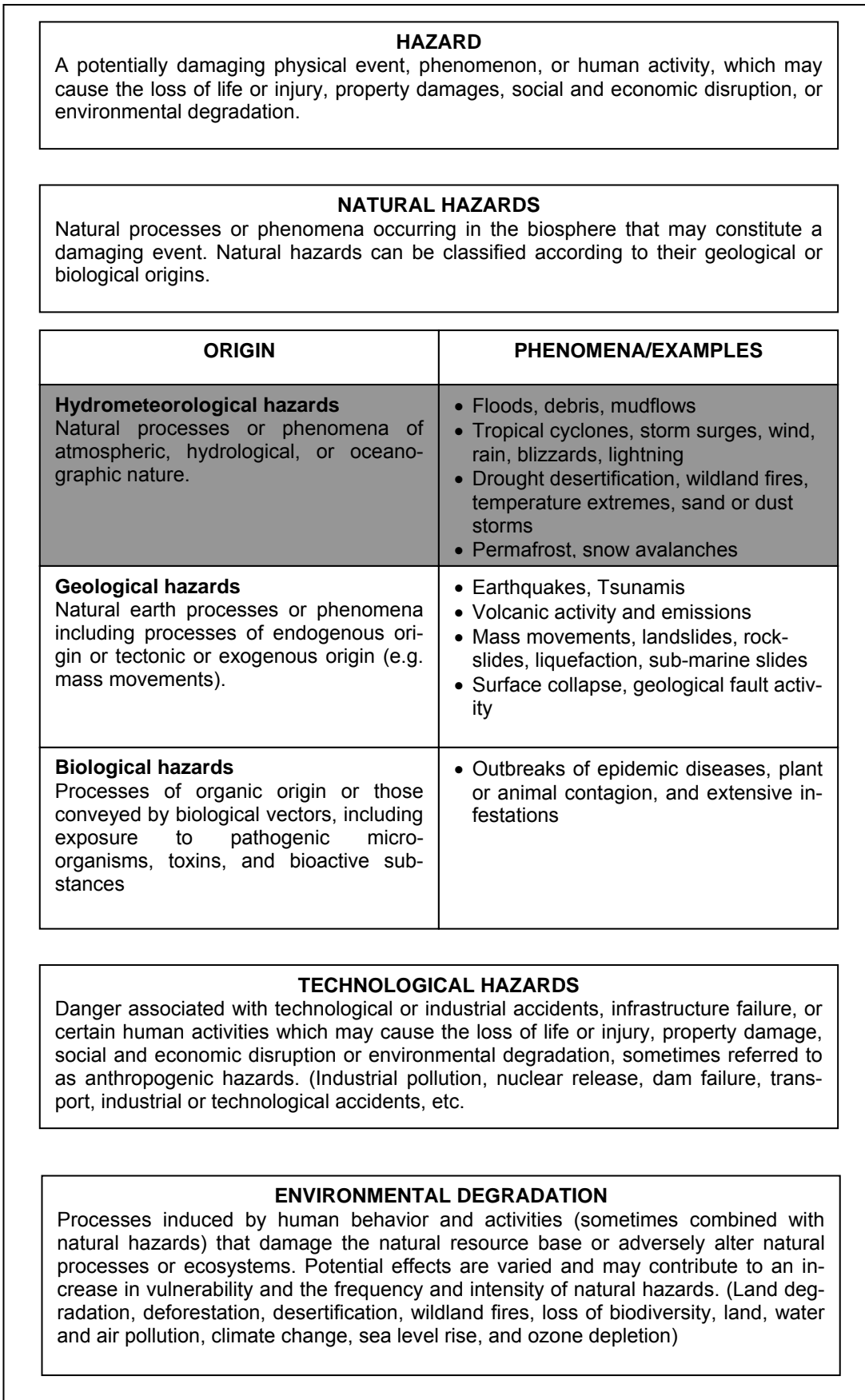


Figure 2-3: Hazard classification (Source: ISDR, 2004:39)

The occurrence of a disaster is directly linked to human presence and activity. A disaster is only caused “because people are in the wrong place at the wrong time, had no choice but to be in the way of a disaster or were caught unawares when it struck” (ISDR, 2004: xi).

It takes several vulnerability factors for a hazard to turn into a disaster. The magnitude of the impact is only one, but not its determining factor. Table 2-3 shows the wide variety of vulnerabilities that enhance the probability of disaster occurrence significantly.

Table 2-3: Enhancing factors to cause a disaster (Source: PEDUZZI, 2000:3)

Types of hazard		Contextual factors enhancing vulnerability															
		Climatic				Physical				Bio/Geo			Socio/economical				
		Precipitation	Atm. pressure	Temperatures	Wind	Elevation	Slopes	Rocks/Soils	Hydrology	Vegetation types	Distance to sea	Latitude	Economical activity	Population density	Infrastructures	Accessibility	Political System
Tectonic	Earthquake																
	Tsunami																
	Volcano	•															
	Landslide	•															
Climatic	Flood	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Drought	•		•													
	Tropical cyclone		•	•		•	•		•								•
	Global warming	•	•	•	•							•	•				•
Human induced	Forest fire	•		•	•							•					•
	Erosion	•						•	•	•	•						•
	Air pollution	•			•	•											•
	Soil pollution	•						•	•	•							•
	Water pollution							•	•	•							•
	Ozone depletion			•	•												•
Bio	Pest invasion	•		•		•	•	•	•	•							•
	Disease			•		•											•

This thesis focuses on coastal hazards. While some natural hazards such as droughts or river floods affect the entire terrestrial landscape, coastal zones are threatened especially by:

- Storms and storm surges,
- Erosion,
- Flooding, and
- Tsunamis.

2.2.1 Storms and storm surges

In terms of frequency of damage and total area affected, storms are the most significant of all natural hazards worldwide (MUNICH RE, 1998).

Storms can be divided into

- tropical storms (hurricanes, typhoons, cyclones),
- extratropical storms (winter storms),
- tornadoes, and
- regional storms (monsoon).

Tropical storms arising over warm tropical seas are called *hurricanes* in the Atlantic and Northeast Pacific, *cyclones* in the Indian Ocean and in the waters around Australia, or *typhoons* in the South Pacific when reaching 12 on the Beaufort scale (MUNICH RE, 1998). Deriving their energy from the evaporation of water over oceans, tropical cyclones can reach wind speeds up to 300 km/h with a storm area of 200-500 km. On average, a cyclone can dump 100 mm of rain per day within 200 km of the eye and 30-40 mm per day at distances of 200-400 km (MUNICH RE, 1998). Coastal regions are affected not only by the storm itself but also by the accompanying storm surges which can cause flooding, enhanced by a heavy rainfall in the aftermath. This may lead to the flooding of coastal lowlands, saline intrusion, erosion, tremendous damages, and a death threat for all people in the affected area. In regions with high economic potential and recreational values, tropical cyclones have an extraordinary catastrophe potential. In contrast, the mid latitude winter storms are recorded with a wind speed of 140 - 200 km/h and with a storm area of 2000 km.

Storm surges are a major factor determining flood risk in coastal areas all over the world. Storm surges not only claim extraordinary numbers of lives but also have an enormous damage potential. In the 10-year period from 1986 to 1995 more than 367,000 people lost their lives in natural disasters worldwide. About 55% of these deaths were due to torrents, river flooding, and storm surges (MUNICH RE, 1998).

Storm surges are characterized by a water level much higher than middle high tide line (MThw). The dimension of storm surges is determined by the shearing stress through wind on the water surface which leads to rising water tables near the coast. This can happen along tidal as well as along non tidal coasts. The character of the event is depending on the wind accumulation, which is in turn depending on wind direction, speed, and fetch. Other additional factors influencing the character of a storm surge are differences in water pressure, external water insertion, the coastal type, the depth of the shelf, as well as astronomical effects such as springtides (BRYANT, 2005). To assess the run of a storm surge, the significant storm surge curve has to be generated from:

- the actual tidal conditions,
- long term SLR,
- meteorological conditions,
- wave characteristics, and
- astronomical influences.

The last three points are summarized in the curve of wind-driven surge building the derivation between actual water level and the calculated astronomical tide, showing directly the wind and its hydrographic effects.

Storm surges cause various forms of flooding. These include wave impact and beach erosion, as well as dike overlap or breach or inundation in estuaries and coastal wetlands. The future risks are related to sea-level rise which causes a higher water level as the basis for storm surges.

2.2.2 Coastal erosion

Erosion describes the physical removal of sediment by wave and current action. Erosion is a phenomenon occurring at many coastlines, especially at soft coasts (e.g. dune coasts or barrier island coasts). 70% of the world's sandy beaches are eroding at an average rate of 0.5 to 1.0 m per yr⁻¹ (UNDP, 2004). The reasons for this are storminess, coastal submerge, decreased sediment movement, shifts in global pressure belts, changes in directional components of wave climate and human activity (BRYANT, 2005). Sea-level rise contributes to the erosion of erodible cliffs, coral-reef islands, and sandy coasts by promoting the offshore transport of sedimentary material. In addition to the direct impact of sea-level rise on coastal erosion, there is also an indirect erosional effect associated with tidal basins and lagoons. This effect is caused by a shift in the overall sediment budget, as the lagoon or tidal basin morphology responds to sea-level rise, increasing erosion on the open coast (CAPOBIANCO ET AL. 1998).

2.2.3 Coastal flooding

Coastal flooding can occur in different forms and for different reasons. A distinction between permanent inundation or episodic flooding has to be made. As a result of sea-level rise, low-lying coastal areas such as deltas, coastal wetlands, and coral atolls may face inundation and land loss. The rate of land loss depends on the slope, sediment availability and biomass production, the ecological health and ability to cope with adverse effects, as well as the potential for these ecosystems to migrate inland. Land loss from inundation is a function of ter-

restrial topography: the lower the slope, the greater is the land loss (KLEIN & NICHOLLS, 1998).

Episodic flooding is due to storm surges induced by storms and high river floods or tsunamis. Some of the most outstanding examples are the cyclones in New Orleans (2005) and Orissa (1999), the Asian Tsunami in 2004, or the "Holland Flood" in the North Sea Region in 1953. Episodic flooding does not primarily cause long-term effects such as land loss and soil degradation. Yet all the more it causes massive damages and deaths.

2.2.4 Tsunamis

Beside earthquakes, volcanoes, landslides, and mass movements geological coast specific hazards are the seldom but disastrous tsunamis. The word *tsunami* is derived from Japanese and means harbor (tsu) and wave (nami). Tsunamis are generated by shock waves associated with seismic activity, explosive volcanism, or submarine landslides (BRYANT, 2005). As seismic sea waves occur after strong seaquakes or large submarine landslides, they spread out in all directions in a great speed which depends on the depth of the ocean (MUNICH RE, 1998). Although not seen on the ocean, these waves reach gigantic heights in narrow bays. In Japan tsunamis up to 30 m have been recorded. Their waves can travel up to 10.000 km, so that even regions that are far away from the earthquake epicenter can be hit (MUNICH RE, 1998).

Investigations made by the Munich Re in the aftermath of the Asian Tsunami in 2004 specified that determining factors for the amount of damages are wave height, penetration depth of the flood, the quality of buildings, the flow velocity, and the material transported by the wave. The velocity can be very different (30 km/h in Sumatra, 70km/h in Papua-New Guinea 1998). The wave height is determined by the magnitude, depth, and fold of the quake on the ocean as well as the near coast topography. Because of this, the wave height can be different in adjacent coastal segments.

Tsunamis are rare phenomena. Yet, they are exceptionally disastrous when occurring. A statistical analysis by the National Oceanic and Atmospheric Administration, NOAA (2003) contains all global tsunami occurrences from 1983 to 2001. According to this statistics, a total number of 157 tsunamis have occurred around the globe. Except for 19, all of these occurred in the Pacific, the others in the Indian Ocean (2), the Mediterranean (9), Red Sea (1), the South Chinese Sea (1), the Marmara Sea (1) and the Caribbean (5). 30 of these tsunamis caused damages.

2.3 Climate change and coastal zones

In the last years a human induced climate change - superimposing natural hazards - became more obvious. This climate change increases the magnitude and frequency of hydro-meteorological hazards and also leads to an increasing risk of extreme events and a changing underlying vulnerability. In order to assess the latest research results on climate change and its impacts, options for mitigating climate change, and adaptation to it, the Intergovernmental Panel of Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and The United Nations Environmental Program (UNEP) in 1988. The IPCC provides scientific, technical and socio-economic advice to the Conference of Parties (COP) and the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC was established in 1995 to reduce the greenhouse gas emissions and mitigate the effects. It was ratified by 175 countries at the end of the 20th century. The latest report which contains the scientific results on climate change is the Third Assessment Report (TAR), which was published in 2001.

In the 20th century, climate changes were going on. Including a global warming that, taking into account the remaining uncertainties, is likely to have been due to the increase in greenhouse gas concentration over the last 50 years. Furthermore, it is very likely that the 20th century warming has contributed significantly to the observed sea level rise. This is due to thermal expansion of sea water and the widespread loss of land ice (IPCC, 2001: 10). The future impacts of this climate change will depend to a large extent on the future economic, demographic, social, and political characteristics to the world.

The IPCC concluded the following most important results about climate change and impacts and described them in the TAR (IPCC, 2001) as follows:

- The atmospheric concentration of carbon dioxide (CO₂) has increased by 31% since 1750. About three-quarters of the anthropogenic emissions of CO₂ to the atmosphere during the past 20 years are due to fossil fuel burning. The remaining amount is predominantly due to land-use change, especially deforestation. The rate of increase of atmospheric CO₂ concentration has been about 1.5 ppm⁹ (0.4%) per year over the past two decades; the atmospheric concentration of methane (CH₄) by 1060 ppb⁹ (151%) and the atmospheric concentration of nitrous oxide (N₂O) by 46 ppb (17%). The radiative forcing due to increases of the greenhouse gases from 1750 to 2000 is estimated to be 2.43 Wm⁻². The total amount of O₃ in the troposphere is estimated to have increased by 36% since 1750.
- The global average near surface temperature has increased since 1861. In the 20th century, the increase was 0.2 - 0.6°C. The last 100 years adapted the greatest increase in the last 1000 years. According to RAHMSTORF & SCHELLNHUBER (2006), the years 2002, 2003, 2004, and 2001 were the warmest years with a new record in 2005.

- The average arctic air temperatures increased by 5°C in the 20th century, ten times faster than the global mean surface temperature. Arctic sea-surface temperatures rose by 1°C over the past 20 years (UNEP). It is very likely that the extent of snow cover has decreased by 10% since the late 1960s. There has been a reduction of about two weeks in the annual duration of lake and river ice cover in the mid- and high latitudes of the Northern Hemisphere as well as widespread retreat of mountain glacier in non-polar regions during the 20th century. Northern Hemisphere spring and summer sea-ice extent has decreased by about 10 to 15% since the 1950s. It is likely² that there has been about a 40% decline in Arctic sea-ice thickness during late summer to early autumn in recent decades and a considerably slower decline in winter sea-ice thickness. Precipitation increased in the Antarctic.
- Sea level has risen 0.1-0.2 meters during the 20th century. It is very likely that global warming has contributed significantly through thermal expansion of sea water and widespread loss of land ice. 70% of sandy shorelines have retreated over the past 100 years. Seawater is seeping into freshwater aquifers and intruding into estuaries in low-lying coastal areas around the world, particularly on low-lying islands. Global ocean heat content has increased since the late 1950s.
- It is very likely that precipitation has increased by 0.5 to 1% per decade in the 20th century over most mid- and high latitudes of the Northern Hemisphere continents, it is also likely that rainfall has increased by 0.2-0.3% per decade. Rainfall has generally declined in the tropics and subtropics; desertification has been exacerbated. More, in Africa's large catchment basins of Niger, Lake Chad, and Senegal, total available water has decreased by 40-60%. An increase in frequency and intensity of droughts in Asia and Africa is recorded.
- An increase in frequency, intensity, and duration of El Nino has occurred since the 1970s.

Today, there are reliable research results which state that global warming is leading not only to an increase in the frequency and intensity of exceptional weather events, but also to new kinds of weather risks³ and greater loss potentials that are linked to climate change (MUNICH RE, 2005).

2.3.1 Climate change in the 21st century – a scientific outlook

The IPCC (2001) emphasizes that human influence will continue to change atmospheric composition throughout the 21st century, especially emissions of CO₂ due to fossil fuel burning. Even if atmospheric greenhouse gas concentrations may be stabilized, the consequences - including increasing global mean temperatures - will continue over the next decades.

² likely = 60-90% chance (TAR)

³ e.g. Hurricane Alex in the region of 40°N, far from the tropics or Florida hit by four hurricanes in a few weeks, making it the costliest hurricane season

Most of the climate change scenarios are based upon highly complex general circulation models (GCMs) of the atmosphere and the ocean. To get a realistic view on how the climate will develop in the future, the so-called SRES (Special Report on Emission Scenarios) was developed for modelling a future climate development. The scenarios model future emissions of greenhouse gases and aerosols on the basis of population and economic growth, land use, technological changes, availability of energy. Four different narrative storylines were developed to describe the relationship between the forces driving emissions and their evolution and to add context for the scenario quantification. For each storyline, several emission scenarios were constructed producing four “scenario families” (A1, A2, B1, B2, cf. figure 2-4).

With the help of the scenarios assumptions concerning the future climate were made in the TAR (IPCC, 2001):

- The global average surface temperature is projected to increase by 1.4 to 5.8°C over the period from 1990 to 2100. The projected rate of warming is much larger than the observed changes during the 20th century and is very likely to be without any precedent during at least the last 10,000 years.
- Both the Arctic and the Antarctic are expected to continue warming. The far north will be threatened by thawing permafrost (e.g. damage of buildings, pipelines, roads). The rest of mankind will be affected by sea-level rise. Polar regions also drive the oceans circulation. Most models show a weakening of the ocean thermohaline circulation; this leads to a reduction of the heat transport into high latitudes of the Northern Hemisphere. Northern Hemisphere snow cover and sea-ice extent are projected to decrease further. Glaciers and ice caps are projected to continue their widespread retreat during the 21st century.
- Global warming will lead to more extreme precipitation events and worse river flooding such as the Rhine floods of 1996 and 1997, the Chinese floods of 1998, the Eastern European floods of 1998 and 2002, and the Mozambique and European floods of 2000. Meanwhile, Central Asia, the Mediterranean region, the Sahel, and parts of Africa, Australia, and New-Zealand are expected to get drier. Water quality and freshwater supply are endangered by sea water.
- Extreme events will increase in frequency and intensity.

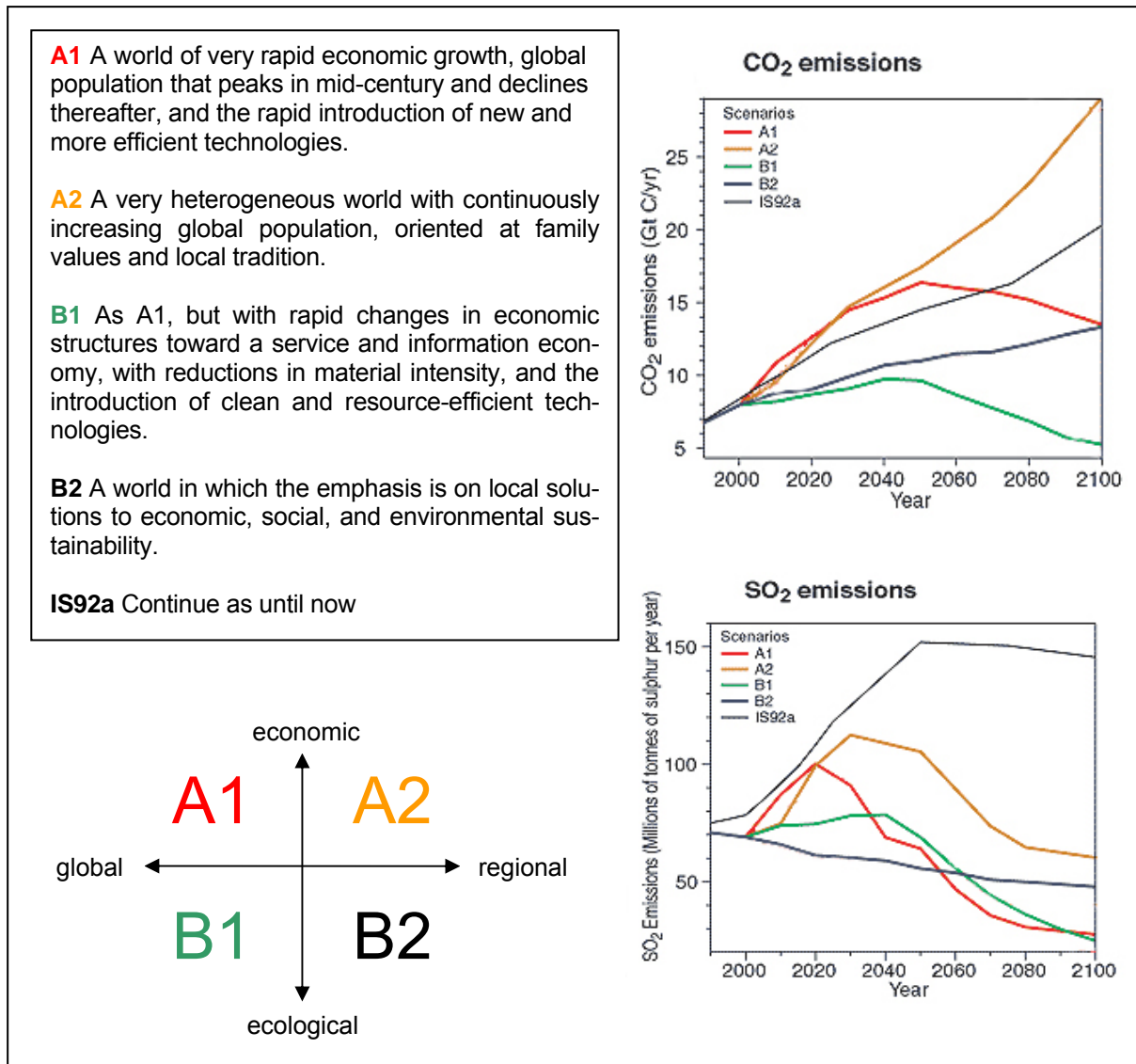


Figure 2-4: SRES scenarios (Source: IPCC, 2001:10, changed)

2.3.2 Accelerating sea level rise jeopardizing coastal zones

The level of the ocean has always fluctuated according to global temperature changes (NICHOLLS & LEATHERMAN, 1995). In connection with climate change and a global warming, and accelerating sea level rise (ASLR) is assumed. For coastal zones, the predicted sea-level rise is one of the most threatening consequences of climate change. A rise of 10 cm has already been recorded. This is noticeable in low lying areas and islands. Due to thermal expansion and loss of mass from glaciers and ice gaps the global mean sea level is projected to rise to an average 48 cm between 1990 and 2100 for the full range of SRES scenarios (cf. figure 2-5). The main contributions to this sea-level rise are: thermal expansion (0.11-0.43 m), glacier contribution (0.01 to 0.23m), Greenland contribution (-0.02 to 0.09 m), and Antarctic contribution (-0.17-0.02).

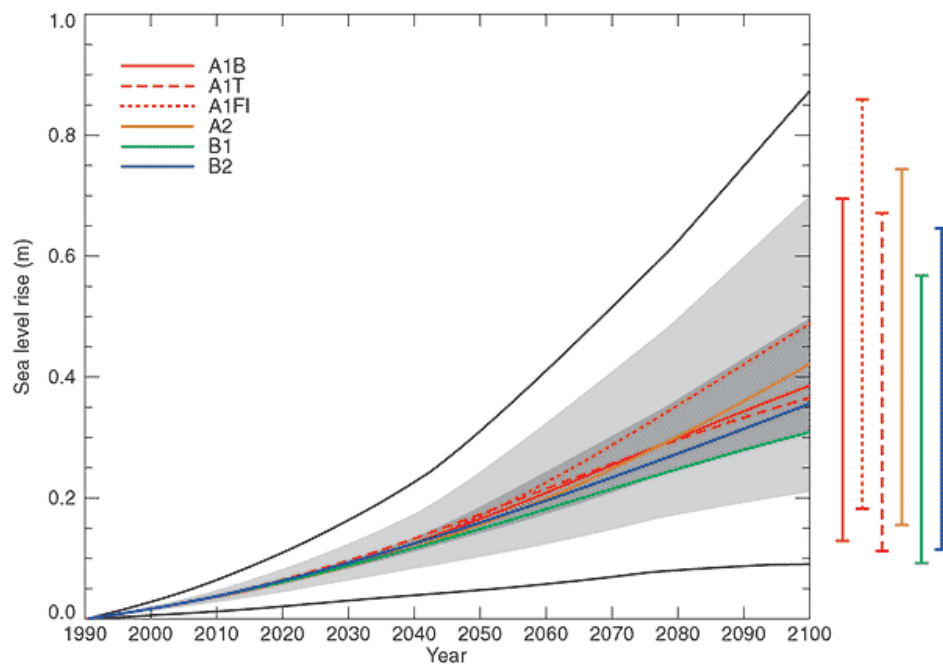


Figure 2-5: Sea level rise scenario (Source: IPCC, 2001:11)

Sea level rise is a slow, long lasting process which continues long after a given impact. Even if atmospheric greenhouse gas concentrations would be stabilized or reduced considerably in the next few decades, ASLR will continue due to lags in the climate system. This has been termed the *commitment to sea level rise* (WIGLEY, 1995).

The local change in sea-level depends on the sum of global, regional and local factors and is termed *relative sea-level change* (NICHOLLS & LEATHERMAN 1995).

Relative sea-level changes depend on regional atmospheric and oceanic changes such as the thermal expansion of the upper ocean layers due to higher sea surface temperature (*steric effect*), melting of Arctic and Antarctic ice sheets and mountain glaciers (*eustatic effect*), on regional and local uplift and subsidence of the land as a consequence of Pleistocene ice sheets (*isostatic effect*), sinking of the underground due to sediment movement and changes in terrestrial water reservoirs. Coastal areas such as deltas as well as cities built on geologically-young sediments are subsiding rapidly due to both natural and human-induced subsidence (NICHOLLS, 1995). Examples of cities that have subsided as a result of groundwater exploitation are Venice, Bangkok, Shanghai, and Tokyo. These areas will experience a relative sea-level rise even with no global rise. Other areas are experiencing uplift, e.g. in high latitudes which were formerly glaciated such as Scandinavia.

2.4 Coastal risks and disasters

The previous chapters outlined the susceptibility of the coastal zone. Only little disturbances such as a small flood may harm society as well as interference by humans may disturb natural processes or ecological conditions which in turn influences society again.

Climate change may not only enhance the most threatening extreme events (e.g., through increasing storminess and changing weather patterns), but it will also have strong influence on water temperature and quality, changes in salinity, and ocean circulation. Thus it aggravates long-term biogeophysical effects, such as sea-level rise, growth of estuaries, flooding, worsening extent of storm impacts and storm-surge floods, shoreline erosion, sediment deficits, saltwater intrusion into coastal aquifers and loss of coastal wetlands and mangroves as well as stress of coral reefs.

Table 2-4 lists the socio-economic sectors and the biophysical impacts related to climate change.

Table 2-4: Direct socio-economic impacts of climate change on sectors in coastal zones (Source: KLEIN & NICHOLLS, 1999:183)

Sector	Biogeophysical effect					
	Flood frequency	Erosion	Inundation	Water table rise	Saltwater intrusion	Biological effects
Water resources			X	X	X	X
Agriculture	X		X	X	X	
Human health	X		X			X
Fisheries	X	X	X		X	X
Tourism	X	X	X			X
Human settlement	X	X	X	X		

An ASLR will especially threaten low-lying coastal regions such as Bangladesh or the Maldives, being not only at risk of potential permanent inundation, but also of increasing frequency and intensity of flooding due to storm floods.

Coastal societies will be affected by sea-level rise causing economic impacts on fisheries, property and infrastructure, recreation facilities, and by a risk of life loss. Sea-level rise will cause primary as well as secondary effects, affecting the people living in the coastal zone, the capital invested in that area and the possibilities for land use, such as agriculture (cf. table 2-5).

Table 2-5: Primary and secondary effects of sea-level rise (adapted from STERR 2001, KLEIN & NICHOLLS, 1998)

Primary impacts of sea-level rise	Secondary impacts of sea-level rise
<ul style="list-style-type: none"> • Increased coastal erosion • Inundation, especially of coastal wetlands and other lowlands • Increased risk of storm surges, storm damages, and flooding • Salinization of surface and groundwater through saltwater intrusion • Encroachment of tidal waters into estuaries and river systems by rising water tables 	<ul style="list-style-type: none"> • Impacts on livelihoods and human health Direct threats to human life due to flood risk, threats to food production capacity including decline in irrigation water quality, decline in coastal crop yields, and degradation/disappearance of crucial ecosystems such as mangroves, corral reefs, decline in health/living standards as a result of decline in drinking water quality, threat to housing quality, associated increasing health hazards linked to relocation, and spreading of disease vectors • Displacement and vulnerable populations • Impacts on infrastructure and economic activity Decline in land and housing property, threats to major infrastructure like strategic harbours, coastal roads, railways, coastal protection works, threats to major coastal industry and services, such as oil/petrochemical plants and tourism, recreation and transport functions • Diversion of recourses to adaptation responses Increasing protection costs which may not be affordable to certain developing countries unless substantial aid is obtained, increasing insurance premiums • Political and institutional instability, social unrest • Threats to particular cultures and ways of life • Changes in water management, salinity and biological activity, agriculture, and aquaculture through decline in soil and water quality

Globally, 197 million people live in the risk zone being exposed to hazards and coastal flooding, ten million suffer from flooding every year (NICHOLLS, 2002). More, the number of people who are affected by flooding will increase due to growing coastal population, including net coastward migration across the globe and settlement in areas that were previously avoided (BIJLSMA ET AL., 1996). Without adaptation strategies, the number of people at risk will increase rapidly (DETR, 1997; cf. figure 2-6).

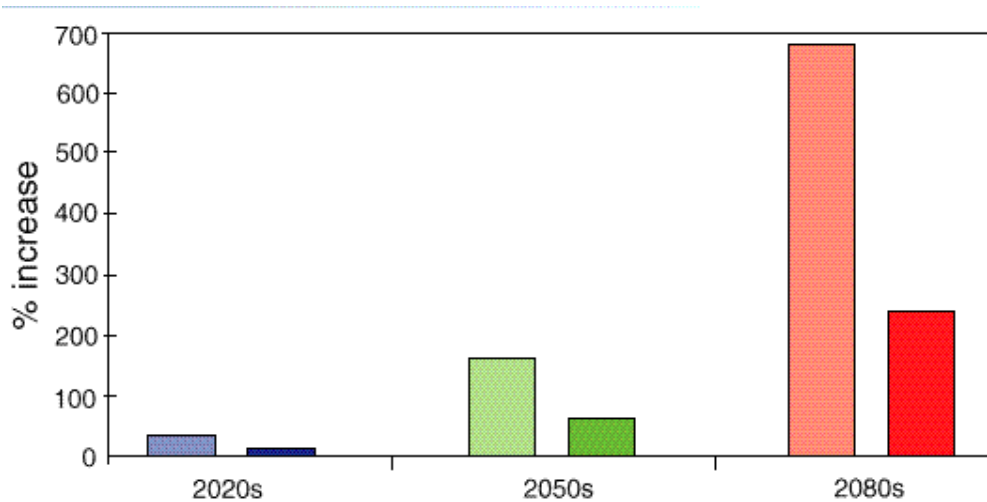


Figure 2-6: Percentage change in the number of people at risk under the sea-level rise scenario and constant (1990s) protection (left bar) and evolving protection (right bar) (Source: DETR, 1997:14)

Especially in developing countries, many people are suffering from this development. The death toll in connection with extreme events is much higher than in developed countries, where coastal protection reduces the risk of loss of life on the one hand. Yet on the other hand economic losses are increasing rapidly.

Small island states (SIDS) are the regions most vulnerable to the impacts of climate change because they are characterized by small size (island), soft coasts, near coast buildings and settlement, limited natural resources, great exposure to water and coastal processes, great exposure to extreme weather events, and an open economic structure extremely sensible to external impacts.

The coastal tourism sector is affected by climate change and natural hazards in different ways. Some regions will benefit from climate change because they improve their conditions from the point of tourism. In other regions tourists will stay away because temperatures rise to high, other regions will receive tourists for the first time. As a consequence of global warming mediterranean destinations might become intolerable hot, while northern destination will become a more pleasant climate. Especially small island states are very sensitive to climate change and at the same time heavily depending on tourism. For some of them the economy-wide contribution of tourism counts for more than half of their total GDP, e.g. in the Seychelles (60%), the Maledives (63%), Antigua (86%), and Aruba (71%) (AMELUNG, 2006). The most Caribbean states with their small populations and generally mono-crop economies for example suffer from every single disaster.

Climate change and extreme events will have impacts on coastal tourist destinations, such as

- beach loss due to erosion and flooding, loss of accommodations,
- salinization of freshwater reservoirs, water conflicts,
- disturbance of mangroves, and coral reefs, and
- disturbance of infrastructure by tropical storms.

Research on climate change and tourism has grown concerning environmental matters and climate change (HAMILTON, 2004; VINER & AGNEW, 1999; AMELUNG, 2006) and the conference on climate change and tourism in 2003, organized by the World Tourism Organisation (WTO), raised awareness of the issue.

Wetlands are not so much threatened by short-term fluctuations of the sea level or singular extreme events, because they have buffer capacities to recover from these impacts. Yet they are susceptible to long-term sea-level rise and changes in sea surface temperature and show a dynamic and non-linear response (NICHOLLS ET AL., 1999). It is estimated that sea-level rise of 1 m could threaten up to half of the world's coastal wetlands (>168,000 km²), while those that survive could be substantially changed (HOOZEMANS ET AL., 1993). The ability to cope with sea-level rise greatly depends on the rate of vertical accretion of intertidal areas, salt marshes, and mangroves. This rate is determined by the tidal characteristics, sediment availability, and ecological processes.

Healthy coral reefs are likely to be able to keep up with sea-level rise, but this is less certain for reefs degraded by coral bleaching, UV-B radiation, pollution, and other stresses. Episodes of coral bleaching over the past 20 years have been associated with several causes, including increased ocean temperatures. Future sea-surface warming would increase stress on coral reefs and result in increased frequency of marine diseases. (IPCC, 2001)

The occurrence and the impacts of natural disasters are analyzed by different institutions and under different aspects. The Natural Hazard Research and Application Information Center (NHRAIC) in the United States assesses all events with at least 100 deaths and damages of about US\$ 1 Mio., but excluding droughts. The RFF (Resource For the Future) database in Washington D.C. already defines an event with a death toll of 25 as a disaster. The Centre for Research on the Epidemiology of Disasters (CRED) in Belgium defines a catastrophe where 10 deaths, 100 concerned, and additionally a demand for international help are documented (SMITH, 2001)

The MUNICH RE insurance analyzes the global and national damages of natural disasters worldwide. Figure 2-7 illustrates a chart showing the number of natural catastrophes from 1950 to 2005 (MUNICH RE, 2006). According to the MUNICH RE there has been an increase in frequency and intensity of natural disasters since 1950. Even the amount of damages increased from 1950 to 2005 from US\$ 10bn to US\$ 170bn (cf. figure 2-8). Yet, year 2005 has broken all negative records. Natural catastrophes have never been that expensive, either for the world's economies or for the insurance industry. The year 2005 has also been one of the deadliest years in recent decades (MUNICH RE, 2006).

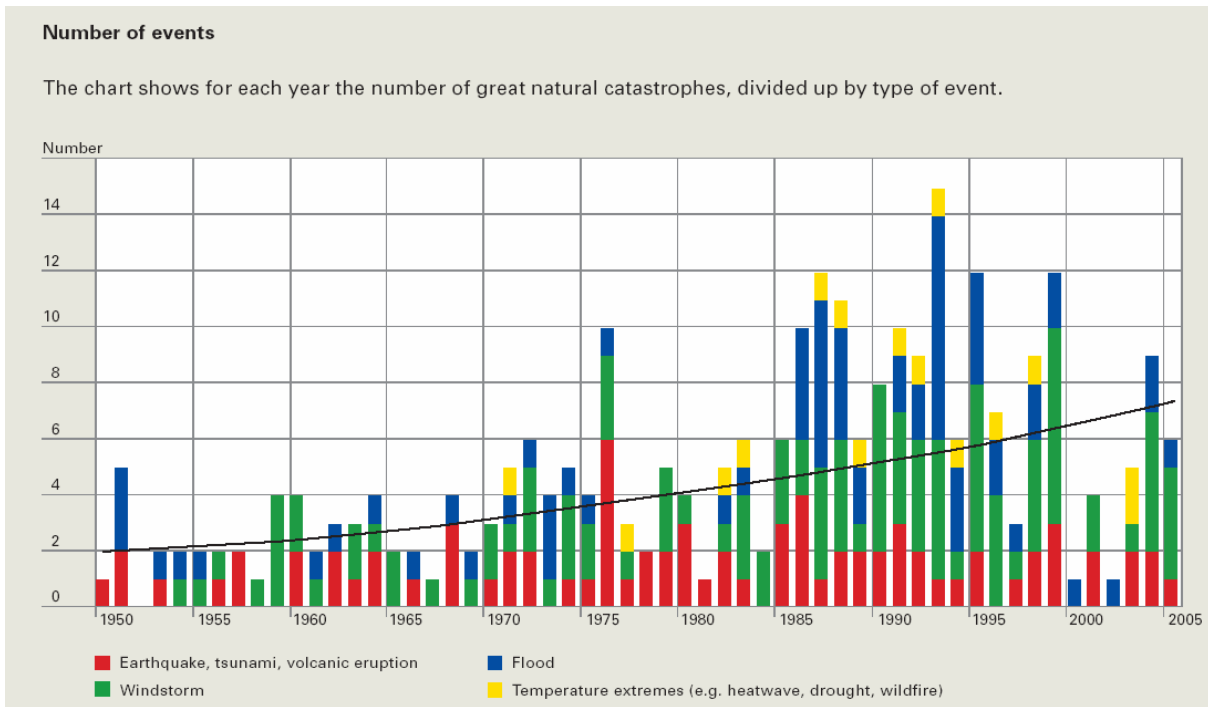


Figure 2-7: Number of natural catastrophes (Source: MUNICH RE, 2006:13)

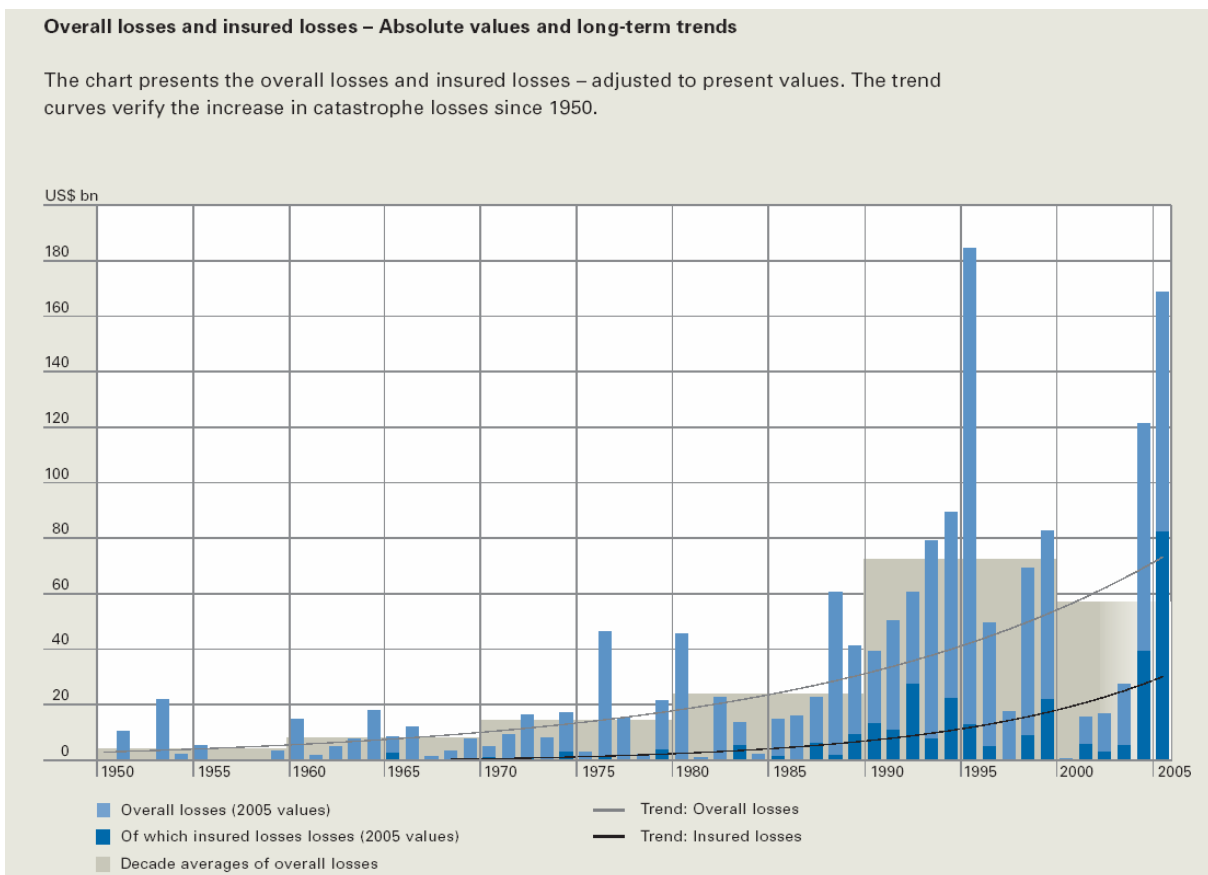


Figure 2-8: Economic losses and insured losses (Source: MUNICH RE, 2006:13)

The sharp increase of damages is not only caused by the increasing number of events but also by an increase of economic values destroyed by natural hazards. Table 2-6 compares the ag-

gregated losses of recent decades, making clear the increase in both number and extent of losses due to natural catastrophes.

Table 2-6: Losses in US\$bn (2005 values) (Source: MUNICH RE, 2006:12)

Decade	1950–1959	1960–1969	1970–1979	1980–1989	1990–1999	Last 10 years
Number of events	21	27	47	63	91	57
Overall losses	48.1	87.5	151.7	247.0	728.8	575.2
Insured losses	1.6	7.1	14.6	29.9	137.7	176.0

A comparison of the last ten years with the 1960s reveals a dramatic increase.

last 10:60s
2.1
6.6
24.8

Losses in US\$ bn (2005 values)

Statistics of the CRED show that the reported number of weather-related disasters worldwide has doubled since the mid 1990s. From January to October 2005, an estimated 97,490 people were killed in disasters globally, and 88,117 of them in natural disasters, according to CRED. The increase in the number of natural disasters is due to many factors. One factor is improved information and reporting. Yet, it is apparent that the most significant factor is the increased vulnerability of humanity due to socio-economic changes such as the steady growth of human population, urbanization, inappropriate land-use planning (building on floodplains or areas vulnerable to erosion or coastal storms), the expanding financial value of homes and infrastructure, the availability of insurance and environmental degradation like deforestation (WISNER ET AL., 2004; BURTON, 1993, SMITH, 2005). However it is striking that the frequency of weather-related events such as floods and cyclones has increased dramatically, while the number of reported earthquakes has been very steady (with an annual range of 20 to 40 events (PEDUZZI, 2004b; cf. figure 2-9).

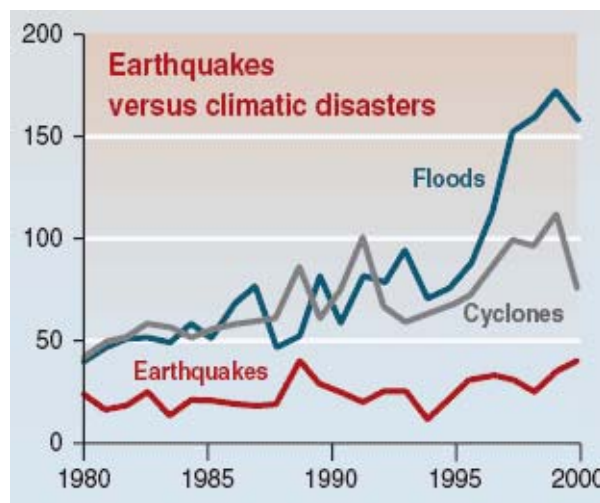


Figure 2-9: Trends in number of reported Events (Source: PEDUZZI, 2004:1)

2.5 Hazard reduction and adaptation to climate change

Until the middle of the 20th century, hazards were considered quite separate from society. They were assumed to be a natural phenomenon which is unavoidable or an act of god. In 1936, Gilbert White was the first researcher who introduced social aspects in the context of natural hazards, recognising the important role of human behavior in connection with disasters.

Meanwhile, there is a long history of human adaptation to natural hazards and developing strategies to reduce the risks and to protect societies.

BURTON ET AL. (1993) give an overview of approaches humans and societies make toward hazard reduction (cf. table 2-7):

Table 2-7: Generic approaches to hazard reduction (Source: BURTON ET AL., 1993:769)

Purposeful adjustment	Option
Choose change	Change location
	Change use
Reduce losses	Prevent effects
	Modify event
Accept losses	Share loss
	Bear loss

They distinguish between choosing change, reducing losses, and accepting losses. By choosing change, people accept the hazard or threat as an inevitable natural phenomenon and avoid it by changing location or accommodating land use in a fitting way. Reducing losses means to mitigate the losses and damages of a hazard event, for example through protection measures such as coastal defense or early warning systems. The last option is to accept the hazard as given, taking no proactive steps and instead acting reactive to bear the loss and establishing strategies for recovery, e.g. insurance.

Climate change research brought new aspects to the field of hazard reduction.

Assuming that climate change is partly man made, leads to a change in the former view of the inevitableness of natural hazards. Instead, the insight that humans are able to influence global warming by influencing the greenhouse concentration leads to mitigation activities.

Mitigation aims at reducing emissions of greenhouse gases and enhancing their sinks to stop global warming. Mitigation demands are manifested in many policy relevant institutions (e.g. UNFCCC, IPCC). The political manifest is the Kyoto Protocol ratified in 2005 as an international agreement of the UNFCCC. This protocol defined the goal to reduce greenhouse gas emissions by 5% until 2012, compared to 1990. Mitigation, if successful, requires a long time

to function and thus can operate in the far future, yet not today, giving the role of adaptation more importance.

Adaptation aims at reducing the risks and adverse impacts of climate change through numerous actions.

Adaptation strategies are currently further developed, yet, they have been neglected in former times. KATES (1997) explains the former negligence of adaptation by the existence of two schools of thought about climate change. The *preventionist school* focuses on emission reduction, fearing that too much attention on adaptation would weaken efforts in order to reduce emissions. The *adaptationist school* refers to the system's natural adaptation capacities to changing conditions where active adaptation only will produce costs. KLEIN & MACIVER (1999) define a third *realist school*, which considers adaptation as a crucial response option besides mitigation.

Adaptation can be *autonomous*, i.e. without intervention of an informed decision maker or *planned*, with strategic action based on the awareness that climate is changing and response action is needed. Adaptation can be either *reactive*, taking place after impacts or *pro-active*, taking place before impacts are apparent (KLEIN & MACIVER, 1999, cf. figure 2-10).

		Proactive	Reactive
Natural Systems			<ul style="list-style-type: none"> • Changes in length of growing season • Changes in ecosystem composition • Wetland migration
	Private	<ul style="list-style-type: none"> • Purchase of insurance • Construction of houses on stilts • Redesign of oil-rigs 	<ul style="list-style-type: none"> • Changes in farm practices • Changes in insurance premiums • Purchase of air-condition
Human Systems	Public	<ul style="list-style-type: none"> • Early-warning systems • New building codes, design standards • Incentives for relocation 	<ul style="list-style-type: none"> • Compensatory payments, subsidies • Enforcement of building codes • Beach nourishment

Figure 2-10: Pro-active and reactive adaptation measures as a response to climate change-related impacts (Source: KLEIN, 2003:19)

Three distinct adaptation strategies for coastal zones which are most widely applied today can be identified (IPCCm 2001):

- Protection – reducing the risk of coastal hazards by decreasing their probability of occurrence
- Accommodation – increasing society's ability to cope with the effects of coastal hazards
- Retreat – reducing the risk of coastal hazards by limiting their potential effects

The ability to adapt, the *adaptive capacity*, varies among regions countries and socio economic groups. It is a function of wealth, scientific and technical knowledge, information, skills, infrastructure, and equity.

BRUCE (1999) lists six categories of adaptation;

- warning systems,
- preparedness,
- safe buildings,
- water structure safety,
- other infrastructure safety, and
- land use planning.

The strategy to reduce losses by protection is the most common in the developed world, where the financial resources to apply them are given. Yet protective measures, e.g. dike building can never guarantee a 100% safety. Technical measures always carry a risk of failure due to unexpected natural forces. In the case of failure, damage and losses might be much higher than without technical measures, because the concerned societies may not be sufficiently prepared and values in potential flood prone sites are potentially higher than they would have been without technical measures.

Increasingly concerned about the impacts of disasters, the UN General Assembly declared 1990s the International Decade for Natural Disaster Reduction (IDNDR). The IDNDR was established to urge all countries to have comprehensive national assessments of risks from natural hazards in place by the year 2000. The IDNDR organized the World Conference on Natural Disaster Reduction (WCNDR) in Yokohama in 1994. This conference conceived the *Yokohama Strategy and Plan of Action for a Safer World* (Yokohama strategy) which stressed that every country has the primary responsibility to protect its people, infrastructure and national, social, and economic, and ecological assets from the impact of natural disasters. Additionally, the strategy emphasized the urgent need to move from a mainly reactive approach to disaster mitigation to a more comprehensive approach that includes preventive measures, which are mainly aimed at reducing the likelihood of translating a natural hazard into a disaster.

The United Nations (UN) Millennium Declaration, adopted in 2000 notes the importance of reducing “the number and effects of natural and man-made disasters” (UN, 2000:23). Furthermore plans were included to develop early warning systems and vulnerability maps for improving research on the causes of disasters and to incorporate disaster risk reduction into national planning processes.

In its *Hyogo Framework for Action 2005-2015*, the World Conference on Disaster Reduction (WCDR) in Kobe, January, 2005 promotes “a strategic and systematic approach to reducing vulnerabilities and risks to hazards” by underscoring “the need for building the resilience of nations and communities to disasters” (A/Conf.206/L.2/Rev.1:3). Further, it is proposed to enhance international cooperation and assistance in the field of disaster risk reduction, including knowledge transfer, sharing research results, enhanced governance, financial assistance to reduce existing risks, and setting-up of governance systems that can avoid the generation of new risks. In order to identify, assess and monitor disaster risk as well as enhance early warning, the Kobe strategy listed some the key activities:

- national and local risk assessments (risks maps, indicators of disaster risk and vulnerability),
- early warning (people centered, information on systems, institutional capacities, better cooperation),
- capacity building (support of infrastructures, databases, and methods), and
- regional and emerging risks (cooperation, early warning, research on long-term changes such as climate change, demographic changes or environmental degradation).

Many communities and regions that are vulnerable to the consequences of climate change are also under pressure from forces such as population growth, resource depletion, and poverty. The actual hazard reduction strategy chosen will depend on local and national circumstances, including the economic and ecological importance of the coastline, the technical and financial capabilities, and the legislative and political structure of the countries concerned.

Traditionally, decision makers have chosen the “appropriate” protection level to be achieved based on the knowledge of the technical flood protection possibilities. For example, in the Netherlands the state is responsible for the coastal regions to have a protection level which ensures security even against extreme flood events with a frequency of occurrence being up to once in ten thousand years. In recent times, coastal flood protection is not only shifting from hard protection (seawalls) to soft protection (beach nourishment), but also from technically oriented flood defense measures to risk management, that involves even aspects but also socio-economic factors and thus it is a more interdisciplinary and holistic view on flood management.

Under changing conditions, more complex interests, and claims for specific use play a more crucial role, determining the potentials of risk reduction as well as their respective costs.

Hence, there is an increasing significance to further develop risk assessment methods which deliver decision support in coastal risk management policy.

3 Risk and vulnerability assessment

Hazards only translate into disasters when societies are vulnerable to them. Research and policy can play a role in reducing the costs of disasters by addressing vulnerability.

Dayton-Johnson, 2004

To protect natural and socio-economic values at risk in coastal zones, it is important to identify the problems that various coastal areas may face. More it is important to point out their possible solutions. In order to understand how people are affected by hazards, it is not enough to understand the hazards themselves. Disasters happen when a natural phenomenon affects a population that is inadequately prepared and unable to cope without external assistance. Vulnerability is the term used to describe the condition of such societies. It results from the impacts on the coastal system, involving not only the likelihood of being killed by a particular hazard, but also the type of livelihoods in which people live and the impact of different hazards on them. As every system has latent abilities to cope or adapt, the vulnerability is the degree of system changes, which remains as negative impact; it is vulnerability that finally turns a hazard into a disaster. The IPCC (1991) announced: “the first step in effectively managing a threat is to understand the nature and implications of the threat and the vulnerability of people, their values and the environment to the potential impacts of the threat. The preparation of an assessment which analyses the vulnerability sets the agenda for the efforts to be undertaken to prevent disasters, minimize the risk and manage the consequences”.

3.1 Concepts and terms

Risk is a common concern we undergo in our daily lives which are being steadily triggered by natural hazards, technological risks (e.g. nuclear power stations) or epidemics.

Risk arises from a hazard affecting a system and the system's vulnerability to this hazard. The terms *hazard* and *risk* are sometimes confused in literature, but have to be distinguished essentially. While *hazard* describes a natural or human induced event, a process or condition which leads to a potential harm or loss for humans and their goods, the term *risk* additionally implies the probability of the occurrence. The distinction is illustrated by OKRENT (1980; in SMITH, 2001): “Two people crossing an ocean, one in a liner and the other in a rowing boat.

The main hazard (deep water and large waves) is the same in both cases but the risk (probability of capsize and drowning) is very much greater for the person in the rowing boat". Consequently you are exposed to hazards but you take the risk by making decisions (KAPLAN & GARRICK, 1997:93).

The discussion about risk occurred predominantly in civil use and nuclear energy before it became increasingly meaningful in the field of natural hazards and coastal management. An essential difference between the risk considerations of technological risk to natural risk is the threatening element itself. While technological risks are human made, risk research on the field of natural hazards considers a phenomenon of nature that cannot be eliminated totally. The research on risk eventually aims at avoiding or reducing risks and losses. The understanding and the knowledge of risk provides basic information for decision making, enables some future prognoses, allows the selection of appropriate alternatives or strategies, and is an essential part of perception and everyday action.

Hence risk is the probability of harmful consequences or expected losses resulting from interactions between natural or human-induced hazards and vulnerable conditions. Risk encloses the uncertainty and describes the dimension of possible damages and losses caused by a natural event in a specific area.

There is no consistent definition of risk. Instead various definitions exist in different research disciplines. The majority of natural scientists define risk as the mathematic product of the occurrence probability and the amount of losses. (e.g. HOLLENSTEIN, 1997; JHC, 2000; PLATE & MERZ, 2001; SMITH, 2001).

Formula (1) is mostly applied in technical risk analysis, for example in coastal defense planning or in the insurance industry.

$$(1) \quad (Risk = Probability\ of\ Occurrence \times Damages)$$

Away from this technical definition, in the 1970s and 1980s the concept of vulnerability introduced socio-economic aspects and cultural structures to the risk process. It is argued that to implement risk management it is not adequate only to deal with the hazard threat. Rather the risk manager has to design policies to reduce vulnerability (BLAIKIE ET AL. 1994; WISNER ET AL., 2004, definition (2)).

$$(2) \quad (Risk = Hazard \times Vulnerability)$$

From the point of social science, these more technical approaches do not consider the societal aspects sufficiently. The capacities of people to cope with the impacts of hazards play an increasingly important role in the context of risk. The ISDR (2004) therefore defines risk as a function of the hazard, the vulnerability of which is exposed, a function of susceptibility to loss and the capacity to resist and recover:

$$(3) \quad (Risk = \frac{Hazard \times Vulnerability}{Capacity})$$

Definition (3) is based on the assumption that disasters always produce victims who have no strengths or capacities to resist and recover. In other words risk can be described as a function of exposure, sensitivity of values and coping capacity. Here hazards can be seen as an external factor, whereas vulnerability is an internal factor.

Based on TOBIN & MONTZ (1997), PEDUZZI ET AL. (2004a: 4) define risk as “a measure of the expected losses due to a hazard event of a particular magnitude occurring in a given area over a specific time period.” They argue that no risk exists if no hazard exists or nobody lives in the affected area and used the formula:

$$(4) \quad (Risk = Hazard \times Population \times Vulnerability)$$

This work applies definition (3), whereby the capacity can be seen as a counterpart of the vulnerability, because it weakens the degree of vulnerability (cf. figure 3-1). Capacity is defined here as

“...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” (ISDR, 2004).

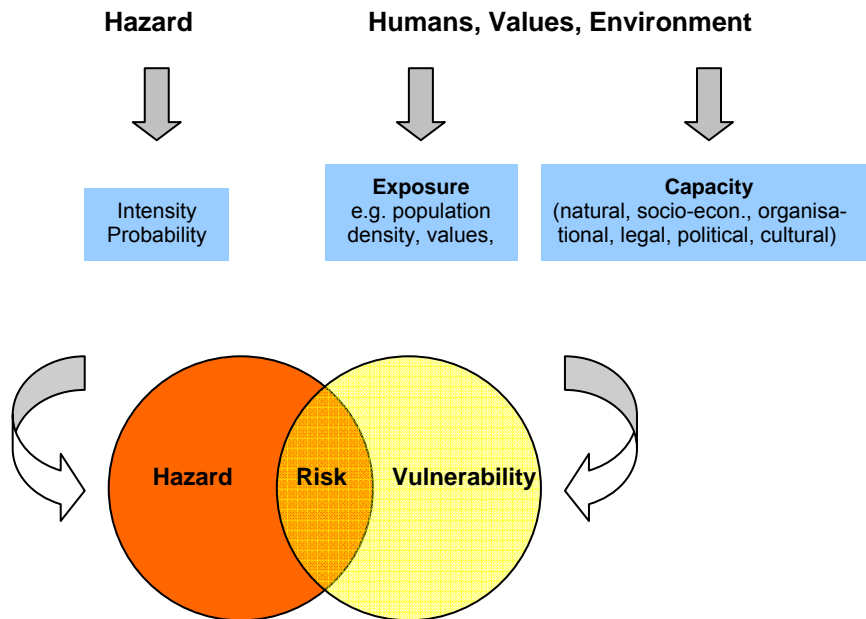


Figure 3-1: The concept of risk

Vulnerability is an essential issue in hazard research and hazard mitigation activities. Numerous definitions and determinants for vulnerability have been used in literature throughout research communities, from food security (DOWNING, 2001), global change research (STEFFEN ET AL., 2004), climate change research (IPCC, 2001), social science (ADGER & KELLY, 1999) to natural hazard or disaster risk management research (BLAIKIE ET AL., 1994; ISDR, 2004). Yet, until today no consistent definition or concept of vulnerability exists. “Vulnerability still means different things to different people” (CUTTER, 1996:530).

Social science focus on people’s ability to deal with harm, defining vulnerability as

“...society’s capacity to anticipate, cope with, resist and recover from the effect provoked on the system” (ADGER & KELLY, 1999).

Climate change research means by vulnerability the likelihood of impacts from weather and climate related events (NICHOLLS ET AL., 1999). Here vulnerability is prevalent 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. 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, 2001).

CUTTER (1996:532) identifies three clusters of definitions of vulnerability:

- Vulnerability as risk of exposure to hazards, focussing on the hazard zone and its human occupancy, the degree of loss associated with occurrence, magnitude, duration, impact, frequency and rapidity of an particular event.

- Vulnerability as social response, including social resistance and resilience to hazards.
- Vulnerability as an attribute of places, where vulnerability is conceived as both a biophysical risk as well as a social response within a specific area or place.

She defines vulnerability as

“...the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazard of place (risk and mitigation) with the social profile of communities”.

She argues (1996:536) that it is the place that forms the fundamental unit of analysis for vulnerability.

In her “Hazard of Place Model” the elements determining vulnerability are shown. Risk, as a likelihood of occurrence combined with mitigation creates the hazard potential. The hazard potential is filtered through the social characteristics of society and the geographic context to determine social and biophysical vulnerability. From that place vulnerability is derived. Place vulnerability provides a feedback loop to risk and mitigation (cf. figure 3-2).

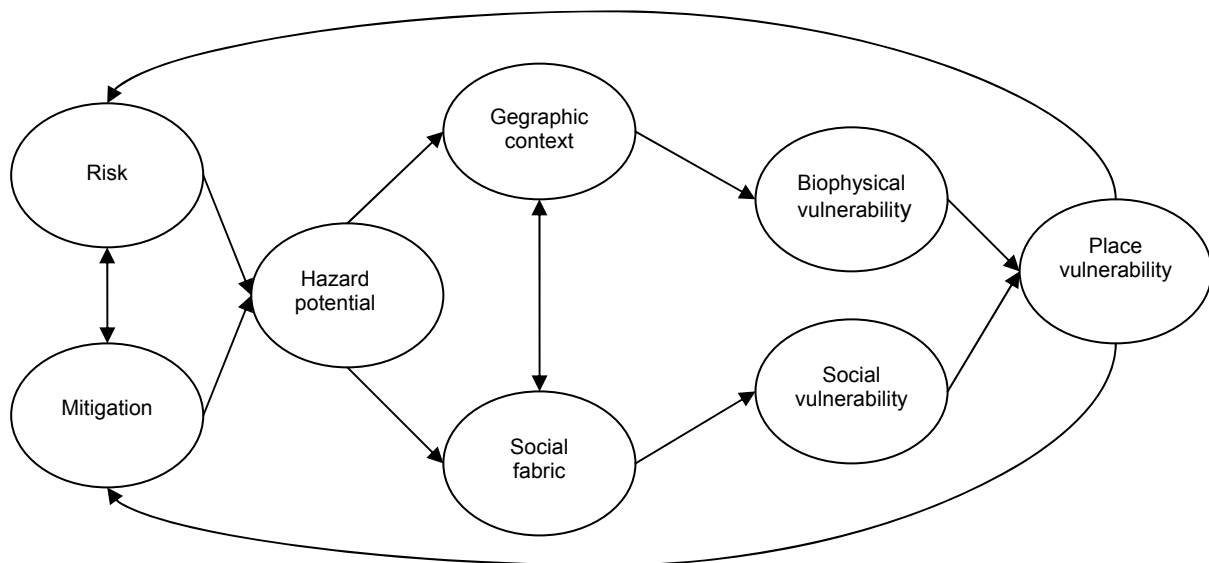


Figure 3-2: Hazard of Place Model (Source: Cutter, 1996:536)

BLAIKIE ET AL. (2004) offered another theoretical framework on disaster susceptibility of societies, the “Disaster Pressure Release Model (PAR). They connect the risks people face and the reasons for their vulnerability to hazards, where vulnerability is only related to society, not to environment or economy. The basic assumption of the model is that disasters only occur, if people are vulnerable. According to this model several factors lead to instable state of the system.

An overview on the most common definitions of vulnerability is given in table 3-1.

Table 3-1: Definitions for vulnerability (adapted from WEICHELGARTNER, 2001:169)

Authors	Definition of vulnerability
TIMMERMAN (1981)	Vulnerability is the degree to which a system acts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by a system's resilience (a measure of the system's capacity to absorb and recover from the event)
PETAK & ATKISSON (1982)	The vulnerability element of the risk analysis involves the development of a computer-based exposure model for each hazard and appropriate damage algorithms related to various types of buildings.
SUSMAN ET AL. (1983)	Vulnerability is the degree to which different classes of society are differentially at risk.
KATES (1985)	Vulnerability is the capacity to suffer harm and react adversely.
PIJAWKA & RADWAN (1985)	Vulnerability is the threat or interaction between risk and preparedness. It is the degree to which hazardous materials threaten a particular population (risk) and the capacity of the community to reduce the risk or adverse consequences of hazardous materials releases.
LIVERMAN (1990)	Distinguishes between vulnerability as a biophysical condition and vulnerability as defined by political, social, and economic conditions of society. She argues for vulnerability in geographic space (where vulnerable people and places are located) and vulnerability in social space (who in that place is vulnerable).
DOWNING (1991)	Vulnerability has three connotations: it refers to a consequence (e.g. famine) rather than a cause (e.g. drought); it implies an adverse consequence (e.g., maize yields are sensitive to drought; households are vulnerable to hunger); and it is a relative term that differentiates among socio-economic groups or regions, rather than an absolute measure or deprivation.
UNDRO (1991)	Vulnerability is the degree of the loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no danger) to 1 (total loss). In lay terms, it means the degree to which an individual, family, community, class, or region is at risk from suffering a sudden and serious misfortune following an extreme natural event.
Dow (1992)	Vulnerability is the differential capacity of groups and individuals to deal with hazards, based on their positions within physical and social worlds.
SMITH (1992)	Human sensitivity to environmental hazards represents a combination of physical exposure and human vulnerability – the breadth of social and economic tolerance available at the same site.
ALEXANDER (1993)	Human vulnerability is function of the costs and benefits of inhabiting areas at risk from natural disaster.
CUTTER (1993)	Vulnerability is the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazard of place (risk and mitigation) with the social profile of communities.
WATTS & BOHLE (1993)	Vulnerability is defined in terms of exposure, capacity, and potentiality. Accordingly, the prescriptive and normative response to vulnerability is to reduce exposure, enhance coping capacity, strengthen recovery potential, and bolster damage control (i.e., minimize destructive consequences) via private and public means.
BLAIKIE ET AL. (1994)	By vulnerability we mean 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 are put at risk by a discrete and identifiable event in nature or in

	society.
GREEN ET AL. (1994)	Vulnerability to flood disruption is a product of dependence (the degree to which an activity requires a particular good as an input to function normally), transferability (the ability of an activity to respond to a disruptive threat by overcoming dependence either by deferring the activity in time, or by relocation, or by using substitutes), and susceptibility (the probability and extent to which the physical presence of flood water will affect inputs or outputs of an activity).
BOHLE ET AL. (1994)	Vulnerability is best defined as an aggregate measure of human welfare that integrates environmental, social, economic, social, and technological factors such as population ages, economic dependency, racism and age of infrastructure are some factors which have been examined in association with natural hazard.
DOW & DOWNING (1995)	Vulnerability is the differential susceptibility of circumstances contributing to vulnerability. Biophysical, demographic, economic, social, and technological factors such as population ages, economic dependency, racism, and age of infrastructure are some factors which have been examined in association with natural hazards.
AMENDOLA (1998)	Vulnerability (to dangerous substances) is linked to the human sensitivity, the number of people exposed and the duration of their exposure, the sensitivity of the environmental factors, and the effectiveness of the emergency response, including public awareness and preparedness.
TOBIN & MONTZ (1997)	The extent to which a community, structure, service, or geographic area is likely to be damaged or disrupted by the impact of a particular hazard.
ADGER & KELLY (1999)	Vulnerability is the society capacity to anticipate, cope with, resist and recover from the effect provoked on the system.
WEICHSELGARTNER & BERTENS (2000)	By vulnerability we mean the condition of a given area with respect to hazard, exposure, preparedness, prevention, and response characteristics to cope with specific natural hazards. It is a measure of capability of this set of elements to withstand events of a certain physical character.
IPCC (2001)	Vulnerability is the degree to which a system is susceptible to, or 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.

Conclusively three schools of thought of vulnerability definitions can be identified:

- (1) Vulnerability as the exposure to a hazard, where vulnerability is defined as a state dealing with hazards, the analysis of characteristics, and impacts of hazardous events (e.g., ALEXANDER, 1993).
- (2) Vulnerability as a social characteristic of a community that is determined by socio-economic factors, attributing coping capacity response, including societal resistance and resilience to hazards (e.g., BLAIKIE ET AL., 1994; WATTS & BOHLE, 1993).
- (3) Vulnerability as a feature of space or hazard of place and an integrative measure of natural risk factors and social coping capacity as it is used increasingly in recent years, especially in the climate change community (CUTTER, 1996; WEICHSELGARTNER, 2001).

3.2 Coastal vulnerability

Coastal zones are classified as extremely vulnerable (KLEIN & NICHOLLS, 1999). The degree of vulnerability of coastal zones depends on human settlement structures and values as well as on the response options/adaptation. The latter are in turn dependent on politics and management strategies as well as awareness and information status. This means coastal vulnerability is in close connection to the social, economic or ecological conditions of a system.

Coastal vulnerability here is defined as

“...the susceptibility of the natural system and of coastal societies (persons, groups or communities) towards one or multiple coastal hazards. It is a condition resulting from a system’s social, economic and ecological properties and is a function of its natural and social coping and adaptive capacity to adverse impacts, namely its resilience”.

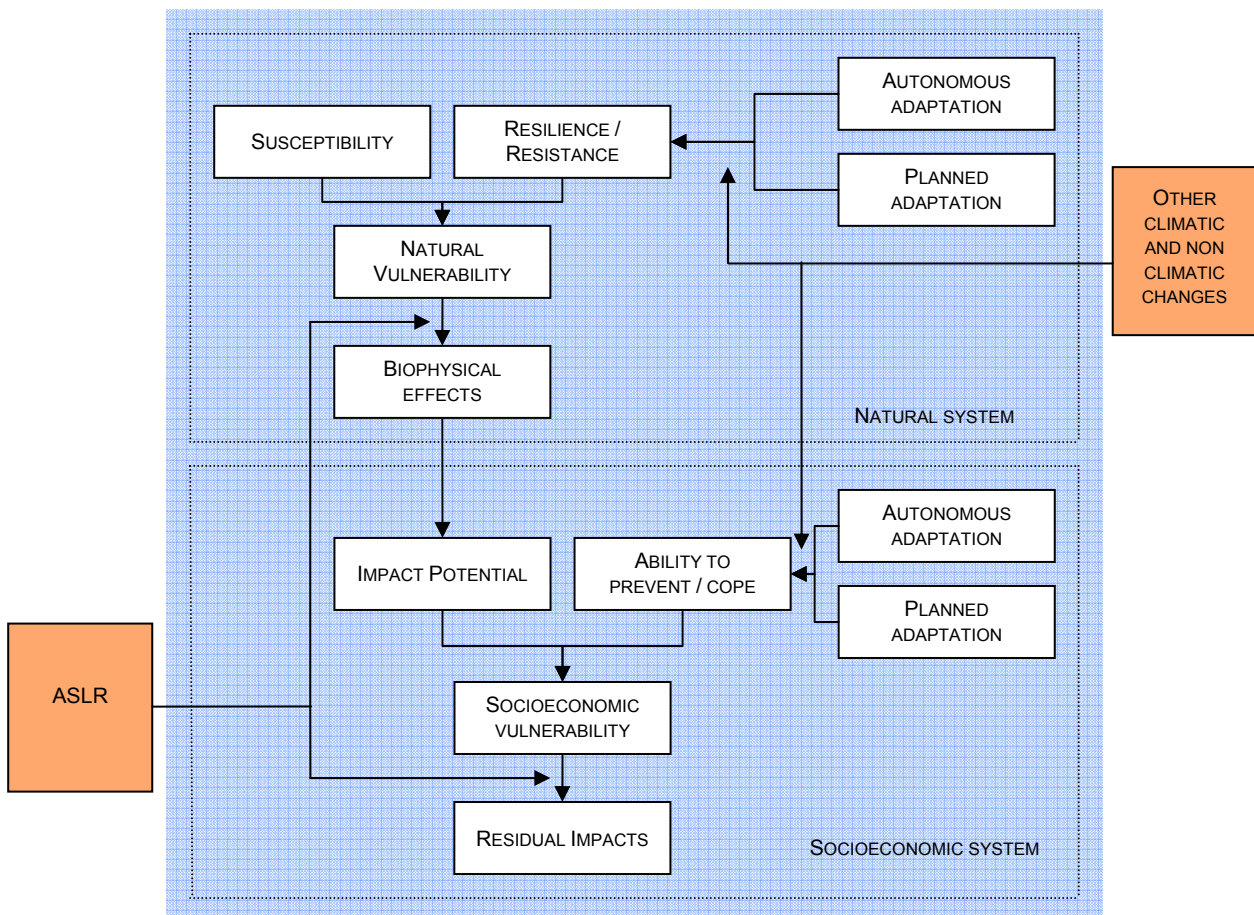


Figure 3-3: A conceptual framework for coastal vulnerability assessment (Source: KLEIN & NICHOLLS, 1999:185)

A framework of coastal vulnerability to climate change was developed by KLEIN & NICHOLLS (1999) (cf. figure 3-3).

According to this framework the coast is divided into a natural and a socio-economic system. The system's natural vulnerability is a function of its susceptibility to natural impacts i.e. the degree to which a system is directly or indirectly affected, either adversely or beneficially and its ability to return to its original state after perturbation, its *resilience*.

In the socio-economic system the *impact potential* corresponds to the expectation of damage. This impact is weakened by the societies *coping capacity*. The coping strategies may be of technical character e.g. coastal defense, institutional character e.g. disaster management, economic character e.g. insurance and cultural coping capacity e.g. retreat. Thus the actual regional impacts are determined by (a) the resilience and susceptibility of the natural system and (b) the coping capacity of the social system.

3.3 Risk assessment

Assessing the vulnerability is only one part of the overall process of assessing the quantitative and qualitative risk. The whole process of risk assessment is a complex process comprising various elements.

Risk assessment is

“...a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend. The process of conducting a risk assessment is based on a review of both the technical features of hazards such as their location, intensity, frequency and probability; and also the analysis of the physical, social, economic and environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios” (ISDR, 2004).

In Principle 1 of the Yokohama Strategy and Plan of Action for a Safer World (1994) it is argued that “...risk assessment is a required step for the adoption of adequate and successful disaster reduction policies and measures”.

In natural hazard research risk assessment can be divided into three parts (HOLLENSTEIN, 1997; ISDR; 2005, REESE, 2003): The analysis of a condition or process, comprising hazard assessment and vulnerability assessment in connection with capacity (risk analysis), the evaluation of its social meaning (risk evaluation) and the process of planning how to deal with this risk (risk management).

Figure 3-4 shows the basic elements of a risk assessment.

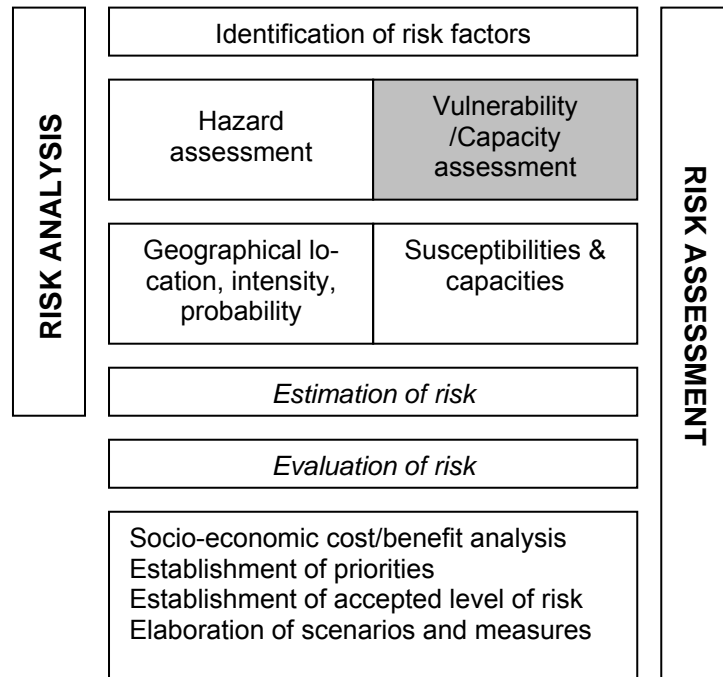


Figure 3-4: Risk assessment (Source: ISDR, 2004:63)

The hazard assessment addresses the issue „what can happen“? by giving information about the characteristics, frequency, intensity and probability of a hazard and its effects (HOLLENSTEIN, 1997). The vulnerability assessment in contrast is part of the socio-economic sphere that can be influenced by humans. Vulnerability is directly related to hazard assessment and complements the results. The aim of a vulnerability assessment is to measure the harm natural hazards have on coastal societies and to calculate the potential damages and costs of an event on the basis of the determined overall damage potential (monetary and non-monetary assets). Both, hazard and vulnerability assessment include data collection, monitoring of vulnerability factors, (GIS) mapping and social survey techniques. From these two assessments, the specific risk can be derived. The risk evaluation investigates the social consequences. Basically the risk evaluation analysis the question „what may happen, what is the likely loss created by each event or what do we accept?“. Finally the evaluation of strategies to handle the risk is part of the risk assessment process.

3.4 Vulnerability assessment

Vulnerability is assessed in the context of a region, a country, a community, a household, a sector or a system with respect to the different types of hazards. Once vulnerability is assessed and evaluated; regulations, capacity building and awareness programs can be designed and implemented to reduce this vulnerability and to minimize it in the future.

Numerous vulnerability assessment methods emanating from different points of view and different research disciplines are developed and tested to determine the degree of vulnerability of a system. Such approaches simplify the framework of vulnerability to a format that allows for its assessment using data available or measurable.

Every methodology has its own framework and purpose, and delivers different results. Therefore, when conducting a VA study, the methodological basis has to be studied and selected carefully. A range of aspects that define the scope of the assessment have to be considered (cf. figure 3-5).

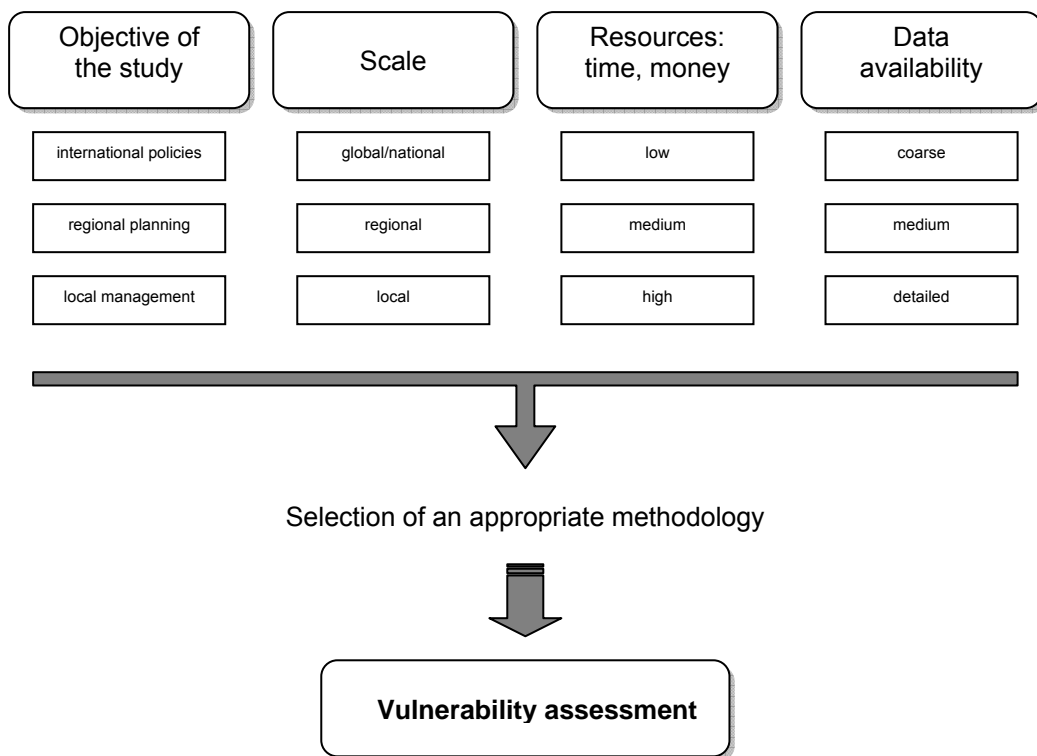


Figure 3-5: Steps to a vulnerability analysis

The objective of the study is decisive; from this objective, it has to be decided on which scale the analysis has to take part to deliver the data that are expected to be gained. Measurement or assessment of vulnerability is considerably depending on the scale at which they work. The method to be chosen and the precision of the results of a specific study must match with the objective of the study. For studies that assess global vulnerable hot spots, even a less detailed method might be appropriate. On the other hand, for studies that aim at the implementation of a single adaptation measure, it is necessary to use a more detailed method. The degree of detail is mostly depending on data availability and quality as well as on budget or time restrictions.

3.4.1 The relevance of scale in vulnerability assessment

In vulnerability assessment scale is of outstanding importance as it limits the scope of every assessment study. "Good vulnerability assessment must measure the right things at the right scale, with suitable conceptual underpinning" (STEPHEN & DOWNING, 2001:114).

The needed scale of assessment depends on the purpose of the analysis. Scales of analysis tend to differ between natural and social science; even their classification is diverse.

In climate change research, NICHOLLS & DE LA VEGA-LEINERT (1999) distinguish between global, regional, and national/local scale. However in the hazard research community the graduation in three stages is common: macro, meso, and micro scale. (REESE, 2003; cf. table 3-2).

Table 3-2: Level of scale of vulnerability assessment

Scale	Area of consideration	Level of planning and management	Research effort	Data accuracy
macro	global/national	hazard mitigation policies	low	low, aggregated, uniform district data
meso	regional	strategic planning	medium	medium, aggregated, differential district data
micro	local	Single protection measures and risk management implementation	high	high, individual data

In disaster research the 'Deutsches Komitee für Katastrophenvorsorge' (DKKV) is deciding between local level, national level and sub-national level.

Accordingly other terms are used, as KLEIN & NICHOLLS (1999) classify the levels of *screening assessment*, *vulnerability assessment*, and *planning assessment*.

The main difference of assessment scales is the level of detail of data and results. The value of scenarios and data decreases with increasing scale. From macro to micro scale the data, accuracy is increasing but even the effort to assess these data.

Here it has to be taken into account that macro-meso-micro is not automatically the same as global-regional-local. Whilst macro-meso-micro implies the degree of resolution, e.g. (a village or single houses), global-regional-local is a geographical dimension of an area. In existing methods and assessment studies it is often used simultaneously because there haven't yet been developed satisfactory methods that enable micro-scale assessment on a regional or global scale.

The classification in global-regional-local is most widely applied in climate change research and is even chosen in this thesis.

Global assessments have a very scientific and methodological character and give an overview on the morphodynamic, biotic and even socio-economic conditions of an area. They are based on aggregated data in form of easily available statistics and prior conducted to develop methodologies and to compare regions on a broad scale to make fundamental decisions. Global scale assessments often deliver similar results than national studies, because most of the data worldwide are available on national scale (e.g. statistics), which are then aggregated to global scale.

National studies are common because most efforts on vulnerability assessment have been elaborated with the goal of comparing the degree of vulnerabilities of countries. The focus on comparison among countries has forced a prerequisite on data availability at this scale, which has led to the use of general indices such as Gross Domestic Product (GDP); Human Development Index (HDI).

Global and national assessments based on aggregated data are constraint by the fact that they do not provide the level of detail and precision that would allow local decision-makers to assess the local conditions of risk and vulnerability and to choose adaptation options.

Regional scale assessments support decisions of large-scale flood mitigation strategies and allow strategic planning. With local assessments vulnerable groups can be identified and risk management strategies implemented. Here it is possible to assess data that are compatible with existing policies and institutional systems, cultural conditions as well as financial, technological and human resources (cf. figure 3-6).

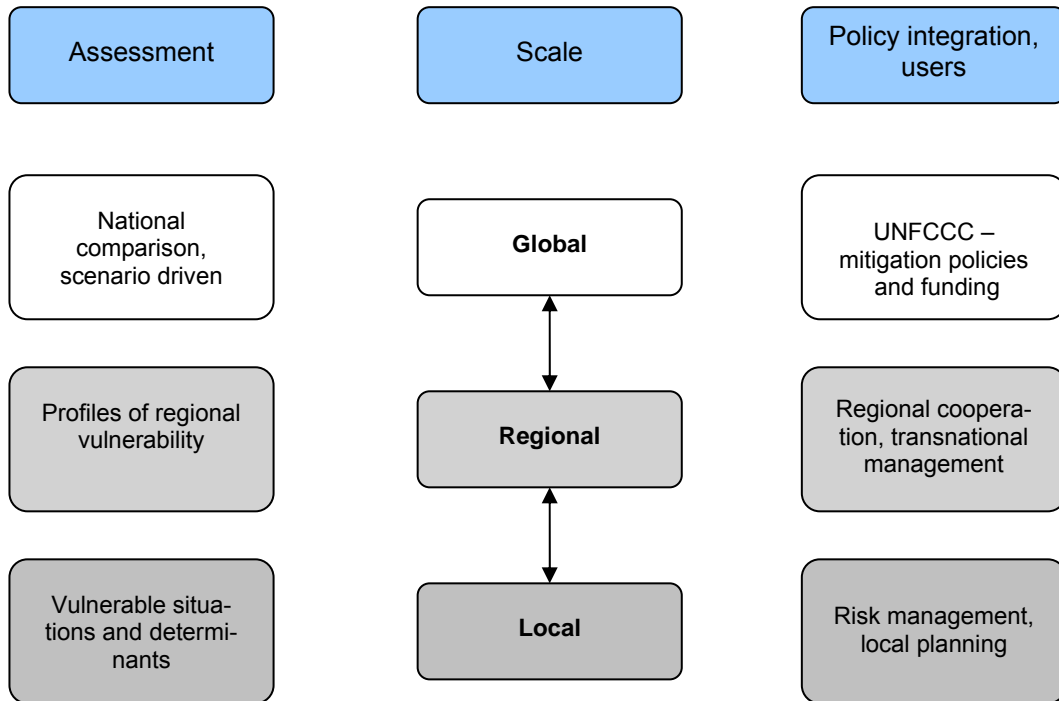


Figure 3-6: Vulnerability assessment according to scale and policy integration

From this point of view it seems clear that local scale assessments are the most useful ones for risk management and the development of appropriate adaptation strategies. But it is also obvious that with increasing scale not only the resolution is increasing but also the efforts of time and money to conduct the assessment (cf. figure 3-7)

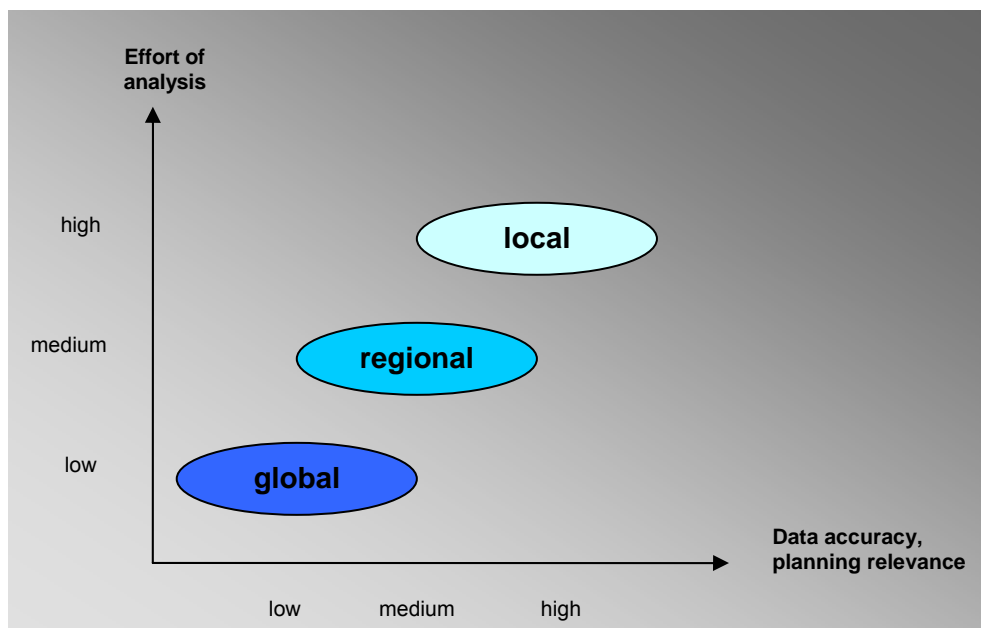


Figure 3-7: Scales and assessment levels
(Source: adapted and changed from REESE, 2003:54)

3.4.2 Measuring vulnerability

To measure the degree of vulnerability, this degree has to be somehow quantified. To estimate the potential harm in case of inundation, flooding or erosion the features and values at risk have to be defined from which the vulnerability can be measured.

These values or flood-damage categories can be categorized into direct and indirect, tangible as well as intangible categories (cf. figure 3-8).

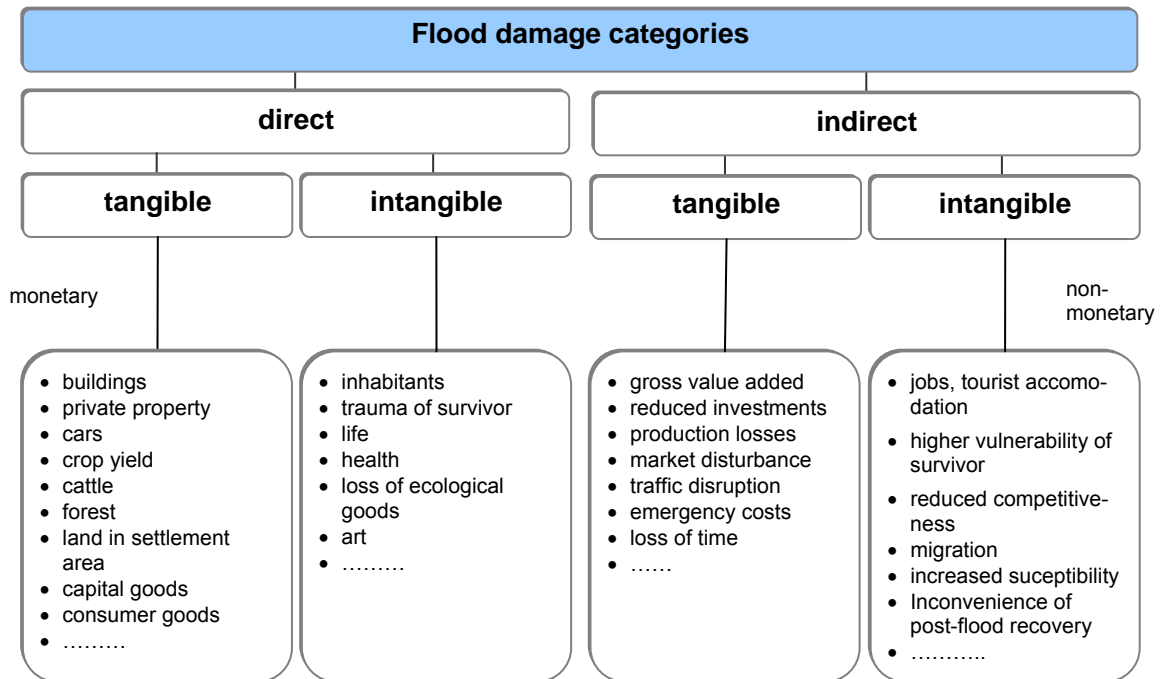


Figure 3-8: Flood damage categories (Source: adapted from SMITH & WARD, 1998:35; REESE, 2003:116)

Direct damages cover all varieties of harm which occur immediately in case of flooding. These include e.g. damage to buildings, infrastructure, economic assets, loss of standing crops and livestock in agriculture, loss of human life, immediate health impacts, and loss of ecological goods. Direct damages are usually measured as damage to stock values.

Indirect flood damages, occurring even outside the flood-prone area, are damages caused by disruption of physical and economic linkages of the economy, and the extra costs of emergency and other actions taken to prevent flood damage and other losses. These include, for example, reduced production of sub-suppliers due to total loss of production in the flooded area. This in turn causes negative growth, the loss of production of companies affected by the flooding, induced production losses of their suppliers and customers as well as the costs of traffic disruption or the costs of emergency services.

Tangible damages can be easily specified in monetary terms, such as damages on assets, loss of production, etc. Damages can be assessed either by “new-for-old payments” calculating with the full replacement value or with their depreciated values.

Intangible damages are casualties, loss of human life, health effects, or damages to ecological goods and to all kind of goods and services which are not traded in a market. These intangible damages are far more difficult to assess in monetary terms. Different methods have been developed to assess them, such as the Hedonic Price Method or the Contingent Value Method (cf. HARTJE ET AL., 2002).

Once the value categories of relevance in a specific area and to a specific natural impact or hazard are selected they have to be quantified.

Two approaches can be distinguished to measure vulnerability:

- a value-category approach, and
- an indicator-based approach.

The value-category approach classifies the values and objects in more or less aggregated categories which are used as a direct measurement. This approach is primarily used in natural hazard research. Detailed flood risk assessments apply value assessment methods by mapping every single element (e.g. buildings) to estimate the damage potential or even the actual damages related to a specific event (e.g. REESE ET AL., 2003).

An eminent constraint that faces many vulnerability assessment studies is the limited availability of data, especially of socio-economic data. Data with high degree of detail are seldom available. More, they are difficult to investigate due to restrictions in time and money.

Where vulnerability is not directly measurable in an extensive manner, it is possible to induce it by gathering information about dynamics of a system with help of indicators.

3.4.3 Indicators and Indicatorsystems

Indicators are parameters which illustrate a specific condition – more or less independent from data quality, and serve to control a current state and development.

An indicator is defined as

“...a parameter or value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter values” (OECD, 2003).

Indicators make it possible to give a summary of a system's very complex behavior by quantifying and simplifying phenomena. They reduce the number of single measurements and parameters which normally would be required to give an exact presentation of a situation (OECD, 1993). These single parameters are often not measurable. In this case indicators serve as a kind of “second best” solution. As they are able to represent complex coherences with help of

variables that are easily to assess and to interpret they are even applicable in regions where data quality is poor, i.e in developing countries.

Indicators can provide an overall analysis in the following areas ([1])

- Performance evaluation: Indicators help evaluate performance if a basis for comparison is clearly identified, for example when a target is specified in policy processes.
- Thresholds: Thresholds are unique and perhaps the most important basis of assessment. In general, crossing a clearly defined sustainability threshold should send an obvious message to policy-makers and to society in general.
- Causal Loops: Indicators are important to support claims for causality, such as the links between pressures and environmental conditions.
- Model construction and scenario analysis: Indicators provide real data and support field testing of models and possible future scenarios.

Indicators can be single variables or aggregated (state) variables. MÜLLER & WIGGERING (2004:124) distinguish between two types of indicators:

- mathematically aggregated indicators
- keyindicators (single elements as representative)

Mathematically aggregated indicators give more detailed and concrete information but this is much more elaborate. Keyindicators on the other hand are more easily to derive but there is the risk that a state variable is not totally complete. Crucial are the properties of an indicator, the methodologies regarding data management to each one, and the availability of data to obtain them.

The major functions of indicators can be summarized to

1. Information and communication
2. Orientation, comparison, benchmarking
3. Evaluation and controlling

As indicators are simplified, and easily to interpret values they help infoming about a specific process and they help to communicate as indicators present complex data sets in a clear and understandable manner. Indicators can serve as thresholds as they show if a critical value is exceeded. They can be used for performance and the control of certain developments.

To satisfy these functions, indicators have to fulfil certain criteria on the fields of

1. **Policy relevance and utility for management**
2. **Analytical correctness**
3. **Feasibility**

(modified from TAEGER, 2004:132, OECD, 1993:7):

Policy relevance and utility for management

Indicators should be:

- *target oriented* and closely related to the purpose of the assessment. In this context, they should have a close connection to coastal vulnerability and the general development goals.
- *valid*, meaning that what has been diagnosed as highly vulnerable. Does the indicator measure the key element under consideration?
- *dynamic*, showing trends over time. Indicators are changing and they are seldom, if ever, complete and must be completed in progress to show clearly changes in development.
- *comprehensible* to politicians and decision makers to enable them to interpret them easily.
- *sensitive* towards changes and time lapses. They should show trends at an early point of time.
- *flexible*, taking into account different locations, people, cultures and institutions.
Different people living in different places have different values. The quality of an indicator strongly depends on its settings because indicators are not simply transferable. A careful selection is needed to determine which indicators may be relevant in a given context and should provide a representative picture of the conditions in the area of investigation. In general the same indicator may not necessarily be used to answer the same question in different locations.
- *relevant* to planning, decision making, and political processes.
- *comparable* in different periods and places, and ideally able to be standardized for a comparison.
- In line with *thresholds* or reference values against which to compare it so that users are able to assess the significance of the values associated with it.

Analytical correctness

- *of scientific quality* having a well founded basis for decision making and management. They should be based on international standards and consensus about validity.
- *flexible and in open indicatorsystem* to monitor and change them under changing conditions.

- *exclusive*, as several indicators should not measure the same issue. This should enable a broad assessment without redundancy. Correlations between indicators should be apparent.
- *scale related*, providing a basis for international comparison. Ideally indicators should be applicable across scales, that means they should be national in scope and be applicable to regional issues (OECD, 1993).

Feasibility

- *measurable* and statistically sound.
- *of good data quality* and easily accessible. The more realistic the relationship between an indicator and the indicated state, the better the quality of the indicator is. Interdisciplinary assessment is necessary to show complex interactions.
- Be available at a reasonable *cost-benefit ratio*. It must be able to collect the data in a financial and time related scope that is feasible for politics and management.
- *documented, monitored, and actual*. Indicators change over time, are more or less relevant or have to be added or deleted. To draw a real picture of the changing systems monitoring and actualization is crucial. Even concerning actualisation and monitoring cost-benefit aspects have to be considered.

Indicators can be developed and organized in indicatorsystems, which include information about the functions, the target groups, the structure or the thematic priorities of indicators. Organizing indicators in an indicatorsystem allows feasible evaluation and decision making. A range of indicatorsystems exist in different scientific communities, differing strongly according to aims and content.

They can be differentiated according to formal criteria and criteria as regards content (FLEISCHHAUER, 2004). Formal criteria include the modelbasis, the spatial scale, specification, development, databases, aggregation or political framework. Criteria as regards content include priority of indicators, target values, relation to measurements, interactions, data acquisition, and updating of indicators.

The best known and most widely applied indicatorsystem is the Pressure-State-Response (PSR) framework, which was developed in environmental science. It is based on the concept of causality: human activities exert pressure on the environment and change its quality and quantity of natural resources. Society responds to these changes through environmental, general economic and sectoral policies. The latter form the feedback loop to pressures through human activities. The framework helps policymakers to combine environmental, economic, and other issues and provides a means of selecting and organizing indicators (OECD, 2003). The

PSR framework has been further developed by the United Nations Commission on Sustainable Development (UNCSD) to the Driving forces - State - Response (DSR) framework on its work on sustainable development indicators. Pressure has been exchanged by driving forces to accommodate the social, economic and institutional indicators. In the latest approach, the European Environment Agency modeled the Driving Force – Pressure – State – Impact – Response (DPSIR) framework, providing an overall mechanism for analyzing environmental problems. The DPSIR framework highlights human components of the system, coupling socio-economics with environmental observations. It provides a general view of the nature of large-scale influences on the state of the environment and on the need to understand and address consequential social impacts driven by environmental conditions. The DPSIR (cf. figure 3-9) framework serves as a tool to manage change.

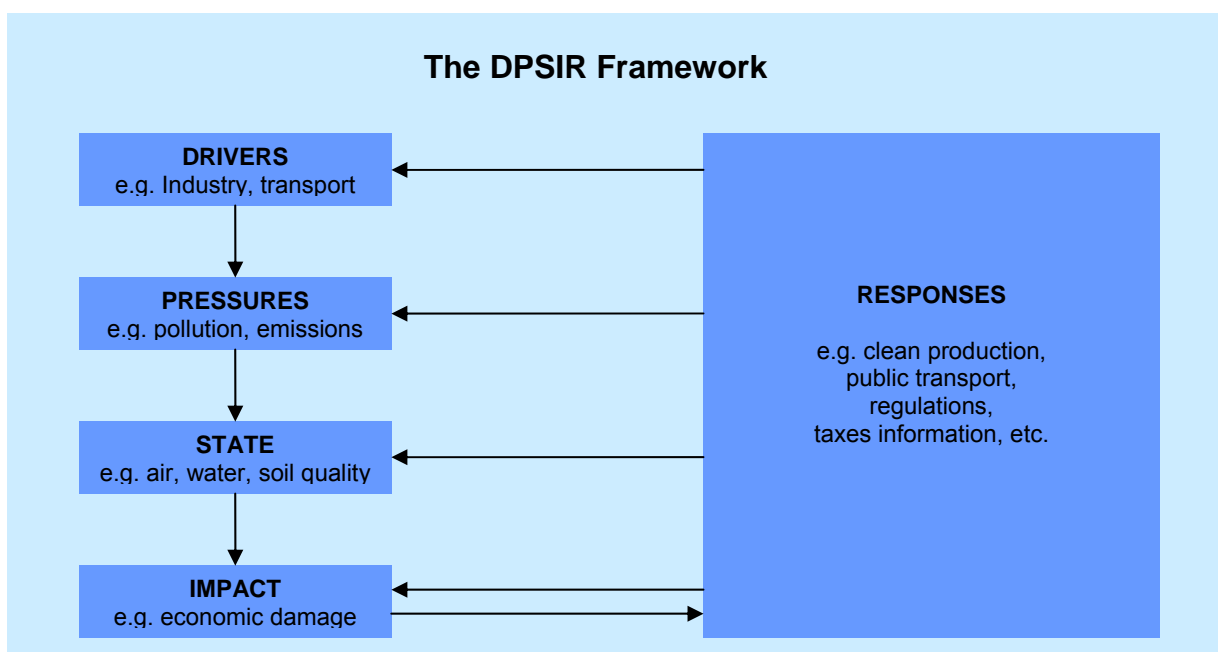


Figure 3-9: The DPSIR Framework (Source: EEA)

Driving forces indicators show changes in large-scale socio-economic conditions and sectoral trends, such as social, demographic or economical developments which cause pressure on environmental systems. Driving forces are social needs which are related to the use of natural resources, such as an increased number of tourists, growth and development of economy in the coastal zone or large-scale changes to human population dynamics.

Pressure indicators show in an aggregated form the amount of stress/change for the environment, such as coastal construction altering coastal wetlands or the introduction of agricultural contaminants and nutrients into the coastal watershed.

State indicators describe the actual state of the environment which has been produced by actual and former use and development (e.g. velocity of temperature changes, enhanced sedimentation in harbours, or saline intrusion into groundwater).

Impact indicators describe consequences and changes to the system in social benefits and values resulting from environmental changes, and the new state (e.g. climate regulation, biomass production) or economic benefit or loss, such as the cost of maintaining coastal transportation systems due to siltation, decline in property values resulting from coastal erosion, or loss in agricultural income from salinization of soils.

Response indicators include reactions of society/politics to environmental changes or economic changes. This includes the whole spectrum of societies possibilities and capacities to stabilize the actual state and to mobilize forces to weaken or change the pressure on the natural system (adaptation/resilience/mitigation). They describe all efforts made to mitigate disasters or to adapt human systems. Contrary to pressure and state indicators, response indicators are always in a socio-political context and have a shorter history, being still in a phase of development. Response indicators are difficult to assess quantitatively (e.g. the money spent for public relations gives no clear information about the efficiency of the funds, the successful information of the public and the changes in behaviour of the public).

Although the use of indicators is most widely applied in environmental science, they play an increasing role in risk and vulnerability research. As coastal management becomes increasingly important in the future due to changing conditions and risks, methods are required that not just give a present view of a system but also are adaptable to dynamics and thus allow monitoring of coastal system developments. Indicators can serve as such dynamic parameters. Organized in indicatorsystems they should help

- to show correlations,
- to increase the awareness of risks,
- to improve risk communication,
- to help defining goals, to build the basis for decision making,
- to control measures,
- to allow a comparison of regions, and
- to fulfill an early warning function.

(FLEISCHHAUER, 2004:194).

3.5 Approaches to coastal vulnerability assessment

Risk and hazard research in the last decades showed that vulnerability plays a crucial role in mitigating and preventing serious impacts of current and future hazardous threats. Therefore “the assessment of risk and vulnerability is important because it is directly related to the quality of the decisions made regarding how to reduce societal and environmental exposure to coastal hazard impacts” (JHC, 2000: XXVII).

Hence various vulnerability assessment methods and tools have been developed and applied in many coastal settings worldwide. These vulnerability assessment methods encompass a broad range of application from cross cutting methods to specific sectoral methods.

Vulnerability assessment methods and studies cannot only be grouped according to their scale, but also to the research communities in which they were developed, which follow partly different objectives.

There are mainly two communities dealing with risk and vulnerability assessment in coastal zones: the climate change community (CCC) and the natural hazard community or disaster risk management community (DRMC).

3.5.1 Methods in the climate change community

The climate change community aims at assessing the impacts and vulnerabilities of systems to evaluate the consequences of climate change and sea-level rise and derive adaptation options. The TAR assesses the vulnerability of natural and social systems of major regions to climate change with qualitative methods rather than assessing the expected impacts of climate change quantitatively. There is no unique method for assessing vulnerability to climate change. There are different scholars and research communities that have developed different concepts of vulnerability. Additionally the methods have also grown in diversity and become more interdisciplinary.

In climate change vulnerability assessment, there has been a shift from science-driven (positive) assessments, assessing potential climate impacts to policy-driven (normative) assessments that recommend specific adaptation measures. The reason for this shift is the upcoming demand to translate the results of vulnerability assessment in management and adaptation strategies, which require a closer connection to the local social-political situation. Assessment methodologies can be categorized in two major categories: Top-down approaches and bottom - up approaches.

Most widely used so far in climate change impact analysis are top-down assessments, also called *first generation* assessments.

Impact assessment (cf. figure 3-10) has been the common method to evaluate the risks affecting coastal zones in the beginning of the 1990s. Starting from emission scenarios, the impacts on a system are described as a function of exposure and sensitivity. Impact assessments give an overview of the potential impacts on a system. However, they are not taking into account the system's vulnerability and adaptive capacity. These assessments lack the necessary information for policy integration.

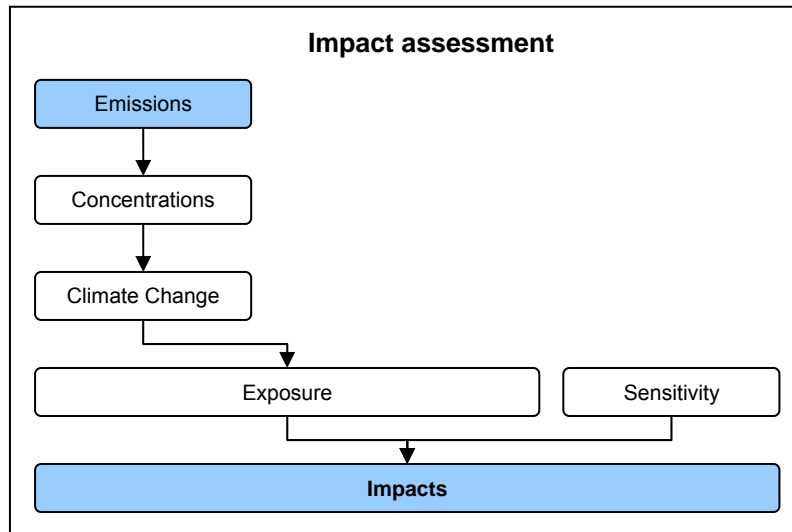


Figure 3-10: Impact assessment (Source: KLEIN & FÜSSEL 2002:8)

In contrast vulnerability assessment selects a particular group or system unit of concern (e.g. coastal community) and seeks to determine the risk of specific adverse consequences for this system. More, it identifies a range of factors that may reduce response capacity. With the analysis of vulnerability, impact assessment is extended with a crucial component.

Top-down, scenario-driven approaches, derived from General Circulation Models (GCM), still focus more on impacts than on adaptation and were applied almost exclusively from 1995-2002, reported in more than 150 national communities (UNFCCC, 2004). These assessments identify impacts of long-term climate change and develop risk reduction strategies. First generation assessments ought to understand how the climate might change and what would be likely impacts. Additionally to climate change, non-climatic factors of ecological, economic, social, demographic, technological, and political character are included in the assessment as well as the need of mitigation and adaptation (cf. figure 3-11).

First generation assessments give answers to the following questions (UNFCCC, 2004):

- How will the climate change?
- What will be the hydrological, biological and other "first order" effects of the projected changes in climate?
- How will these first order effects impact humans?
- How might humans adapt?

- How might these adaptations alter the impacts?

Key methods and tools of this approach are downscaling techniques for developing scenarios of future climate and socio-economic conditions. These approaches and tools are strong in biophysical aspects of impacts and certain types of dynamic interactions, but do not well in representing human interactions and local abilities to adapt (UNFCCC, 2004).

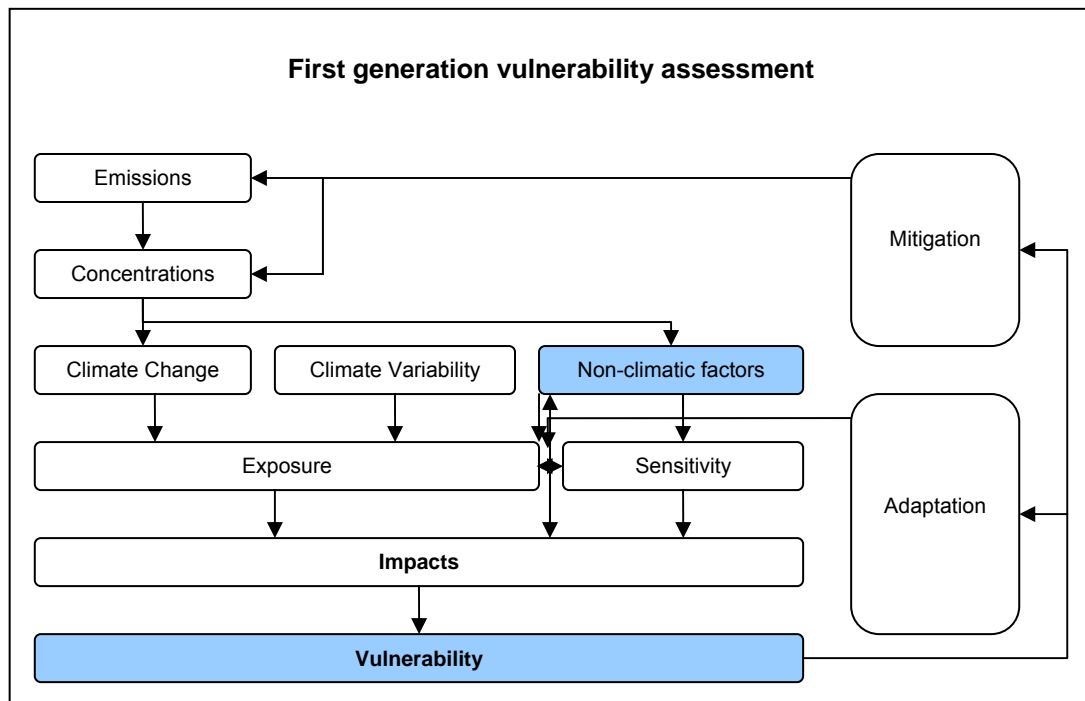


Figure 3-11: First vulnerability assessment (Source: KLEIN & FÜSSEL 2002:11)

In recent years, more studies have employed the bottom-up approach, which should link adaptation more directly to policy.

Bottom up approaches, also called “multi-stressors”, are orientated towards localized vulnerability and for answering how a community can adapt to climate change and how adaptation policy can be applied (UNFCCC, 2004). This approach assesses both climate related factors and non-climate-factors and the capacity of a system to cope.

It also includes evaluation of vulnerability to future climate related risks, involves key stakeholders in the evaluation process, and leads to adaptation policies that strengthen adaptive capacity. These approaches, also called *second generation* assessments are more able to present local purposes and allow developing and implementing local planning strategies (cf. figure 3-12).

Second generation assessments give answers to these questions (UNFCCC, 2004):

- Who is vulnerable to, or made more vulnerable by, climate change?
- What are the sources and nature of their vulnerability?

- What are the capacities to cope with recent climate variability and extremes and what are the lessons for adapting to future climate change?
- Who needs information to develop and implement strategies to adapt and thereby lessen vulnerability?
- What information do they need?
- How can users of the information be engaged in the production of that information and so assure that it has credibility and relevance for their needs?

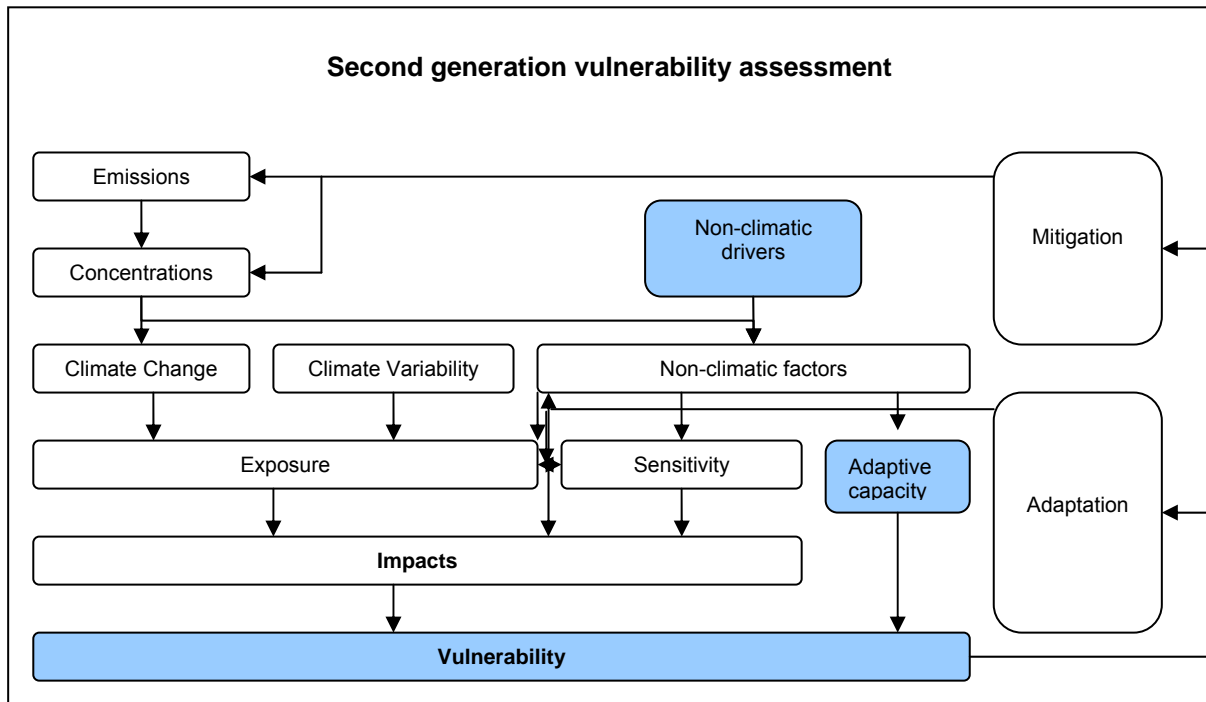


Figure 3-12: Second generation vulnerability assessment (Source: KLEIN & FÜSSEL 2002:15)

1st and 2nd generation impact assessment and vulnerability assessment are called *positive* assessments (KLEIN & FÜSSEL, 2002). KLEIN & FÜSSEL (2002) defined a fourth category, the *adaptation policy assessment*, where an explicit focus is given to the purpose to contribute to policymaking. They distinguish facilitating adaptation such as awareness raising and capacity building, and implementation adaptation aiming at reduction of the exposure or sensitivity. In the same way, they divide mitigation in facilitation activities to strengthen the mitigative capacity (e.g. carbon trading scheme) and implementation measures such as replacing old power plants. Here, not the possibility of a comparison of regions is the prior goal, but the local or community specific adaptation and policy options to reduce to adverse impacts (cf. figure 3-13).

Which of the approaches is chosen for the analysis depends on the aim and the scale of investigation. The two approaches, top down and bottom up, are not necessarily competing. Studies using a vulnerability-driven approach can be conducted parallel to or integrated in scenario-driven studies.

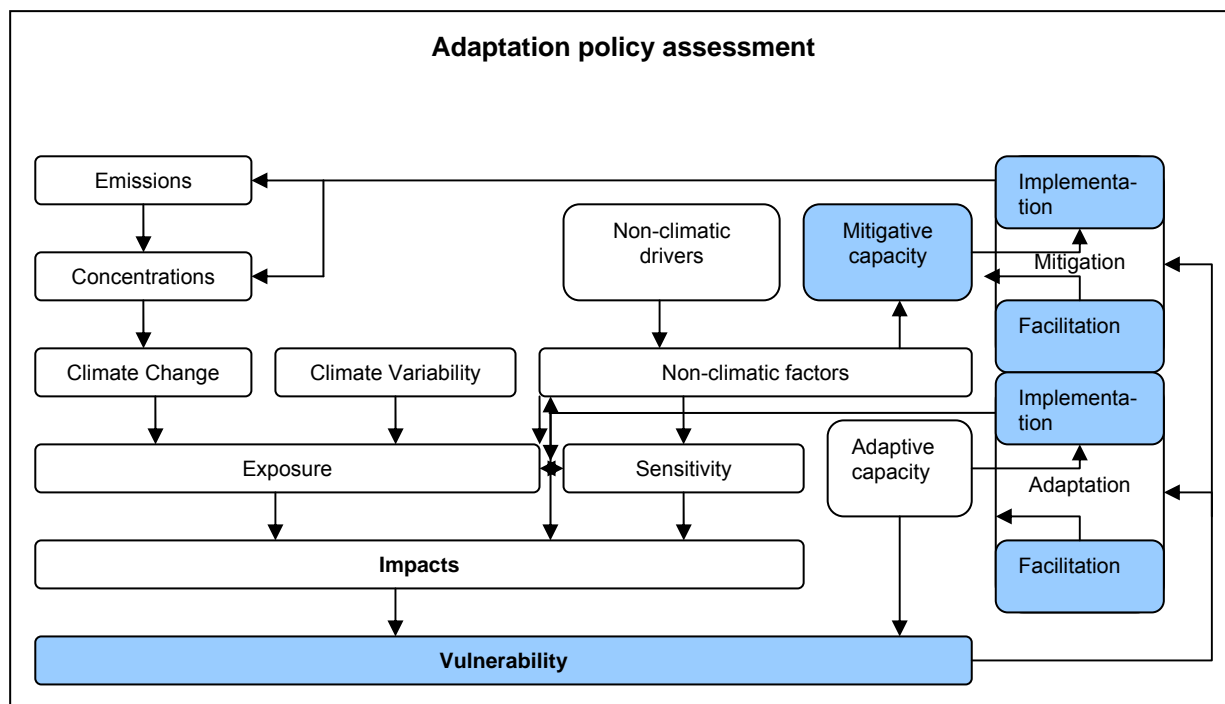


Figure 3-13: Adaptation policy assessment (Source: KLEIN & FÜSSEL 2002:18)

The first investigations on the impacts of sea-level rise were made in the developed world. In the Netherlands (PEERBOLTE ET AL., 1991) or in the USA (SMITH & TIRPAK, 1989; TITUS ET AL. 1991), they initiated policy and coastal management activities. Influenced by these studies, the first generic vulnerability assessment methodology was developed by the IPCC, Coastal Zone Management Subgroup (CZMS) in 1992. The *Common Methodology (CM)* comprises a seven step approach (details cf. figure 4-1). In total, 30 national/sub-national studies, eight local studies and one global study were conducted (e.g. BEHNEN, 2000; EBENHÖH ET AL., 1997; NICHOLLS, 1995; NICHOLLS & LEATHERMAN, 1995; NICHOLLS & MIMURA, 1998; HOOZEMANS ET AL., 1993), eight local assessments and one Global Vulnerability Assessment (GVA) (HOOZEMANS ET AL., 1993). The CM is the most widely applied methodology so far.

The CM was drafted to assist countries in making rapid analyses of potential coastal impacts of and adaptations to sea-level rise.

In detail, the aims of the CM were:

- to identify and assess physical, ecological, and socio-economic vulnerabilities to accelerated sea level rise and other impacts of global climate change and coastal zones,
- to understand how development and other socio-economic factors affect vulnerability,
- to clarify how possible responses can mitigate vulnerability and to assess their residual effects, and
- to evaluate a country's capacity for implementing a response within an ICZM framework.

The studies using the CM gave a first overview of coastal zones at risk. These early studies had some methodological deficits such as assuming a single global scenario of sea-level rise (1 m by 2100), ignoring the spatial distribution of relative sea-level, neglecting extreme events such as storm surges as well as local adaptation strategies (or simplifying them to just protection). Many studies carried out a simple linear first-order assessment, shifting the coastline landward with corresponding sea-level rise, not considering more complicated coastal processes. The CM was followed by a range of similar methodologies (e.g. NICHOLLS & LEATHERMAN, 1995; YAMADA ET AL., 1995).

Several distinct methodologies have been developed as attempts to remedy some of the limitations of the CM. They include a semi-quantitative methodology for the South Pacific Island countries, proposed by KAY & HAY (1993), the South Pacific Islands Methodology, SPIM (YAMADA ET AL. 1995), the IPCC Technical Guidelines (CARTER ET AL. 1994; PARRY & CARTER 1998), the US Country Studies Program, USCSP (BENIOFF ET AL. 1996; LEATHERMAN & YOHE, 1996), and the UNEP Guidelines (KLEIN & NICHOLLS, 1998) all belonging to the first generation vulnerability assessments. The UNEP Handbook methodology has been applied in developing countries under the UNEP Country Studies Programme and in the first phase of the Netherlands Climate Change Studies Assistance Programme. The disadvantage of all these methodologies is that they have not been applied and tested widely.

Like the CM the *IPCC Technical Guidelines*, consist of seven analytical steps. However, as shown in figure 3-14, they are not identical. The reason for this is that the CM was developed specifically for application in coastal zones, whereas the Technical Guidelines have been designed to serve as a more generic framework for any natural or socio-economic system.

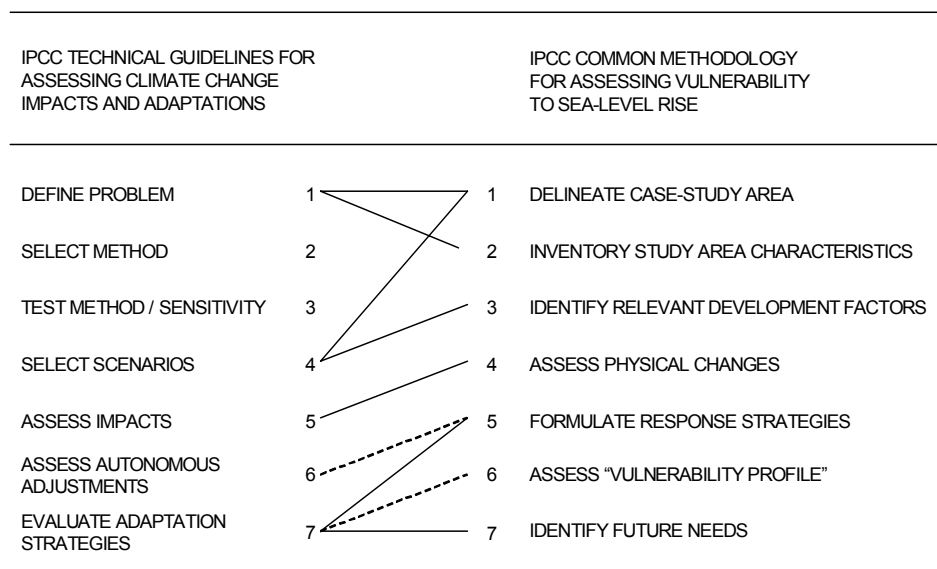


Figure 3-14: Comparison of IPCC Technical Guidelines and the CM (Source: KLEIN & NICHOLLS., 1999:34)

As well as the Technical Guidelines the *USCSP* was developed not only for coastal zones, but also to support climate change country studies in developing and less developed countries on the sectors of: agriculture, grassland/livestock, forests, water resources, coastal resources, health, fisheries, wildlife. The *USCSP* followed a six step approach:

1. Define scope of the problem
2. Choose scenarios
3. Conduct biophysical + economic impact assessment
4. Integrate impact results
5. Analyze adaptation policies and programs
6. Results

To overcome the lack of data (physical, demographic, economic, topographic) on large scales in developing countries, LEATHERMAN (1995) developed the Aerial videotape-assisted vulnerability analysis (AVVA). AVVA works on altitudes of 70/100m and 300m and provides a low-cost primarily vulnerability assessment.

The *South Pacific Island Methodology* (YAMADA ET AL. 1995), providing an approach especially for small island states, is an index-based approach that uses relative scores to evaluate different adaptation strategies. The coast is divided into six subsystems: natural environment, people and infrastructure as hard systems, and the institutions, the socio-cultural factors, and the economic systems as soft systems. Special about this methodology is that vulnerability as well as resilience receive scores by the user. Scenarios used are today's situation, SLR with and without management. For each subsystem, a capacity index is combined for each scenario.

In the EU-funded project SURVAS (Synthesis and Upscaling of Sea- Level Rise Vulnerability Assessment Studies) all available coastal vulnerability studies were synthesised and up-scaled and it was tried to develop standardised data sets for coastal impact indicators suitable for regional and global analysis (NICHOLLS & DE LA VEGA- LEINERT ET AL., 2000). However, this was difficult to realise because synthesis and upscaling was impeded by the fact that studies had used different methodologies, scenarios and assumptions.

The most recently developed method is the *Dynamic Interactive Vulnerability Assessment, DIVA* (DE LA VEGA-LEINERT ET AL.; HINKEI, 2005), which comprises a global database of natural system and socio-economic factors, scenarios and adaptation algorithms as well as a graphical user interface. Erosion, flood, salinization, and wetland loss are considered in coastal regions. DIVA is for vulnerability assessment on national, regional, and global scale.

Today second generation approaches have been increasingly developed. Examples are the UNDP Adaptation Policy Framework (APF) policy framework (BURTON ET AL., 2002) and the Assessment of Impacts and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC), the Guidelines for the Preparation of National Adaptation Programs of Action (NAPA) and the UK Climate Impacts Program (UKCIP) (WILLOWS & CONNELL, 2003).

Both the *APF*, *NAPA* as well as the *AIACC* frameworks are not only coast specific and seek to integrate national policy making efforts and stakeholders and to strengthen adaptive capacity with a bottom-up movement. The *APF* consists of five steps: (1) Scoping and designing an adaptation project, (2) assessing vulnerability under current climate, (3) characterizing future climate related risks, (4) formulating an adaptation strategy and (5) continuing the adaptation process (BURTON ET AL., 2002). *AIACC* aims to fill gaps in the current understanding of vulnerability and opportunities for adaptation by funding, training and mentoring developing country scientists to undertake multisector, multicountry research driven and focused on building capacity (UNFCCC, 2004). 24 regional study teams conduct studies in 46 developing countries.

The *UKCIP* takes up the problem of uncertainty in vulnerability and adaptation assessment. It helps decision makers to judge the significance of climate change risk compared to other risks to work out appropriate measures.

SMP (DEFRA, 2001) is a generic approach to the strategic management of erosion and flooding in coastal areas. Applied in the UK, developed for developed countries with extensive coastal defense structures, and dividing the coast in subcells, *SMP* selects a series of strategic options to be applied over the next 50-100 years: (1) advancing the line, (2) holding the line, (3) managed realignment, (4) limited intervention and (5) no active intervention. A *SMP* provides a large-scale assessment of the risks associated with coastal processes and presents a long term policy framework to reduce these risks to people and the developed, historic, and natural environment in a sustainable manner.

All these studies focus on the estimation of socio-economic consequences of climate change impacts. They also estimate what is vulnerable and how high the costs or the number of life loss are. Social aspects such as *who* is vulnerable and *why* are widely neglected.

3.5.2 Methods in the hazard or disaster risk management community

In the context of hazard and disaster research O'KEEFE ET AL. (1976) is the first mentioning vulnerability. Here, socio-economic factors such as "weakness" are responsible to react on natural impacts. In the beginning of the 1980s, the concept of vulnerability was developed by SUSMAN, O'KEEFE, and WISNER (1983). TIMMERMAN (1981) refers to the importance of socio-

economic factors and their economic connection regarding the susceptibility to natural hazards. HEWITT (2002) considers in his vulnerability concept especially how communities are exposed to dangers, the ways they are harmed and the protection that they lack.

There is no uniform concept of vulnerability in hazard research. The DRMC describes vulnerability more as the relationship between an exogenous hazard to a system and its effects (ISDR, 2004), focusing on multiple effects of a single event. That means that vulnerability is a status, initiated by human activity, depending on human settlement, infrastructure, and the know how to deal with natural hazards from the part of administration and politics as well as population. The evaluation of capacities as well as the determination of the acceptable level of risk to make local cost-benefit calculations for measure planning plays a crucial role. In the DRMC there are mainly two research directions concerning the assessment of vulnerability, both of them following the second generation approach.

One group is conducting technical oriented studies to estimate flood risk in case of storm floods, or other extreme events, by calculating the possibility of sea defense failure and conducting damage (potential) analysis (REESE ET AL., 2003; MEYER, 2004; BERGER, 2001; KYSTDIREKTORATET, 2005; PENNING-ROUSELL ET AL., 2003, and in the framework of the FLOODSITE project, www.floodsite.net). The damage potential in terms of flood risk refers to the values potentially at risk in case of a specific impact in a specific area. The damage potential analysis gives information about the total damage occurring in a worst case. The damage potential is most commonly calculated with help of so called depth-damage functions, where data are gained with survey data or estimations (synthetic data) and collected in databases such as the German HOWAS database to calculate standardised damage functions. These studies often aim at coastal defense measure planning and are thus based on cost-benefit calculations. Climate change is considered in these studies but it builds only a boundary condition for the necessity of efficient coastal defense. In contrary to most climate impact studies these methods operate on regional or local level.

The other group is focusing on disaster reduction, which is addressed by the ISDR Inter-agency Task Force Working Group 3 on Risk, Vulnerability and Impact Assessment. Here, to build a basis for prevention, methods and instruments for *Vulnerability and Capacity Assessment (VCA)* have been developed together with the International Federation of the Red Cross (IFRC, 1999). The VCA toolbox was designed to help communities to understand the nature and level of risks they face, who will be worst affected, what is available at all levels to reduce the risks; and what capacities need to be further strengthened. It is a diagnostic tool to be used for better-informed relief, mitigation and development programmes.

It comprises three steps (IFRC, 1999):

1. Identifying potential “threats” (natural hazards, violence, health)
2. Identifying vulnerabilities with help of three basic characteristics that make some groups more vulnerable than others:
 - Proximity and exposure
 - Poverty
 - Exclusion / marginalization (people who are left out of economic and social systems)
3. Assessing people’s capacities to prevent or cope according to three categories:
 - Physical and material (people with physical resources are better able to cope)
 - Social and organizational (functioning of social networks)
 - Skills and attitudes

3.5.3 Commonalities between adaptation to climate change and disaster risk management

Although pursuing the same goal of reducing the adverse impacts of coastal hazards, the climate change community and the disaster risk management community follow partly different approaches in risk and vulnerability assessment and even in hazard reduction. There are two main differences between the analyses of both research communities: temporal and spatial scale.

In the CCC impacts of ongoing changing conditions such as sea-level rise are considered. Frequently hazards like storm surges are only partly taken into account. In so doing vulnerability assessment is always related to long time scales. Although climate models have improved significantly vulnerability assessments in the CCC are always constraint with uncertainty, above all because socio-economic scenarios - which are crucial for vulnerability assessment - can not be made that clearly for the future. In the DRMC in contrast climate change scenarios are only partly considered. Instead risks to a concrete hazard are assessed. In so doing the system is analysed as it is today, without regarding long-term development. The vulnerable community develops its own local adaptation strategies. Often the risks are know because of recurring events like hurricanes or storm floods, so that the hazard analysis is not scenario-based but can be measured from past events. The results are not simply comparable to other regions because of the very specific data analysis. Mitigation in the DRMC is not as important as in the CCC because natural hazards have been seen as natural forces that cannot be influenced by humans, but in the context of anthropogenic climate change the role of man made climate – related hazards becomes more important.

Climate change assessments based on scenarios are on much broader scale, following a more top-down approach being mainly a global political issue, allowing a comparison of re-

gions. Downscaling efforts are made but they are constraint by the fact that scenario data decrease with increasing spatial scale. Methods in the DRMC on the other hand are place based and work on more local scale. Here different administrative and financial possibilities play a crucial role as well as social and cultural factors like risk perception, demographic structures, educational structures or cultural attitudes. In hazard research vulnerability is the starting point of an assessment while in climate change research it is an outcome (KLEIN & FÜSSEL, 2002). The DRMC distinguishes internal (vulnerability) and external factors (hazard potential). For the CCC, the distinction of external and internal factors is difficult because of the global scope of anthropogenic climate change. Here, impacts of climate change in one region can even have impacts on other regions. The main differences are demonstrated in table 3-3.

Table 3-3: Characteristics of the climate change community and Disaster risk management community (adapted from THOMALLA, 2006:40 and KLEIN & FÜSSEL, 2002:20)

Climate Change Community	Disaster Risk Management Community
Hazard attribution	
<ul style="list-style-type: none"> • human influenced • climate change 	<ul style="list-style-type: none"> • natural variability • multi-hazard
Research field	
<ul style="list-style-type: none"> • strong scientific basis 	<ul style="list-style-type: none"> • engineering and natural science basis
Assessment	
<ul style="list-style-type: none"> • IPCC Assessment Report 	<ul style="list-style-type: none"> • IFRC Vulnerability Capacity Assessment (VCA) • RC World Disaster Report • International disaster databases: EM-Dat, NatCatSERVICE (MunichRe) • Sigma (Swiss Re)
Approach	
<ul style="list-style-type: none"> • scenario-driven • top down, partly bottom up • vulnerability as a result • positive, normative • risk management 	<ul style="list-style-type: none"> • place-based • bottom-up • Vulnerability as a starting point • normative • risk management
Targets of risk reduction	
<ul style="list-style-type: none"> • external vulnerability • (hazard potential), internal vulnerability 	<ul style="list-style-type: none"> • internal vulnerability
Spatial scope	
<ul style="list-style-type: none"> • regional to global 	<ul style="list-style-type: none"> • local, regional
Temporal scope	
<ul style="list-style-type: none"> • long-term perspective 	<ul style="list-style-type: none"> • short term but increasingly longer term
Systems of concern	
<ul style="list-style-type: none"> • all systems 	<ul style="list-style-type: none"> • social systems, infrastructure
Rationale for action	
<ul style="list-style-type: none"> • self interest, compulsory assistance 	<ul style="list-style-type: none"> • self interest, voluntary assistance

Climate stimuli temporal

- gradual changes in mean and variability
- discrete hazard event

Uncertainty

- medium to high
- low

Familiarity with hazard

- new and known hazards
- known

System view

- dynamic and adaptive
- static

Focus of adaptation

- normal operation mode, emergency mode
- emergency mode

Organisations/Planning level

- international organisations, UNFCCC, IPCC
- stakeholder involvement
- United Nations, UN
- Provention Consortium (World Bank)
- International Red Cross and Red Crescent Societies (IFRC)
- National to local stakeholder involvement
- Participatory approaches

International conferences

- Conference of Parties (COP)
- World Conference on Disaster Reduction (WCDR)

Strategies

- National communications of the UNFCCC
- National Adaptation Plans of Action (NAPA) for Least Developed Countries
- UN International Decade for Natural Disaster Reduction (IDNDR)
- Yokohama Strategy and Plan of Action for a Safer World
- UN International Strategy for Disaster Reduction (ISDR)
- Hyogo Framework for Action 2005-15

Table 3-4: Overview on the most important methods for coastal vulnerability assessment (adapted from NICHOLLS, 1998:21)

Methodology	Application	Characteristics
Common Methodology (IPCC CZMS, 1992)	<ul style="list-style-type: none"> • 30 country studies, e.g. Germany (EBENHÖH ET AL.), the Netherlands (DELFT HYDRAULICS, 1991), Poland (ZEIDLER, 1992 Bangladesh (Gov. of Bangladesh, 1993) • One Global Vulnerability Assessment, GVA , (HOOZEMANS, 1993) 	<ul style="list-style-type: none"> • First generation approach • Most widely applied methodology • Inflexible methods due to clearly defined steps • VA tools are not described and discussed • Assessment of the impacts of SLR only • Assumption of landward shift of the coastline • Consistent results, useful for global aggregation • Adaptation options insufficiently developed • Non-monetary economies and quantitative data
IPCC Technical Guidelines (CARTER ET AL., 1994; PARRY & CARTER, 1998) / UNEP Handbook Methodology (KLEIN & NICHOLLS , 1998)	e.g. Egypt (EL RAEY ET AL., 1999)	<ul style="list-style-type: none"> • First generation approach • Remains to be widely tested • More flexible than CM • All impacts considered • Guidance on possible VA tools provided • Neglecting public involvement (e.g. perception), non technical aspects of adaptation
US Country Studies Methodology (BENIOFF ET AL., 1996)	e.g. Senegal (NICHOLLS & LEATHERMAN, 1994) Egypt (EL-RAEY ET AL., 1995), Uruguay (COMISION NACIONAL SOBRE EL CAMBIO GLOBAL 1997)	<ul style="list-style-type: none"> • First generation approach • Methodology for developing countries • Some VA tools described • Rapid, low cost method for primary VA (AVVA) • Only addresses land loss impacts • Stresses susceptibility, not vulnerability • Simplistic estimates of erosion (Bruun Rule)
South Pacific Islands Methodology (YAMADA ET AL., 1995)	Fiji (NUNN ET AL. 1996)	<ul style="list-style-type: none"> • First generation approach • Estimates both vulnerability and resilience • Results are qualitative to semi-quantitative • Comparability with results limited • Useful in areas with limited data

<p>Dynamic Interactive Vulnerability Assessment tool (DIVA) (DE LA VEGA-LEINERT, & NICHOLLS, 2005; HINKEI, 2005),</p>	<p>Global to regional database developed in the DINAS Coast project (DE LA VEGA & NICHOLLS, 2005)</p>	<ul style="list-style-type: none"> • First generation approach • Climate, socio economic and adaptation scenarios • Providing a graphical user interface • Considering multiple hazards • Global, national and regional scale • Wide range of vulnerability indicators used • Lack of local data • Not applicable for local coastal management
<p>Assessment of Impacts and Adaptation to climate Change (AIACC)</p>	<p>24 regional studies, 46 country studies in developing countries e.g. Argentina (BARROS, 2004); Pacific Island Countries (KOSHY, 2004)</p>	<ul style="list-style-type: none"> • Second generation approach • Several methods to choose, DSS, Indicators, multi-criteria, sustainable livelihoods, cost-benefit, disaster analysis • Not only coast specific • Integration of national policy and stakeholders • Strong focus on adaptation and adaptive capacity
<p>Shoreline Management plans (SMP)</p>	<p>Local studies in the UK</p>	<ul style="list-style-type: none"> • Strategy for management of erosion and flooding • Design for developed countries with defense structures • Focus on development of protection strategies
<p>Vulnerability and Capacity Assessment (IFRC)</p>	<p>Applied in many national (IFRC) case studies, e.g. Gambia, Uganda, Palestina</p>	<ul style="list-style-type: none"> • Not only coast specific • Diagnostic and planning tool • Programs for disaster preparedness • Using participatory approaches and stakeholder involvement • High flexibility of the tool inhibits comparison
<p>Damage (potential) analysis to flood risk</p>	<p>MERK (REESE ET AL., 2003), Ribe / COMRISK (KYSTDIREKTORATET, 2005)</p>	<ul style="list-style-type: none"> • Detailed micro-scale assessment • Detailed information about potential damages • Useful for coastal planning and risk management • Huge effort of time and money • Not transferable to regions with lack of data

4 Evaluation of coastal vulnerability assessment studies

Assessment of risk and vulnerability is important because it is directly related to the quality of the decisions made regarding how to reduce societal and environmental exposure to coastal hazard impacts.

JHC, 2000

In the following chapter, it is examined which results selected coastal vulnerability assessment studies can deliver, both in the climate change community and in the hazard or disaster risk management community. Scale is by far the most critical factor concerning the outputs of vulnerability assessment studies, because it decides about the level of accuracy and about the application of the results in policy and decision making. Hence, here VA studies are grouped and analyzed according to scale.

4.1 Vulnerability assessment studies on global and national scale

According to scale, global to national studies give the most spacious overview. They are primarily conducted in climate change research to identify hot spots and most vulnerable regions in the world. The outcomes of global studies can be as far as possible compared to national studies, because they often use national data sets for aggregation.

Five VA studies are considered here:

- the German IPCC Case Study (EBENHÖH ET AL, 1997; BEHNEN, 1998)
- the Global Vulnerability Assessment (GVA) conducted by HOOZEMANS ET AL. (1993),
- the DINAS COAST project (DE LA VEGA-LEINERT ET AL. 2005), and
- the US Country Study Program (LEATHERMAN & YOHE, 1996)
- the PNNL Vulnerability assessment programme on impacts of climate change (MOSS ET AL., 2001)

The German IPCC Country Study - EBENHÖH ET AL., 1997, BEHNEN, 1998

Initiated by the IPCC, CZMS (1992), the CM defined an era in terms of vulnerability assessments. In total, 30 national/sub-national studies, eight local studies and one global study were conducted (e.g. CALLAHAN, 1994; NICHOLLS, 1995; NICHOLLS & LEATHERMAN, 1995; NICHOLLS & MIMURA, 1998; HOOZEMANS ET AL., 1993). The regional distribution of the studies is shown in Table B-1 (Annex B). Following the guidelines of the CM, these studies consider the potential impacts on population, on economic, ecological and social assets, and on agricultural production, using present sea-level and SLR of 0.3 and 1.0 m by 2100. Scenarios of global climate change factors, local development factors and response options were included. National or local development is considered by extrapolating 30 years from the present situation.

The indicators used in the CM are summarized in table 4-1 to: people affected, people at risk, capital value at loss, land loss, protection/adaptation costs, and wetland loss.

Table 4-1: Vulnerability classes developed and used in the Common Methodology (Source: STERR ET AL., 2000:18)

Input categories	Vulnerability classes			
	Low	Medium	High	Critical
People affected (no. of people/total population) x 100%	< 1%	1-10%	10-50%	> 50%
People at risk Σ (no. of people x flood probability)/1000	< 10	10-100	100-500	> 500
Capital value loss (total loss/1990 GNP) x 100%	< 1%	1-3%	3-10%	> 10%
Land loss (area loss/total area) x 100%	< 3%	3-10%	10-30%	> 30%
Protection/ adaptation costs (annual cost/1990 GNP) x 100%	< 0.05%	0.05-0.25%	0.25-1%	> 1%
Wetland loss (area loss/ total area) x 100%	< 3%	3-10%	10-30%	> 30%

Table 4-2 shows aggregated results of some IPCC country studies. It can be seen that around 178 million people would be affected by a 1-m rise in sea level and assuming no human response in terms of adaptation. It has to be noted that in terms of adaptation, IPCC country studies have usually made very simple assumptions, such as costing protection for all areas, except those with a low population.

In Europe, the CM was applied in Germany (EBENHÖH ET AL., 1997, BEHNEN, 1998), Poland (ZEIDLER, 1992), and the Netherlands (DELFT HYDRAULICS, 1991) (cf. figure B1 ANNEX B)

Table 4-2: Aggregated results of country studies (Source: NICHOLLS, 2003:16)

Country	People Affected		Capital Value at Loss		Land At Loss		Wetland At Loss	Adaptation/ Protection Costs	
	#People (1000s)	% Total	Mil US\$	% GNP	Km ²	% Total	Km ²	Mil US\$	% GNP
Antigua	38	50	-	-	5	1.0	3	71	0.32
Argentina	-	-	5000	>5	3400	0.1	1100	>1800	>0.02
Bangladesh	71000	60	-	-	25000	17.5	5800	>1000	>0.06
Belize	70	35	-	-	1900	8.4	-	-	-
Benin	1350	25	118	12	230	0.2	85	>400	>0.41
China	72000	7	-	-	35000	-	-	-	-
Egypt	4700	9	59000	204	5800	1.0	-	13100	0.45
Guyana	600	80	4000	1115	2400	1.1	500	200	0.26
Japan	15400	15	849000	72	2300	2.4	-	>156000	>0.12
Kiribati	9	100	2	8	4	12.5	-	3	0.10
Malaysia	-	-	-	-	7000	2.1	6,000	-	-
Marshall I.	20	100	160	324	9	80	-	>360	>7.04
Mauritius	3	<1	-	-	5	0.3	-	-	-
Netherlands	10000	67	186000	69	2165	5.9	642	12300	0.05
Nigeria	3200	4	17000	52	18600	2.0	16000	>1400	>0.04
Poland	235	1	24000	24	1700	0.5	36	1400	0.02
Senegal	110	>1	>500	>12	6100	3.1	6000	>1000	>0.21
St Kitts	-	-	-	-	1	1.4	1	50	2.65
Tonga	30	47	-	-	7	2.9	-	-	-
Uruguay	13	<1	1700	26	96	0.1	23	>1000	>0.12
U.S.A.	-	-	-	-	31600	0.3	17000	>156000 ⁸	>0.03
Venezuela	56	<1	330	1	5700	0.6	5600	>1600	>0.03
TOTAL	178834		1146310		149022		58790	27124	

The German IPCC Case Study, carried out by EBENHÖH, ET AL. (1997) and BEHNEN (1998) follows the CM as by the seven steps outlined in figure 4-1.

One meter in SLR was chosen as a climate change scenario, while the suggested socio-economic scenario of 30 years was not taken into account. Instead, a static consideration of the present situation was used by assessing actual, aggregated socio-economic statistical data on country level to derive vulnerability profiles. The characteristics of the coastal zone were assessed with a scale of 1:50,000 to 1:200,000. Regionally specific characteristics such as storm surges were included in the assessment. The study distinguished between the North Sea coast and the Baltic Sea coast, where flood prone areas were allocated to 10 m contour line (North Sea), and 5 m contour line (Baltic Sea). Respectively, economic protection and adaptation scenarios were developed.

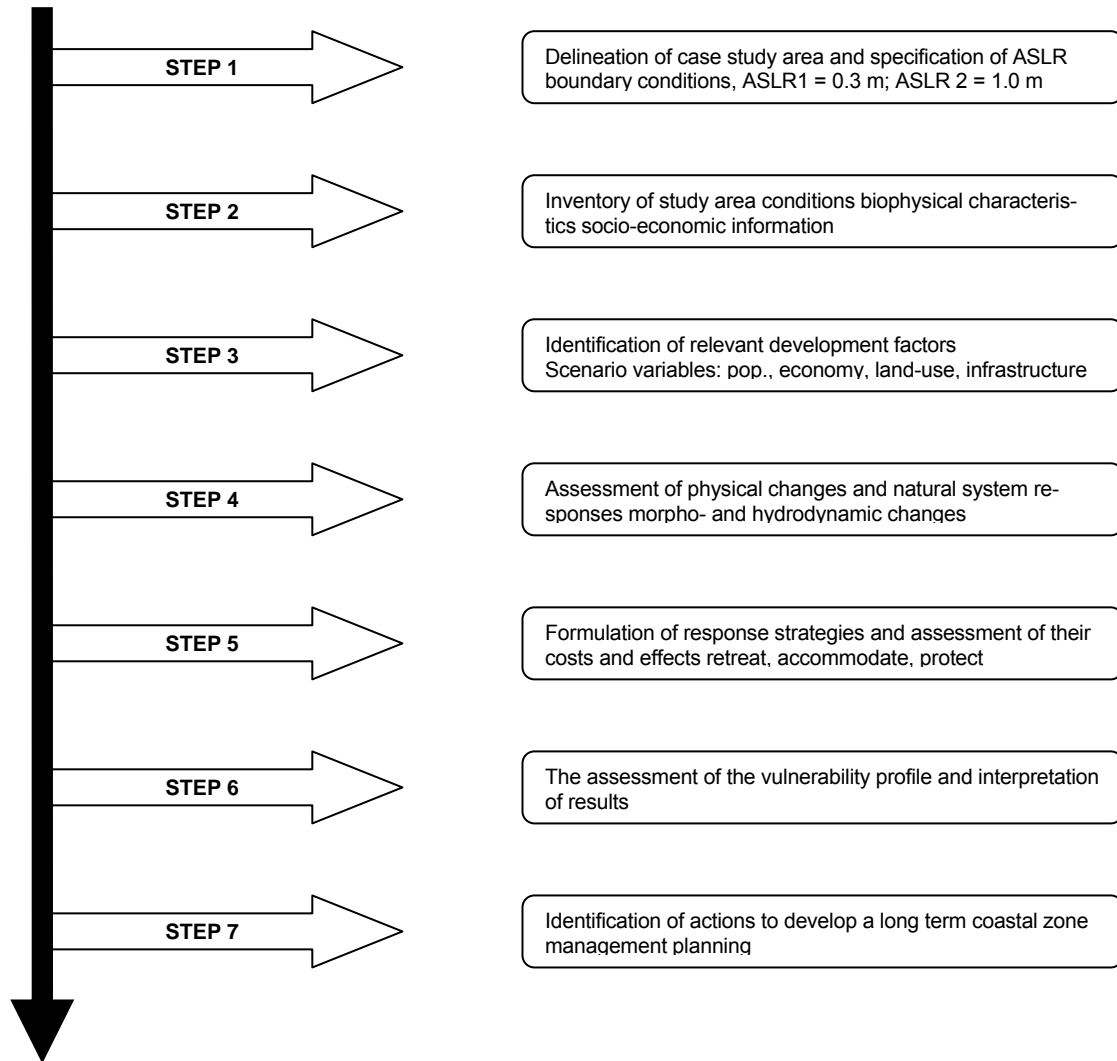


Figure 4-1: The seven steps of the Common Methodology (Source: IPCC, 1992)

The vulnerability assessment was conducted by estimating the damage potential on the level of municipalities. The values are maximally investigated on community level and distributed equally on the whole area of the community. Main data sources were official statistics. Sometimes data were not available, e.g. numbers could be gathered from municipality level statistics, but other values such as residential capital or fixed assets are only published on state level. A disaggregation to municipality level is done, which lead to restrictions in accuracy. Furthermore the spatial distribution of damage potential within the municipality is not differentiated. Instead equal distribution of values is assumed over the whole area, leading to inaccuracy.

In the German IPCC case study, the exposure was calculated from SLR (1 m), elevation, coastal type, storm surge characteristics, tidal range, wave height, and coastal protection.

The damage categories listed in table 4-3 were chosen on municipality level as indicators for vulnerability:

Table 4-3: Value categories and indicators used by EBENHÖH ET AL., 1997 & BEHNEN, 1998)

population (absolute/density)	land loss	capital value at loss
employees	settlement area	agriculture
inhabitants/job density	agricultural area	producing industry
	forest	trade and traffic
	water	supply of services
		private property (buildings, land)
		public excavation

Thus, the CM aims at assessing vulnerability across physical and social domains, it uses predominantly physical indicators rather than clear indices of social vulnerability. Although socio-economic aspects are considered in step 5 on formulating response, the problem of the study is to define the future risk to social and natural systems, based on changes in natural parameters only. The CM avoided using precise definitions and prescriptions of methods to allow maximum flexibility to the user. This has the disadvantage that different tools were used in different countries, aggravating comparison.

Due to these limitations, of different assumptions, parameters and scenarios in local studies a global study was added by HOOZEMANS ET AL. (1993) allowing a comparison of country data.

Global Vulnerability Assessment (HOOZEMANS ET AL., 1993; HOOZEMANS & HULSBERGEN, 1995)

The Global Vulnerability Assessment, GVA (HOOZEMANS ET AL., 1993), was the first global study estimating socio-economic and ecological implications of ASLR. It was conducted parallel to the IPCC country studies, out of the idea that numerous country studies would take decades to complete.

The vulnerability classes used in the GVA had to be reduced due to data and modeling constraints and because of the aim of comparability.

In table 4-4 the vulnerability classes used in the GVA are listed:

Table 4-4: Vulnerability classes and indicators used by Hoozemans et al., 1993

Population at risk
Wetland at loss
Rice production at change
Protection costs

- Population at risk (number of people subject to regular flooding) on a global scale
For the estimation of the population at risk, the coast was divided into 192 coastal zones (databases). Assumed were the population density of 1990, the height of the maximum flood level with 4 storm surge elevations 1/1, 1/10, 1/100, 1/1000, a uniform subsidence of 15cm/century, present state of protection (World Bank classification), protection scenarios: constant protection (1990), and evolving protection in phase with increasing GNP/capital, (without regard to SLR)
- Wetland at loss at 1 m SLR (the ecologically valuable coastal wetland area under a serious threat of loss) on a global scale
- Rice production at change in South, South-east and East Asia
- Protection costs (Population at risk is calculated together with protection costs, then, the regional protection costs are compared to the regional GNP to quantify their relative cost-factors)

Just as the Country Studies, the GVA is a macro-scale assessment, using aggregated national data. Yet due to the global comparable view some more assumptions have to be made:

1. coastal flood plain has a constant slope
2. population is distributed uniformly across the coastal zone
3. if sea defense fails, the area behind is flooded totally

The results of the GVA were aggregated to 20 “GVA regions” (cf. figure 4-2).

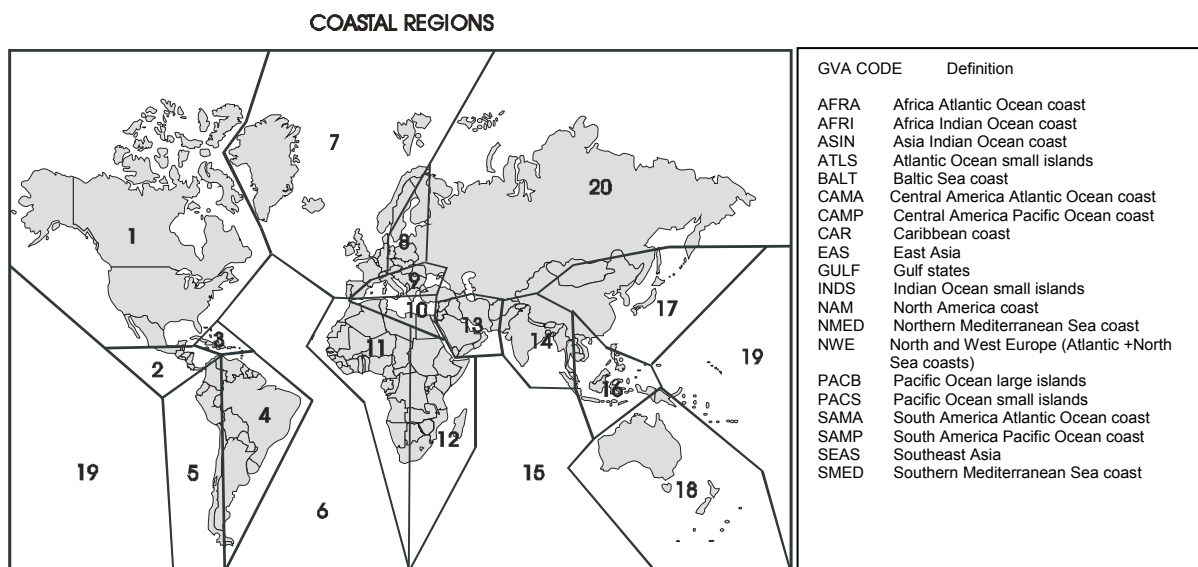


Figure 4-2: Coastal Regions according to the GVA (NICHOLLS & HOOZEMANS, 2000:17)

Again comparable to the country studies, the GVA helped to shape a first approach to global top down vulnerability assessment and gives an overview over vulnerable regions in the world. However, it is limited by the same constraints as the country studies and additionally

includes less indicators, mostly physical ones. The obsolescence of underlying data sources lead to a static, one-scenario approach.

The GVA was later updated by (cf. BAARSE, 1995), and basis data were also incorporated in the DINAS Coast project.

DINAS COAST (DE LA VEGA-LEINERT ET AL. 2005)

Based on the GVA and the outcomes of the SURVAS project in the EU Fifth Framework Program, the project DINAS-COAST (Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise) was conducted between 2002 and 2005. In SURVAS, it became obvious that most existing vulnerability assessment studies follow a case study approach without attempting a synthesis at national scales, using different methods, scenarios, and assumptions. Global vulnerability assessments solve this problem by producing more homogenous data. However, their limitations are the limited resolution, making the results insufficient for coastal management on local level, where decisions about adaptation are made. A further limitation is their often one-scenario approach, assuming a static socio-economic situation.

The DINAS COAST project took up these limitations combining data, scenarios and assessment models into an integrated model by shaping the dynamic, interactive, and flexible tool DIVA (Dynamic and Interactive Vulnerability Assessment), based on the GVA. DINAS COAST has conducted a top-down, integrated modeling afford on potential impacts of and adaptation to accelerated sea-level rise.

Working on national, regional, and global scale, and covering all 180+ coastal nations (excluding Antarctica), quantitative data were produced on a range of coastal vulnerability indicators and user selected climatic and socio-economic scenarios and adaptation policies (DE LA VEGA-LEINERT ET AL., 2005; cf. figure 4-3)

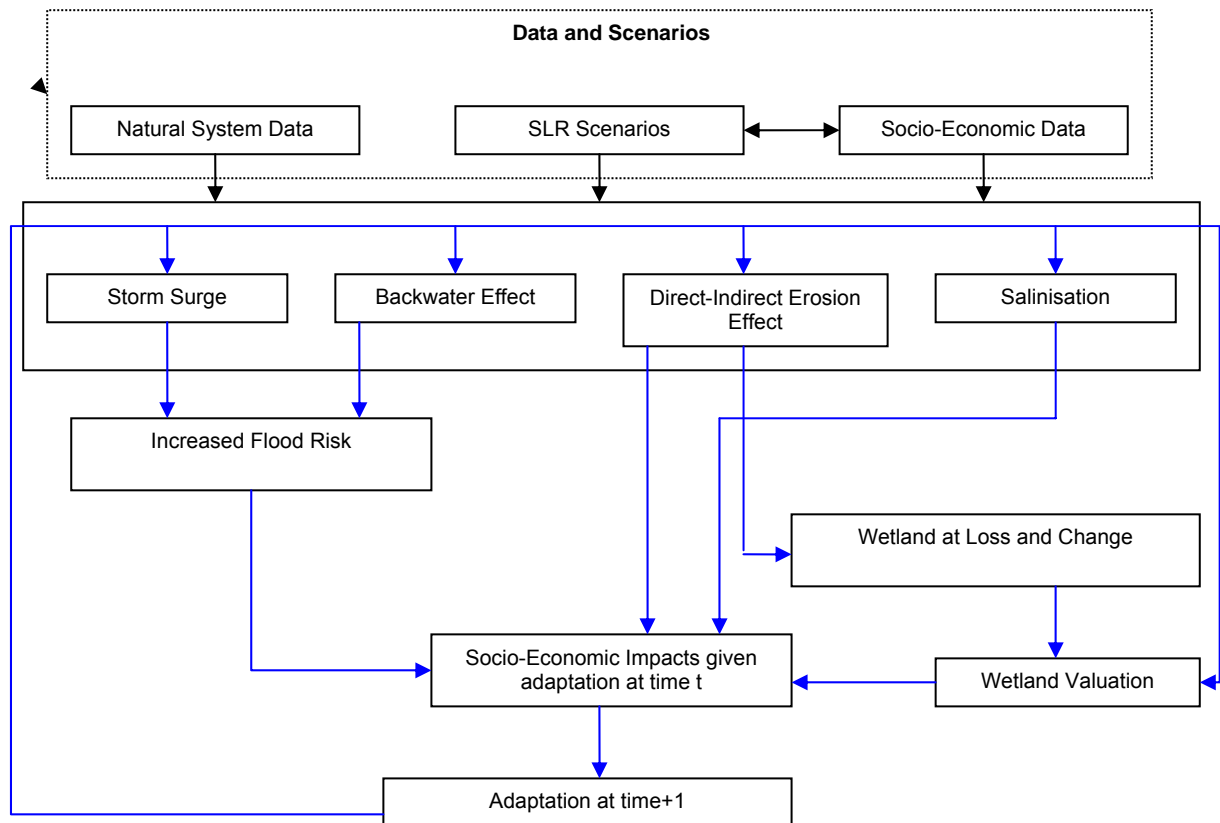


Figure 4-3: Schematised methodology of DINAS COAST (Source: MC FADDEN ET AL., 2005:3)

The outcomes of DINAS-COAST were

- a GIS database with natural and socio-economic data sets on the present state of the world's coastal zone,
- sea-level rise scenarios (until 2500) socio-economic scenarios on population growth, urbanization, and other development trends until 2100,
- a module to assess potential costs and benefits of impacts and adaptation on various spatial and temporal scales (four different adaptation strategies),
- a segmentation of the world coast (except Antarctica),
- a Graphical User Interface (GUI), and
- an integrated model enabling the exchange of modules and discrete time steps until 2100

DIVA comprises the DIVA method and the DIVA tool.

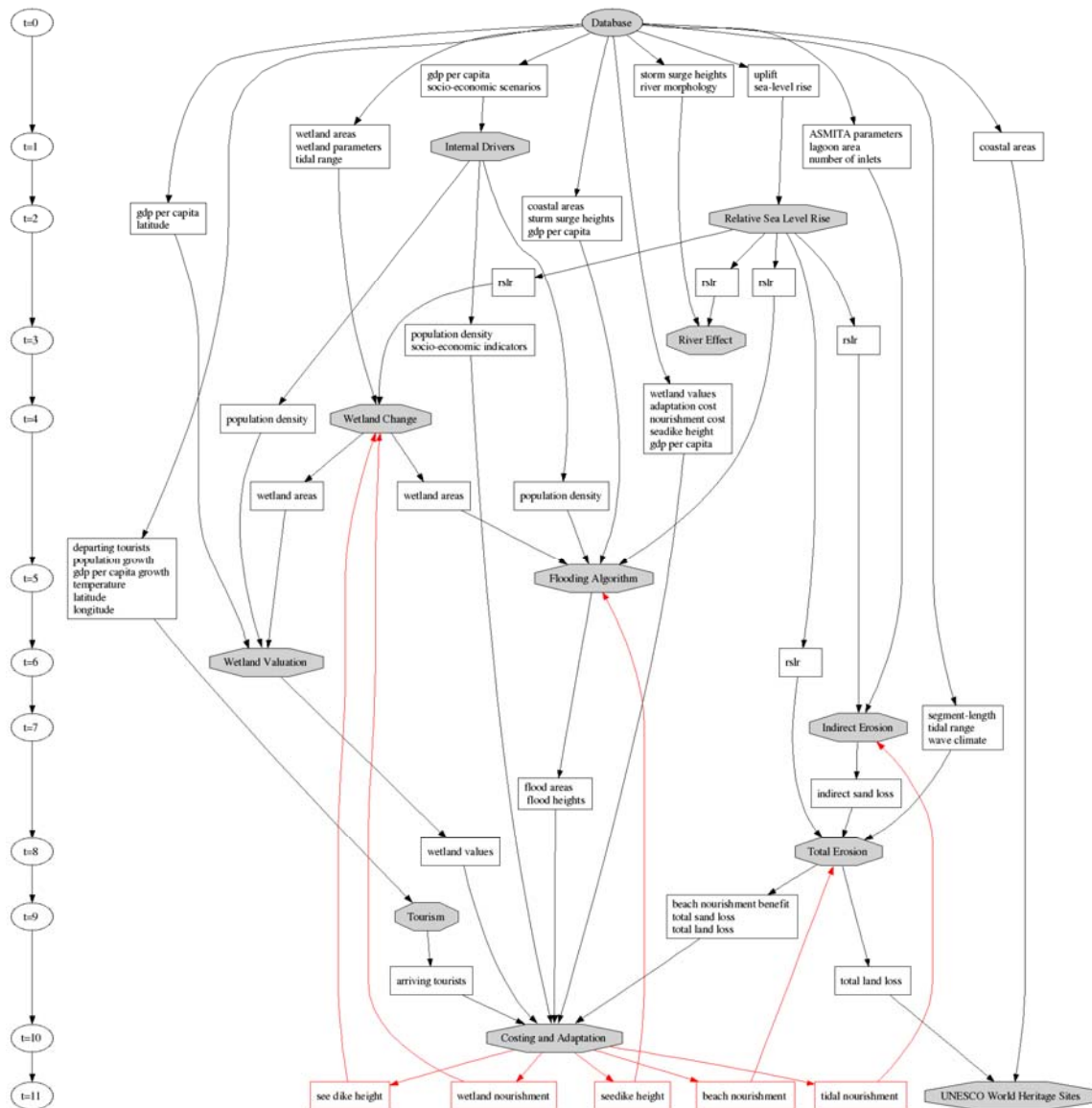


Figure 4-4: Module linkages in the DIVA model. Ovals represent the modules, boxes represent data, the black arrows represent the flow of data during one time step, the red arrows represent the data fed into the next time step (Source: DE LA VEGA-LEINERT ET AL., 2005:89)

The DIVA method consists of a conceptual frame, an iterative development process, a generic model, and a build and documentation tool (HINKEL, 2005, cf. figure 4-4). The modules used in DIVA were: internal drivers, SLR, river effect, wetland change, flooding, wetland valuation, indirect erosion, total erosion, tourism, costing and adaptation, and world heritage sites.

The DIVA tool is an interactive tool enabling the user to explore the effects of climate and socio-economic change as on adaptation.

In DINAS Coast the world’s coastline was segmented in units according to their natural and socio-economic diversity that were homogenous in terms of vulnerability to sea-level rise. These units vary in length with an average of 70 km. In doing so all the data in the DIVA database are referenced to 12,148 linear coastal segments and are expressed as attributes of five main geographic features: the geomorphic structure of the coastal environment, the po-

tential for wetland migration, the location of major rivers and deltas, the population density classes, and the administrative boundaries.

DINAS Coast follows an indicator-based approach using a range of indicators on population, health, economy, governance on global and regional level (cf. table 4-5).

Table 4-5: Vulnerability classes and indicators used in the DINAS COAST project

Exposure	Area data	Population data	Social indicators
Bruun Rule factor (S)	Coastal forest area (S)	Coastal population (S)	Life expectancy (C)
Surge height (S)	Freshwater marsh area (S)	Coastal Population density (S)	Literacy (C)
Coastal slope (S)		Population growth (C)	
Sediment supply (S)	High unvegetated wetland area (S)	Growth of per capita income (C)	Political stability (C)
Tidal range (S)	Low unvegetated wetland area (S)		Tourist departures/ arrivals (C)
Uplift/Subsidence (S)	Mangrove area (S)		Tourism added value (C)
Wave climate (S)	Saltmarsh area (S)		Individualism (C)
Potential wetland migration (S)	World heritage sites		Government quality (C)
Sea dike height (S)	Accommodation space (S)		Gini Index (C)
River data (R)			GDP per capita (A)
Tidal basin data (T)			Economic freedom (C)
Adaptation			Democracy (C)
Nourishment (A)			Corruption (C)
Flood protection (A)			Civil liberties (C)
SLR (S)			Religion (C)
Temperature (C)			Masculinity (C)
Coastal eurousion			Land use

Coastline segments (S), Administrative units (A), Countries (C), Rivers (R), Tidal basins (T)

Outputs of the DIVA model, generated with these indicators, are e.g. erosion, flooding, salt-water intrusion, wetlands, and costs.

DIVA is the first interactive tool allowing the use to choose of a range of scenarios and indicators and is so a very broad spectrum of vulnerability indicators (cf. table 4-3). Yet, it is constraint by the limited resolution. The social indicators are only available on country level. On administrative level, they are only a few indicators, such as GDP, and nourishment to choose.

US Country Studies Program, USCSP (LEATHERMAN & YOHE, 1996)

The US Country Studies Programme (BENIOFF ET AL. 1996) follows a six step approach which is close to the technical guidelines. The guidance provided for the coastal regions (LEATHERMAN & YOHE, 1996) outlines four steps:

1. Preliminary screening
2. Aerial Videotape-Assisted Vulnerability Analysis (AVVA)
3. Economic Analysis
4. Adaptation Analysis

The special about the USCSP is the usage of an AVVA. The AVVA was developed to overcome the lack of data (physical, demographic, economic, and topographic) on large scales in developing countries. AVVA works on altitudes of 70/100m and 300m and provides a low-cost primarily vulnerability assessment. It was used as a major tool to acquire coastal data, combined with other statistical data sources, in the USCSP, focusing on the land loss impacts of sea-level rise (erosion and inundation).

The AVVA provides information about

- the terrain,
- types of coastal environment (geomorphic type, elevation),
- land-use (agriculture, aquaculture),
- infrastructure (buildings, tourist resorts, commercial establishments),
- the affected population.
- land loss, estimated with the Bruun Rule.
- adaptation analysis consisting of the determination and of the costs of four protection scenarios against sea-level rise (combined of port upgrade, beach nourishment, sea walls).

The AVVA allows a low cost assessing method especially in developing countries where data availability is low.

PNNL Vulnerability assessment programme on impacts of climate change (MOSS ET AL., 2001)

The study addresses two challenges: To improve approaches for comparing and aggregating impacts across diverse sectors and populations, and to model socioeconomic transformation as well as climate change in assessing the future significance of climate change (MOSS ET AL., 2001). A prototype computer-based methodology for assessing vulnerability and resil-

ience to climate change was designed taking present circumstances and three alternative scenarios of the future. The model calculates indicators of sensitivity to climate change, and coping-adaptive capacity. Indicators for climate sensitivity and coping capacity were defined resulting in a total vulnerability indicator.

As the selection of indicators is an iterative process based on data availability, sectors for climate sensitivity and coping capacity were selected. These categories were: settlement and infrastructure, food security, ecosystems, human health, water resources for climate sensitivity and economy, human and civic resources and environment for coping capacity (cf. table 4-4).

The indicators were aggregated to a vulnerability-resilience indicator, build from the difference of vulnerability (negative) and capacity (positive).

The indicatorsystem was applied in 38 countries in the world. MOSS ET AL. (2001) alluded that the application on national level is just giving an overview where detailed assessments have to be conducted on a micro-scale level.

The study is able to deliver aggregation of indicators, allow indexing and is based on available data. But at the same time detailed analysis concerning the weighting of the indicators is missing.

Table 4-6: Indicators, sectors, and proxies used in the vulnerability-resilience indicator prototype (VRIP) model (MOSS ET AL., 2001:49)

Sensitivity or Adaptive capacity category	Proxy variables	Proxy for	Functional relationship
Climate sensitivity			
Settlement/infrastructure sensitivity	Population at flood risk from sea level rise Population without access to clean water/sanitation	Potential extent of disruptions from sea level rise Access of population to basic services to buffer against climate variability and change	Sensitivity ↑ as population at risk ↑ Sensitivity ↑ as population with no access ↑
Food security	Cereals production/area Animal protein consumption/capita	Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and Change Access of a population to markets and other mechanisms (e.g., consumption shift) for compensating for short-falls in production	Sensitivity ↓ as production ↑ Sensitivity ↓ as consumption ↑
Ecosystem sensitivity	% Land managed Fertilizer use	Degree of human intrusion into the natural landscape and land fragmentation Nitrogen/phosphorus loading of ecosystems and stresses from pollution	Sensitivity ↑ as % land managed ↑ 60-100 kg/ha is optimal. X < 60 kg/ha, sensitivity ↑ due to nutrient deficits and potential cultivation of adjacent ecosystems. X > 100 kg/ha (capped at 500 kg/ha), sensitivity ↑ due to increasing runoff
Human health sensitivity	Completed fertility Life expectancy	Composite of conditions that affect human health	Sensitivity ↓ as fertility Sensitivity ↓ as life expect-

		including nutrition, exposure to disease risks, and access to health services	tancy ↑
Water resource sensitivity	Renewable supply and inflow Water use	Supply of water from internal renewable resources and inflow from rivers Withdrawals to meet current or projected needs	Sensitivity calculated using ratio of available water used: Sensitivity ↑ as % water used ↑
Adaptive- and coping capacity			
Economic capacity	GDP(market)/capita Gini index	Distribution of access to markets, technology, and other resources useful for adaptation	Coping-adaptive capacity ↑ as GDP per capita ↑ At present Gini held constant
Human and civic resources	Dependency ratio Literacy	Social and economic resources available for adaptation after meeting other present needs Human capital and adaptability of labor force	Coping-adaptive capacity ↓ as dependency ↑ Coping-adaptive capacity as literacy ↑
Environmental capacity	Population density SO ₂ /area % Land unmanaged	Population pressure and stresses on ecosystems Air quality and other stresses on ecosystems Landscape fragmentation and ease of ecosystem migration	Coping-adaptive capacity ↓ as population density ↑ Coping-adaptive capacity as SO ₂ ↑ Coping-adaptive capacity ↑ as % unmanaged land ↑

4.2 Vulnerability assessment studies on regional scale

By far the most studies are conducted on regional level or meso scale. In contrast to the national and global studies, these assessments are conducted with the aim of delivering more concrete advice for handling and policy making. To limit the effort of time and money, predominantly aggregated data were used.

In the following, the outputs of three regional studies are compared:

- a coastal risk assessment database (GORNITZ, 1997)
- an erosion hazard vulnerability assessment study (BORUFF ET AL., 2005), and
- "Bewertungsgutachten", a meso scale evaluation at the German coast (HAMANN & KLUG, 1998; COLIJN ET AL. 2000)

A coastal risk assessment database - GORNITZ ET AL., (1994, 1997)

Among the first regional analyses in the US were GORNITZ ET AL., (1994, 1997), developing an index of vulnerability to sea-level rise based on seven and later 13 physical parameters. GORNITZ ET AL. (1994; 1997) developed a large scale coastal hazard database assessing the vulnerability of the U.S. Southeast and Southwest coast to sea-level rise and the consequences of permanent inundation, erosion, and coastal flooding. Based on the global haz-

ards database (GORNITZ & WHITE, 1992), the coastal risk assessment database was developed for use with a GIS.

They used 13 physical (table 4-7) variables to build a coastal vulnerability index (CVI):

Table 4-7: Vulnerability classes and indicators used by GORNITZ ET AL., 1997

Mean elevation variable
Relative sea level rise
Geology
Landform/geomorphology
Historical shoreline erosion/accretion
Tide range
Wave height
Hurricane probability of occurrence
Tropical storm probability of occurrence
Hurricane strike frequency
Tropical cyclone forward velocity
Mean annual number of extratropical cyclones
Mean hurricane surge height variables

The CVI with a ranking from 1-5 was built by grouping the variables in

- Inundation
 - ➔ permanent: elevation, local subsidence
 - ➔ episodic: tropical storm probability, hurricane probability, hurricane frequency, tropical cyclone velocity, extratropical cyclone, hurricane storm surge, tide range
- Erosion: geology, landform, shoreline erosion, wave height

The USGS enhanced the initial studies creating an improved coastal vulnerability index (CVI) (THIELER & HAMMER-KLOSE, 1999, 2000 a + b) having less data gaps and better metric of physical vulnerability at the county level.

They use the vulnerability indicators:

- (a) geomorphology (ranking from 1-5: low to high vulnerability
1= Rocky, cliff coasts, fjords; 2= Medium cliffs; 3= Low cliffs, alluvial plain; 4= Estuary, lagoons; 5= Sand beaches, salt marshes, mangrove, coral reefs)
- (b) shoreline erosion and accretion rate (m/y)
- (c) coastal slope (%)
- (d) rate of relative sea-level rise (mm/yr)
- (e) mean tidal range (m)
- (f) mean wave height (m)

Calculation: $CVI = \sqrt{((a * b * c * d * e * f) / 6)}$

The special with the study by GORNITZ ET AL. is that it includes variables for hurricane characteristics in the investigation. On the other hand this study as a crucial deficit as socio-economic vulnerability indicators were not included at all. Furthermore, salinization and storm surges were not considered.

An erosion hazard vulnerability assessment study - BORUFF ET AL., (2005)

BORUFF ET AL. (2005) followed an indicator-based approach designing a Social Vulnerability Index (SoVI), combined it with the Coastal Vulnerability Index (CVI) of THIELER & HAMMER-KLOSE (1999), and built a Place Vulnerability Index (PVI).

The SoVI describes the construction of an index of social vulnerability to environmental hazards. This index uses socio-economic and demographic data from all 3,141 counties in the USA, with a computer analysis of 42 (39) independent variables and 11 diverse key factors in vulnerability to generate a composite score for each county and enable relative assessments between counties. Beside indicators of exposure (mean tidal range, coastal slope, SLR, erosion/accretion, mean wave height, geomorphology), a wide range of social indicators were used on population structure, ethnical backgrounds, personal welfare, buildings and manufacturing and commercial infrastructure as well as inequality and health (cf. table 4-8). Variables used in the investigation:

Table 4-8: Indicators used in the study by - BORUFF ET AL., (2005)

Per capita income
Median dollar value of owner-occupied housing units
Median rent for renter-occupied housing units
Percentage voting for leading party
Net international migration
Land in farms as a percent of total land
Percent of civilian labor force that is unemployed
Average number of people per household
Percent of households earning more than \$100,00
Percent living in poverty
Percent renter-occupied housing units
Percent rural farm population
General local government debt to revenue ratio
Percent of housing units that are mobile homes
Percent of population 25 years or older with no high school diploma
Number of housing units per square mile
Number of housing permits per new residential construction per square mile
Number of manufacturing establishments persquare mile
Earnings in all industries per square mile
Number of commercial establishments per square mile
Value of all property and farm products sold per square mile
Percent of the population participating in the labour force
Percent females participating in civilian labour force
Percent employed in primary extractive industries (farming, fishing, mining, forestry)
Percent employed in transportation, communications and other public utilities
Percent employed in service occupation
Percent female headed households, no spouse present
Per capita social security recipients
Nursing home rents per capita
Number of community hospitals per capita
Number of physicians per 100,000 people

Median age
 Birth rate
 Percent population change 1990/2000
 Percent urban population
 Percent female
 Percent African America
 Percent Native American
 Percent Asian
 Percent Hispanic
 Percent of population under 5 years old
 Percent of population over 65 years

The results revealed spatial patterns in vulnerability and the relevant significance of particular factors in increasing vulnerability or moderating its effects.

Limitations of this study were that social data in the index were at county level and physical attributes were at shoreline segments scale. Physical data include longer-term conditions (SLR) as well as daily averages (mean tidal range), while the social data represent only the actual situation in 2000. Therefore the PVI is a static indicator (BORUFF ET AL., 2005). Mitigation indicators (such as coastal protection) are not included in the indices, although they in fact reduce vulnerability. This study outlined that when comparing physical and socio-economic vulnerability attributes there are spatial differences between them. For example in their study at the Pacific and the Atlantic coast physical factors determine vulnerability, while at the gulfcoast more social characteristics of the people are decisive. That’s why BORUFF ET AL. (2005) introduce the “place vulnerability”.

Bewertungsgutachten, a meso scale evaluation German Coast - HAMANN & KLUG (1998); COLIJN ET AL. (2000)

In Germany, a meso-scale assessment was conducted to evaluate the potential flood risks of sea level rise on community level. More, a value assessment that was more detailed than the IPCC Case Study was conducted. The value assessment and the damage potential analysis were based on economic data only, including (cf table 4-9):

Table 4-9: Indicators used in the study by - Boruff et al., (2005) Hamann & Klug (1998); Colijn et al. (2000)

Intangible damage categories	Tangible damage categories
Inhabitants	private buildings
Hotel beds	fixtures
	cars
	economic used land
	estate buildings
	assets
	stock value
	cattle
	traffic areas
	agricultural area
	Gross value added

Social, ecological, and cultural values were neglected.

The study was based on the methodology of the “Wesermarsch-Gutachten” (KLAUS & SCHMIDTKE, 1990), which uses official statistics. The “Bewertungsgutachten” was compiled in the framework of downscaling approach made in Germany, starting with the IPCC country study, followed by the meso-scale assessment (HAMANN & KLUG, 1998; COLIJN ET AL., 2000), and ending up in a micro scale approach (MERK), which is described in the following sub-chapter.

4.3 Vulnerability assessment studies on local scale

The most detailed vulnerability assessment studies are on local level or micro-scale. Here, the evaluation takes place on object level, i.e. single valuables of one category. Indicators were only additionally used. Local scale assessments provide the possibility to give adaptation or protection advice for policy integration on a local level, e.g. in a community.

On this level, climate change impact studies are seldom because of the lack of local SLR scenarios. Most of the local studies are conducted to assess the vulnerability to a concrete, recurring local hazard such storm surges or hurricanes.

In the following, three local or micro-scale studies are considered:

- Case study Sylt - HARTJE ET AL. (2002)
- MERK - REESE ET AL. (2003)
- Risk assessment for the Ribe Area – COMRISK (KYSTDIREKTORATET, 2005, PIONTKOWITZ, 2005)

Case study Sylt - HARTJE ET AL. (2002)

HARTJE ET AL. (2002), evaluate possible consequences and damages of climate change on the island Sylt. As impacts, erosion (climate change erosion, sediment transfer, and sand loss until 2050 with and without protection) as well as the loss of Wadden Sea biotops were considered.

In the study, the market prices at the time of loss were used for calculation.

HARTJE ET AL. assessed only the values of the areas directly affected in their climate scenarios.

The damage categories used by in this study are listed in table 4-10.

Table 4-10: Value categories and indicators used by HARTJE ET AL., 2002

build land
buildings
streets/traffic areas
beaches
biotops
and dunes

For these categories, different adaptation measures and price developments were calculated using a cost benefit analysis.

MERK - REESE ET AL. (2003)

MERK project (Micro-scale Risk Evaluation for Coastal Lowlands, REESE ET AL., 2003). The GIS-based micro scale valuation analysis as the last step of the German downscaling approach was conducted for selected communities at the German North Sea and Baltic coast that are susceptible to be flooded in course of extreme storm surges. The project aimed at solving the problem of unappropriate macro –and meso scale results by developing a GIS based micro scale instrument for vulnerability assessment, which can be implemented into an integrated coastal defense management. The impacts of extreme storm floods on the socio-economic system were examined for eight exemplary communities (rural-urban-tourist).

A deterministic hazard estimation was carried out, basing on records obtained from historical storm floods. Different storm flood- and dike breach scenarios were elaborated to realise the simulation of various corresponding flooding processes. To realize this high-resolution DEM (1:5000) was constructed for exact delineation of the risk zone, especially for the Baltic coast.

The vulnerable tangible and intangible structures were identified and all individual objects were considered.

In total, 13 tangible and 3 intangible value categories (cf. table 4-11) were assessed on object based level.

Table 4-11: Indicators used by REESE ET AL. (2003)

Intangible damage categories	Tangible damage categories
Inhabitants	private buildings
employees	land property
Hotel beds	fixtures
	cars
	economic used land
	estate buildings
	assets
	stock value
	cattle
	traffic areas

agricultural area
 forest area
 settlement area
 green space
 Gross value added

To fulfill the required micro scale details, detailed surveys were conducted to receive information about age, construction, type, and function of every building. To determine the possible damages, the assets at risk (damage potential) were analyzed on the basis of different flooding scenarios. To record the damages subject to the flood heights at the object itself, depths damage functions have been derived for coastal areas by expert interviews. The micro scale results allow to support coastal defense and adaptation planning and give recommendations.

Risk assessment for the Ribe Area – COMRISK (KYSTDIREKTORATET, 2005)

In the framework of the COMRISK project, a probabilistic flood risk analysis of the Ribe flood defense system was made with help of a hazard analysis and a vulnerability analysis to determine the damage potential. The VA considers the valuation of tangible risk elements by defining damage functions for each element at risk. Inundation scenarios are set up in order to assess the extension and depth of different inundation scenarios. The combination of the value of risk elements and the related damage factors determines the damage within a specific scenario. The vulnerability analysis as in the MERK project was divided into a valuation analysis and a damage analysis. Only direct and tangible flood damage is considered in this study. A damage analysis was then made under different scenarios.

The following elements (table 4-12) of risk were part of the vulnerability analysis (KYSTDIREKTORATET, 2005)

Table 4-12: Indicators used in the COMRISK Case study

Intangible damage categories	Tangible damage categories
Inhabitants (mean value for the number of persons per household)	Buildings (residential, agricultural, industrial, type, use, number of floors)
Employees (number and distribution)	Movable property (mean value for different building types)
Tourism capacity*	Agricultural acreage, crops (per block) Livestock Electric installations (pumps, wind-mills, number from maps) Traffic systems (roads, railways) Vehicles (number of cars per household)

- only qualitative described, because hotel beds do not consider day visitors

Table 4-13 summarizes the value categories used in the presented micro scale assessment studies.

Table 4-13: Overview over damage categories in selected local VA studies (modified after BERGER, 2001; MEYER, 2004)

	Climate Impact research	Direct, tangible categories														Indirect tangible categories				
		Private living				Economic activity				Infrastructure				Ground value		Inhabitants	GDP	Hotel beds	Employees	Environmental goods
		Properties	Buildings	Fixtures	Cars	Economic used area	Estate buildings	Assets	Stock value	Livestock/Cattle	Roads	Railroads	Electric Installations	Green Space	Forest area					
HARTJE ET AL. (2002), Sylt																				
REESE ET AL. (2003), German Coast																				
KYSTDIREKTORATET (2005), Ribe																				

4.4 Synthesis on coastal vulnerability assessment studies

In the previous section, eleven selected vulnerability assessment studies were opposed. They were arranged according to scale, from global to local in order to compare what results they deliver on different scales, because the success of an analysis depends on the scale of implementation and the criteria used to evaluate it at each scale (ADGER ET AL., 2005).

It can be concluded that there are two crucial determinants that differentiate the studies:

- the dependence on scale, and
- the number and variety of indicators or vulnerability classes.

Studies on global to national scale are predominantly conducted in the climate change community, assessing the impacts of sea level rise. As climate scenarios mostly are on global scale, their use on regional and local level is limited. Global assessments follow a very scientific approach. It is the superior goal to develop methodologies and approve the feasibility of indicators and models (e.g. flood models). The results are not only useful for further research but also for global climate and environmental policy making, e.g. by the UNFCCC or the IPCC. This macro level allows a comparison of countries and regions, because data are so much aggregated that identical vulnerability classes can be used worldwide. As it is not possible to make a very detailed place-based assessment of e.g. economic goods in one community or of specific social characteristics of single groups or individuals, macro-scale studies mostly use indicators to derive information about the vulnerability classes.

Most of the global and national studies in the last two decades used the Common Methodology. The IPCC Country studies and the GVA gave an overview of world wide coastal vulner-

ability to sea level rise for the first time. Although they partly used different tools and were impeded by national restrictions and data availability, they allow a comparison of vulnerable sites in the world and arise the awareness of coastal risks due to an ASLR. NICHOLLS (1995) compares the country studies and the GVA to check if the GVA can deliver reliable results concerning the number of people affected (no measures), wetlands at loss (no measures), and costs for protection. He concludes that the GVA delivers quite good results although some problems occurred. Some country studies were geographically incomplete, while the GVA analyzes the entire coastal area of a nation. Furthermore there was different data accuracy in the countries. For most areas, the sample size of case studies available for comparison remains small. In some cases results differ extremely, e.g. in Bangladesh: 71 million people are affected in the country study and only 22.7 million in the GVA. NICHOLLS (1995) concludes that a reason for this is the fact that country studies included change in river flow and its interaction with sea level rise.

Nevertheless, studies using the CM have some crucial limitations. They rely on sea level as the only climate variable. Other impacts of climate change, i.e. storm surges or erosion as well as locally specific interactions with river flooding are neglected. Furthermore they focus on a generalized ASLR of 1 m, ignoring the spatial distribution of ASLR due to the lack of regional scenarios.

From the socio-economic view, not enough data are included; indicators for social vulnerability and resilience are not taken into account. Even response strategies are generalized, not taking into account locally specific adaptation capacities.

The USCP deals with only two of hazards produced by sea-level rise: erosion and inundation. Even the USCP uses only a limited number of vulnerability classes. The special with the USCP is the application of the AVVA, portioning the coast into a number of linear sections based on coastal geomorphology, land use, and land cover characteristics (LEATHERMAN, 1995). Although the USCSP is also constraint by a limited number of vulnerability classes, it is useful for the application in developing countries. Using the AVVA an assessment is possible where only little data is available.

The DINAS COAST project took up the limitations of global vulnerability assessments and is the most complex study on this scale, modeling a future view of the world under changing climatic conditions, i.e. with an ASLR.

They took up a key factor of large scale assessments, namely, the segmentation of the coastline. Using large scale assessments the area of investigation (be it the whole world) has to be segmented somehow. While HOOZEMANNS ET AL. (1993) and even GORNITZ ET AL. (1994) use national or administrative boundaries for segmentation, DIVA takes the dynamics

of the coastal system and its characteristic to change steadily in temporal and spatial terms into account. Assuming that the coast is no linear entity but physical, ecological, and socio-economic spheres are interacting with each other, DIVA regards variations in vulnerability within the coastal zone to be controlled by primary variations in the human and physical coastal environment (MC FADDEN, 2003). In so doing a total of 12,148 segments were produced. These segments are similar physical, socio-economic, and administrative units which define the minimum number of reasonably homogenous units along the coast.

On a global scale DIVA is more sophisticated than the global studies by HOOZEMANS ET AL. (1993), BAARSE (1995), and NICHOLLS (2002), especially, because it provides a sophisticated model, using a wide range of coastal vulnerability indicators. The interactive model enables the user to define scenarios and select adaptation options.

Nevertheless the coarse geographical scale of the analysis limits the applicableness for coastal management. DIVA is very useful for science and education but it will not help decision makers concerned with coastal protection planning or risk management more than give an overview and an idea of the vulnerability factors and the possible adaptation options.

From all global to national (or macro) studies it can be concluded that:

- Global and national assessments are useful for developing new methodologies – e.g. indicators, new data application (e.g. remote sensing) - to assess the impacts of sea level rise in the climate change community.
- Global and national assessments are relevant for international policy making such as climate policies by the UNFCCC, because they give insights in the future development of the world and allow the selection of global hot spots and the comparison of regions.
- Although using aggregated data, a global analysis is always constraint by the lack of data in some regions. Consequently data have to be interpolated leading to low accuracy.
- Global and national scales allow the use of a wide range of indicators. DINAS COAST for example is using various social indicators such as health or religion.
- National assessments can deliver a variety of results because many indicators or databases exist only on national level. The national policy is in many countries determining the response and resource allocation to sub-national units.
- Nevertheless, the deciding disadvantage of global and national studies in terms of coastal risk management is, that they do not deliver the detailed results local planners need for decision making. They can only help decision makers by giving information. The interpretation of spatially and temporally aggregated data is difficult because within countries vulnerability is geographically and socially differentiated, national indicators must therefore be completed by local indicators to yield a full picture of vulnerability. Even if the overall vulnerability of a country is low, certain subgroups may be strongly effected. Yet they would not be regarded in aggregated data sets.

By far the most studies are conducted on regional level or meso-scale. These studies consider regional conditions, but are still using aggregated results. In doing so they face the same problems as global studies do. While GORNITZ ET AL. (1992) assess only natural vulnerability without taking into account socio-economic indicators, BORUFF ET AL. (2005) use a wide range of social indicators which make up very specific social conditions at different places.

The "Bewertungsgutachten" compared with the MERK project for the same area and the same vulnerability classes clearly showed the differences and the inaccuracies concerning concrete values as well as the number of people at risk (cf. REESE, 2003). The studies analysed on this level showed very different results. This is due to the fact, that they don't follow concrete guidelines, as studies using the CM.

Below the regional level, a large number of tools to measure vulnerability exist. In difference to global studies they are not dominated by assessments of a global sea level rise and future scenarios. Yet, local or micro-scale studies are mainly applied in the hazard community and mainly investigate the potential threat of a hazard more or less common in the specific location. Based on the assumption that measures that have to be taken in one community may differ completely from those taken in another, due to localized special conditions, they use very detailed, object based, and site specific data to deliver the desired output for coastal management. Here one climate change study and two damage potential assessment studies were introduced, which assess capital values of a region on an object based level and so deliver very detailed data on the damage potential.

However, the results of the local studies are frequently constrained by the fact that they are not conducted with the goal of providing a representative sample and use a range of different methods, scenarios, and assumptions. Local (micro-scale) analyses are time consuming and require an immense amount of detailed data. Both time and data as well as the associated costs are not practicable for an analysis of a large area or under conditions, where data, know how, and money is not available. The greatest part of regions at risk in the world is in developing countries where data availability is very limited. Often, data on local level are not available or protected, so that great inhomogeneities can occur. Due to the large efforts, the assessment of intangible and social factors is limited, as well as the assessment of ecological or cultural goods.

From all local (or micro-scale) studies the following conclusions can be made.

- Their outputs are useful and appropriate to transfer them in decision making in coastal management.
- The specific local conditions can be taken into account.
- With help of object based value assessments, a damage analysis can be conducted giving exact information about the monetary loss to a given hazard scenario.

- The main disadvantage is the effort in connection with micro-scale assessments. Irrespective of pilot studies, micro-scale assessments can not be generalized or applied widely because of the high demands on data and the effort to assess them.
- A comparison of local sites, which is sometimes urgently required for trans-regional decision making, is not feasible. This is due to difficulties in applying the same VA method in different areas due to different conditions, e.g. urban or rural, because substantially different communities and political systems are involved dealing with different problems. Furthermore, cost-benefit calculations are not always the same, e.g. in developing countries, often other problems are of greater importance (war, epidemics) than coastal risks.
- As micro-scale assessments are for the most conducted to give advice for cost-benefit calculations in coastal defense planning, the assessment of economic values is in the focus of these studies.

What kind of scale and methodology is chosen depends on:

- the goal of the study (e.g. place-specific measure planning),
- the size of the area of investigation,
- if it is a risk assessment of long-term hazards or short-term hazards,
- the availability of data,
- the availability of time and manpower, know how and resources, and
- the management level for which it should provide decision making support.

A large number of local studies have been carried out in coastal vulnerability assessment. Yet, most of these studies look at the vulnerable zone as itself considering the effects on the system instead of looking on changes in the global drivers affecting a system (ZIERVOGEL ET AL., 2004). Several attempts have been made towards downscaling and taking up the problem of how local regions might be affected by global changes. However even the most recent scenario-based assessments of impacts and vulnerability are on regional or global scale. On a local scale, their results may enhance awareness of the need to adapt, but they provide decision makers with little information about the most efficient or effective way to adapt. (KLEIN 2004).

As every vulnerability assessment study is more or less constraint by limited availability of data or a mismatch of scale leading to disproportionate effort, this leads often to inappropriate expectations concerning the outcomes of VA. This is especially concerning the usefulness of the outcomes for local planners and decision makers.

Irrespective from scale, different countries or regions use different methods and data types. Global databases for example would carry additional value if local and sub-national databases use uniform data, allowing comparison and aggregation. There is a need to work to-

ward the standardization of all issues related to the technical soundness, political neutrality, methodologies and processes related to the collection, analysis, storage, maintenance, and dissemination of data.

Decision makers need to know local conditions to develop optimised management strategies. Therefore community-based assessments are required to make use of VA assessment. Similarly, it is only at this local level that the coastal population can make decisions on the possible benefits of flood insurance or on site-specific economic investments. Political authorities usually see economic considerations as highly influential in their decision-making. Only on the basis of detailed and comprehensive information will it be possible for policy makers to design the most appropriate response strategies, that is, to decide whether and which strategies are most suitable for minimising risks in a specific site while optimising future coastal resource use.

As ideally an investigation as detailed as possible should be achieved, cross scale assessments, using micro scale assessment methods where it is absolutely necessary and choose more meso scale data in cases where it is assumed to be detailed enough, should be applied. Furthermore easily available data, like remote sensing, should be included more intensively. The advantage of these data is that they are largely unaffected by national data collection practices, can be aggregated comparatively easily and are readily available. The integration of remotely-sensed and analogue cartographic data offers the most promising approach to globally coherent, up-to-date, and scientifically valid databases.

Although the considered studies include a range of indicators and value categories, there is still a lack of integrated studies working on a scale that is useful to give advice for decision making.

In the early studies, there is a strong focus on biophysical characters. Vulnerability is to a large part derived from the exposure characteristics of a system (e.g. GORNITZ ET AL. 1997). Although the IPCC Country studies, the GVA and the USCSP include socio-economic features, they still have a strong focus on the physical system characteristics.

In the most recent studies, approaches to integrate social and physical data were made. The DINAS Coast project, and BORUFF ET AL. 2005 used variables such as health status, poverty, or ethnicity to determine vulnerability. The local assessment studies focus on a wide array of economic data instead of including social ones.

An overall deficit all studies face is the absence of the consideration of the resilience factor of a system. The role of humans, their social characteristics, their community networks, and their awareness of risk are assumed to be crucial when estimating vulnerability and decisive when handling disasters.

In the following table (4-14) the indicators and value categories of the selected studies were opposed

- **[1]** IPCC Case study Germany - EBENHÖH ET AL. (1997); BEHNEN (1998)
- **[2]** Global Vulnerability Assessment - HOOZEMANS (1993)
- **[3]** US Country Study Programme -LEATHERMAN & YOHE (1996)
- **[4]** DINAS Coast - DE LA VEGA-LEINERT & NICHOLLS (2005)
- **[5]** PNNL Vulnerability assessment programme on impacts of climate change (MOSS ET AL., 2001)
- **[6]** Erosion Hazard vulnerability - BORUFF ET AL. (2005)
- **[7]** A coastal risk assessment database - GORNITZ ET AL. (1992)
- **[8]** Meso scale evaluation German Coast - HAMANN & KLUG (1998); COLIJN ET AL. (2000)
- **[9]** MERK - REESE ET AL. (2003)
- **[10]** COMRISK, Ribe - KYSTDIREKTORATET (2005)
- **[11]** Sylt - HARTJE ET AL. (2001)

5 An approach to indicator-based integrated risk and vulnerability assessment

An integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century.

UN/ISDR, 2003

Despite numerous efforts to estimate and handle coastal risks, disasters are still occurring and causing damages, more serious than ever before. Thus, it is necessary to further investigate the coherences between changing natural and socio-economic conditions and to develop strategies to manage risks in coastal zones. Beyond that, decision makers keep on asking for methodologies that are more appropriate to give them concrete advice on what to do and where to invest in adaptation strategies to long term changes.

In Chapter 4 it was asserted that for a long time, flood risk was predominantly assessed in technical terms, focusing on physical impacts. However, disasters do not just come from unexpected natural events. They are the predictable results of interactions among the biophysical system and the social characteristics of the communities that experience them. It is clear that the problems associated with natural hazards cannot be solved in isolation; they are rather symptoms of more basic social and political issues (JHC, 2002:27). To handle risks in coastal zones requires an overall understanding, of the natural and social characteristics of a system as well as its capacities to resist adverse impacts. "One of the challenges for the 21st century will be the effective integration of physical, social and economic processes at the coast" (NICHOLLS & BRANSON 1998:255).

The following chapter is addressing this issue by designing a conceptual framework integrating natural and social science for the assessment of coastal vulnerability.

5.1 Conceptual framework for integrated coastal risk assessment

Today there is still a deficit of integrated assessment methods that consider the full range of impacts from coastal hazards and yield data that are adequate for coastal risk management

and sustainable planning. Thus, a major issue is the question of how hazard, vulnerability, and risk assessments can be combined and used effectively to reduce risk. More, how can they be structured so that results are not fragmented and incomprehensible when transferred to decision makers? As a consequence of the focus on technical flood risk assessments, aiming at a quantification of damages and deaths in flood prone areas policy interventions were mainly flood defense, land use planning, and infrastructural changes. Yet, disasters affect people's livelihoods in many more ways than just economic losses and mortality. Depending on the type of hazard, social infrastructure may be destroyed, people may suffer from illnesses or injuries and be unable to work or study. More, ecological settings may be harmed and lose their function.

While there are great achievements in the quality of data allowing a more concrete identification, evaluation, and monitoring of hydro-meteorological hazard characteristics, (e.g. by sophisticated flood models), some aspects of the overall risk assessment process remain weak. In particular, assessing and measuring social, economic and ecological vulnerability is still not equally developed.

This problem can be addressed by an integrated assessment (IA), defined as

“...a methodology for complexity, its strength lying in making the links and feedback mechanisms explicit that exist between natural, economic and social systems” (GOUGH ET AL. 1998, in AMELUNG, 2006).

Combining bio- and geophysical with social, economic, and ecological data sets to conduct an integrated assessment and management can greatly improve our understanding of exposure at a range from local to global scales (NICHOLLS & SMALL, 2002; IPCC, 2001).

In coastal vulnerability assessment this is meant to join different disciplines to create a holistic base for the consideration of system characteristics. Integrated assessment as an interdisciplinary approach aims at bridging the gaps between disciplines, i.e. between different scientific disciplines as well as policy and stakeholder involvement.

In the framework designed in figure 5-1, segments for coastal risk and vulnerability assessment are brought into a context. Here, impacts of coastal hazards are related to the social sphere (as flood disaster), the economic sphere (as flood damage), and to the ecological sphere (initializing disturbance of the ecosystem equilibrium) of a system.

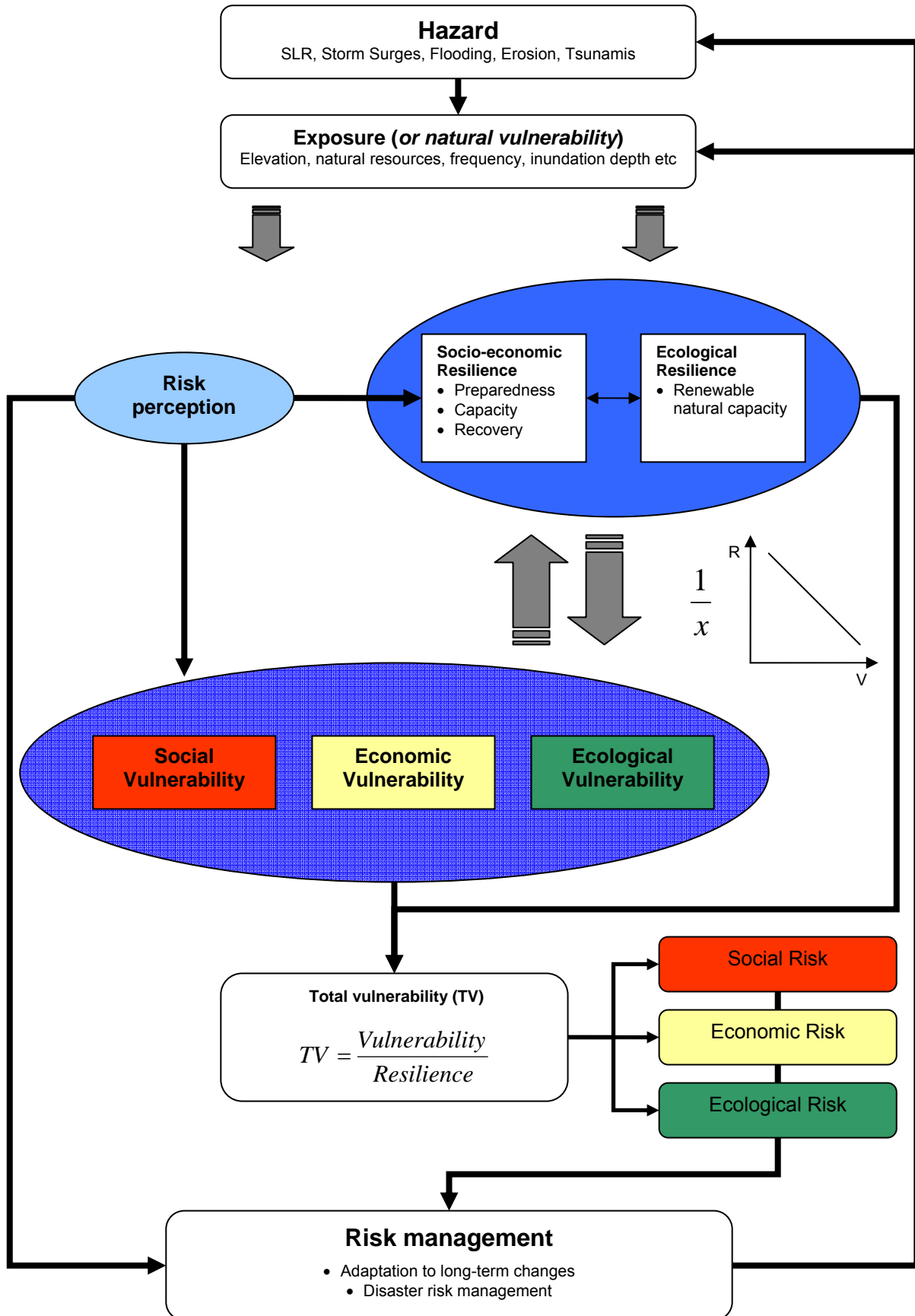


Figure 5-1: Holistic framework of coastal vulnerability assessment

Characteristics of coastal hazards include flood frequency, flood duration, inundation depth, sea-level rise scenarios, saltwater intrusion, and river flooding in deltas or estuaries as well as wave heights. These characteristics identify the degree to which coastal areas might be physically affected by coastal hazards.

Additionally, four types of scenarios can be distinguished for vulnerability assessment to climate induced and non-climate induced impacts. (KLEIN & NICHOLLS, 1999, cf. table 5-1)

Table 5-1: Four ideal types of scenarios for coastal vulnerability assessment (adapted from KLEIN & NICHOLLS, 1998:185)

	Environmental Changes	Socio-Economic Developments
Climate-Induced	<ul style="list-style-type: none"> • Accelerated ASLR • Changes in wind and wave parameters • Sediment-budget changes 	<ul style="list-style-type: none"> • Autonomous adaptation • Planned adaptation
Non Climate-Induced	<ul style="list-style-type: none"> • Vertical land movement • Sediment-budget changes 	<ul style="list-style-type: none"> • Population changes • Land-use changes • Changes in GDP

The degree to which coastal land is exposed to flood impacts, inundation, erosion, and salinization depends on its exposure characteristics, i.e. morphology, coastal slope, elevation, vegetation, trends in sediment supply and erosion/accretion patterns.

What is often called *natural vulnerability* in the literature is here the exposure of the elements at risk. The exposure to a hazard is defined as

“...the areas or regions liability to respond adversely to a hazard” (GORNITZ, 1991).

It is ambivalent if a natural system with sandy beaches is more ‘vulnerable’ (natural vulnerability) to flooding than a cliff coast or more ‘exposed’ (exposure) to it. In terms of social science, disaster management, and even in the scope of coastal defense, vulnerability is not given if no one is settling in an area, no economic use is taking place, and no capital values are at risk. Nevertheless, assessing the biophysical conditions is crucial; they are, just as the hazard characteristics a basis for estimation of vulnerability.

A system is vulnerable due to its specific social structure, its economic conditions and its ecological meaning. As every system has a capacity to buffer, the resilience factor has to be opposed to vulnerability. Vulnerability and resilience are balancing each other; while vulnerability has a negative connotation, resilience has a positive one. The outcome of this relation is the residual risk. This remaining risk can be adressed to social risk, economic risk, and ecological risk. It can differ significantly from site to site. Finally, it is a task of risk management to handle this residual risk. As coastal risk management is strongly related to governmental structures and financial resources it is important for the coastal planner to exactly know the residual risk, preferably quantitatively. Over- or underestimation would lead to mismanagement.

The individual or collective perception of risk plays a crucial role in the whole concept of vulnerability. How risk is perceived may determine where people settle, how they are prepared, how they behave in case of an emergency, and finally -of importance for management- what kind of risk they accept. The accepted risk is essential because protection measures and political decisions depend on aversion or acceptance of a certain degree of risk. Aversion arises if the perception of risk crosses an individual or societal risk level beyond which the risk is deemed unacceptable. In so doing the risk perception is leading to a more or less strong awareness of risk. This risk perception is decisive whether people expose themselves to a certain risk and to which degree they are able to cope and thus is influencing vulnerability.

In an investigation in the North Sea Region, with the help of a public and an expert survey (see chapter 5.7), the role of risk perception is investigated in order to appraise whether risk perception should be included in vulnerability assessment .

5.2 Composite vulnerability

Vulnerability is an overall term, determined by various aspects. If a coastal community is vulnerable to a specific or multiple hazards depends on a range of factors that make a system functioning. These factors have to be considered in conjunction to define overall vulnerability.

VILLAGRAN DE LEON (2006) summarizes the general factors that lead to vulnerability or reduce it (cf. table 5-2)

Table 5-2: Factors which generate or reduce vulnerability (adapted from VILLAGRAN DE LEON, 2006:49)

Factors which can lead to the generation of vulnerability	Factors which can enhance vulnerability	Factors which can reduce vulnerabilities
<ul style="list-style-type: none"> • Inequality due to prevailing political, social and economic models • Demographic differences • Unequal terms of international trade • Marginality, poverty and level of development • Lack of access to credit, mobilization of resources • Trends in land occupancy • Habits and traditions • Inadequate organization systems • Lack of responsibility regarding the generation of vulnerabilities • Unemployment, income deficits, illiteracy • City expansion, uncontrolled, unplanned growth due to migration to urban areas • Development aggression • Use of inappropriate technology • Lack of building codes or their enforcement 	<ul style="list-style-type: none"> • Increasing population • Densification of vulnerable areas in particular geographic regions • Marginality, poverty and level of development • Lack of access to credit, mobilization of resources • Trends in land occupancy • Habits and traditions • Unemployment, income deficits, illiteracy • Social and domestic violence • City expansion, uncontrolled, unplanned growth • Development aggression • Use of inappropriate technology • Lack of building codes or their enforcement • Previous disasters • Gender • Disintegration of social patterns and livelihoods 	<ul style="list-style-type: none"> • Improvements in social networks and livelihoods • More equal distribution of political and economic resources • Training and education • Urban planning • Implementation, enforcement of building codes • Diversification, duplication of resources • Provide more opportunities, resources, and power to women • Target marginal, informal, and micro-economic sectors during reconstruction phases after disasters

Considering all these factors vulnerability can be segmented into system components, all having their specific vulnerability criteria.

WILCHES-CHAUX (1989) distinguishes eleven types of vulnerability: natural, physical, economic, social, political, technical, ideological, cultural, educational, ecological, and institutional vulnerability.

PEDUZZI ET AL. (2001) distinguish economic vulnerability (impact of a disaster on the economy), human vulnerability (human loss and injuries), and social vulnerability (social structure influences). They develop vulnerability indicators for two categories of hazards: droughts and floods/cyclones/earthquakes. More, they created nine categories of vulnerability: economic, type of economic activities, dependency and quality of the environment, demography, health and sanitation, politics, early warning, education, as well as development.

CUTTER (1996) distinguishes between biophysical, built and human vulnerability. They define the vulnerability of the built environment as a measure of potential economic loss of structure and infrastructure. Human vulnerability is related to individual characteristics of people that make them more susceptible to harm from natural hazards. Biophysical vulnerability is produced by the interaction between physical processes and human activity. Among others, BROOKS (2003) and SLAFSZTEIN (2003) distinguish between social and natural/biophysical vulnerability.

Compared to WILCHES-CHAUX (1989), three categories build superior ones which summarize the eleven types he outlines (cf. figure 5-2):

- social vulnerability,
- economic vulnerability, and
- ecological vulnerability.

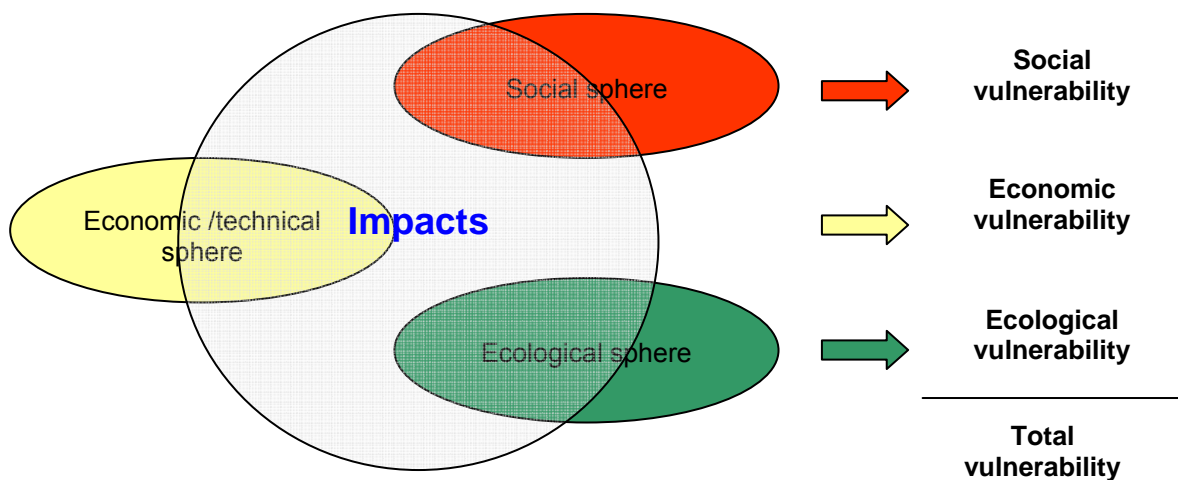


Figure 5-2: Composite vulnerability

Complex interactions of social, economic and environmental factors operating on different spatial and temporal scales give rise to vulnerability as they affect the ability of societies to prepare for, cope with, and recover from disasters.

Finally, the three segments of vulnerability can be summed up to build total vulnerability in which every part has its specific weighting. In terms of coastal hazards, social vulnerability describes for example the incidence of hurricanes in the Caribbean with respect to mortality or social disruption (social risk). Economic vulnerability describes e.g. the consequences of storm surges in the North Sea Region with respect to economic damages (economic risk). Ecological vulnerability describes the disturbance of mangroves, reefs, or wetlands to complex system changes like salinization, water temperature changes or heavy wave impact like in connection with the Asian tsunami (ecological risk). Understanding the interaction between socio-economic and biophysical system components is difficult, because terms, methods, and scales of analysis differ between natural and social science and are often not comparable. These data have to be related to each other in a way that makes sense for analysing vulnerability in a specific region and for a specific society in a specific environment on a scale that is useful for delivering outputs that can be transferred into decision making processes.

5.2.1 Social Vulnerability

Vulnerability to coastal hazards is to a great part determined by physical aspects, but it can be assumed that the natural characteristics alone cannot explain why some regions or groups are more vulnerable and more at risk than others. A hazard may cause no damage if it hits an unpopulated area or a region where human systems are well adapted to cope with it. Disasters only occur when a hazard affects a population unprepared to recover without assistance. Furthermore, the impacts of hazards differ for people at different levels of preparedness, and with varying capacities to cope and recover. What is called *social vulnerability* is thus viewed as a prior state, determined by the underlying political, economic, and social processes (ADGER, 1996), and refers to the susceptibility of groups or individuals to stress.

The concept of social vulnerability is widely applied in the context of famine. It has been worked out and discussed by ADGER (1999) and ADGER & KELLY (1999) and has in recent times been implemented in climate and environmental research (DOWNING, 2004; BOHLE ET AL., 1994; RIBOT, 1996; MOSS ET AL., 2001; HANDMER ET AL., 1999).

In the hazard community, social vulnerability has been used in many definitions to distinguish the social factors from the physical, economic, and political ones.

Social vulnerability is defined as

“...the exposure of groups or individuals to stresses both from exogenous risks and from their social and economic situation (ADGER, 1996:3) it is determined by the ability of social groups to respond to, in the sense of cope with, recover from and adapt to any external stress placed on their livelihoods and well-being”. (ADGER & KELLY, 1999:253)

Social vulnerability is a complex set of characteristics that includes a person's

- initial well-being (nutritional status, physical, and mental health, morale),
- livelihood and resilience (assets and capital, income, qualifications),
- self-protection (safe buildings, use of safe sites),
- social protection (building codes, mitigation measures, shelters, preparedness), and
- social and political networks and institutions (social capital, peoples rights to express need, access to preparedness) (CANNON ET AL., 2003:5).

Hence, it becomes clear that vulnerability is socially differentiated and that certain social characteristics influence vulnerability. For example a lack of human resources can limit the ability of some weak groups such as women, elderly, uneducated, or handicapped people to respond to coastal hazards adequately. Minorities or marginalized groups can be excluded from community actions and communication lines. Even social deficits on community level such as infrastructure and industry development influence vulnerability.

Social networks of individuals or of communities play a crucial role in coping with hazards and thus are a factor influencing vulnerability.

ADGER (1996) distinguishes between *individual* and *collective* vulnerability. Individual vulnerability is determined by access to resources and the diversity of income sources, the social status of individuals. Collective vulnerability of a nation, region, or community is determined by institutional and market structures, such as the prevalence of informal and formal social security and insurance, infrastructure, and income.

Unlike natural vulnerability social vulnerability is not a function of hazard. Nevertheless the nature of social vulnerability will partly depend on the hazard to which the human system is exposed because certain properties of a system will make it more vulnerable to certain types of hazard than to others. For example the number of hospitals will be an important indicator for vulnerability to heavy flood disasters, caused by a tsunami or a hurricane. Yet, it is less likely to influence the vulnerability to coastal erosion due to a slow sea level rise. So, although social vulnerability is not a function of hazard, it is, to a certain extent at least, hazard specific (BROOKS, 2003). These determinants are *specific* to particular hazards. Anyhow, certain factors such as poverty, inequality, health, access to resources and social status are

likely to determine the vulnerability of coastal societies to all coastal hazards. Such factors can be called *generic* determinants of social vulnerability (BROOKS ET AL., 2005).

5.2.2 Economic Vulnerability

Economic vulnerability relies primarily on the description and quantification of economic risk potentials in systems at risk. The economic vulnerability of a region can be measured by the economic losses due to climate change and coastal hazards, mostly in monetary terms. It encompasses a wide range of harmful effects on humans, their health and belongings, infrastructure, cultural goods, and industry.

Economic vulnerability comprises different economic aspects as:

- directly measurable values (capital values) at risk like buildings, personal belongings, land and infrastructure,
- trade relations,
- well being of a community or country (e.g. GDP),
- linkages between industries (supplying industries outside the areas of risk), or
- dependence on certain sectors (like tourism).

The assessment of the economic vulnerability is most common and has been widely applied in flood risk assessment (e.g. RESSE ET AL., 2003; KYSTDIREKTORATET, 2005).

The broad application of economic vulnerability assessment to flood risk in coastal regions (and especially to river floods) is mostly due to the necessity of cost-benefit analyses related to coastal defense planning and for the insurance industry. Here the scale is of outstanding importance as aggregation of data leads to an over- or underestimation of values in a huge amount.

5.2.3 Ecological vulnerability

Ecological vulnerability describes the susceptibility of ecological structures of a system concerning their protection status and their relevance for the system.

As coastal zones are not only socio-economic eminent regions they are also of ecological value. Unique habitats make coastal zones vulnerable to adverse impacts. Habitats, wetlands or special species are endangered by sea level rise, followed by salinization, flooding or changes in ground water level. Large areas of coastal wetlands can be lost by sea level rise, worldwide.

This ecological uniqueness is threatened by human pressure and the mutual interaction and dependence of humans and the environment. Especially river deltas are among the most vulnerable systems on earth, so are tropical reef coasts and mangroves. Intact ecological systems are also important for humans as, e.g. mangroves or reefs mark natural coastal protection structures, which - if destroyed - cause an increased vulnerability to societies.

5.3 Resilience of the coastal system

So far risk and vulnerability assessment studies have focused on human exposure to hazards - determined by the nature of the hazard and the systems sensitivity - rather than on the ability of people to cope with hazards. Thus it has been neglected that every natural system has a capacity to buffer and every social system has abilities to cope. This refers to the concept of resilience. The concepts of vulnerability and resilience have great similarities. However, they are often used separately. Resilience describes the possibilities a system has to react, while vulnerability relates to why a system responds in a given way.

5.3.1 Ecological resilience

The concept of resilience first occurred in ecology in the 1970s and 1980s, recognizing that systems are inherently dynamic and can recover from disturbance back to the former situations. However it is well adaptable to other scientific disciplines, even to climate impact research or natural hazard research.

HOLLING (1973:2) criticized the existing equilibrium theories in environmental science by stating that "...the equilibrium centered view is essentially static and provides little insight into the transient behaviour of systems that are not near the equilibrium". HOLLING (1986:296) defines resilience as

"...the ability of a system to maintain its structure and pattern of behaviour in the face of disturbance".

He also argues that ecosystems go through regular cycles of organization, collapse, and renewal: he calls this the adaptive renewal cycle.

Today, different definitions and meanings of resilience exist. As the originally Latin word is *resilio*, meaning to jump back, the Oxford English Dictionary defines resilience as "the act of rebounding or springing back".

GUNDERSON & HOLLING (2001) argued that resilience is measured by the magnitude of disturbance the system can tolerate and still persist. They contrast this definition with that pro-

posed by PIMM (1984), for whom the appropriate measure is the ability of the system to resist - defined as "the ability to stop (or resist) change" (NICHOLLS & BRANSON, 1998:255) - disturbance and the rate at which it returns to equilibrium following disturbance. According to CARPENTER (2001) Two systems may have the same resilience, but differ in their resistance as measured in terms of how much they are displaced by a given physical force or pressure (cf. figure 5-3).

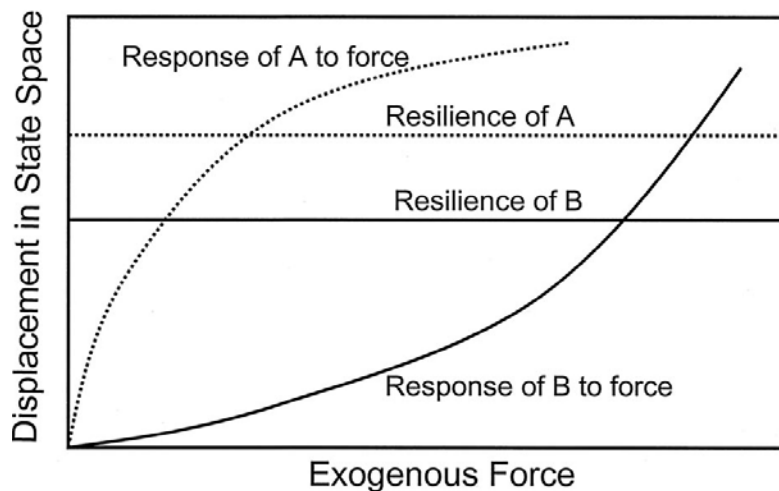


Figure 5-3: Displacement versus exogenous force (Source: CARPENTER ET AL., 2001:779)

The curves depict to the relationship between force and the distance in state space as the system moves from equilibrium for two hypothetical systems, A and B. System B is more resistant to displacement than system A. The horizontal lines indicate the resilience of the systems. System A is more resilient than system B. The intersection of a curve and line for a given system indicates its persistence - that is, the level of exogenous force the system can tolerate before moving to a new domain of attraction

5.3.2 Social resilience

The concept of resilience was also developed in social science where it is applied to describe the response of communities to hazards or other disturbances of a system's equilibrium. The Resilience Alliance ([3]), is a network of scientists which aims to provide academic research on the links between ecological and social resilience and aims to inform global policy on sustainable development (FOLKE ET AL., 2002). They seek to overcome the separate handling of ecological and socio-economic resilience to promote an integrated consideration of resilience.

Resilience in social systems means the capacity of humans to anticipate and plan for the future. Because of the links between ecosystems and humans - humans depend on ecologi-

cal systems and at the same time continuously impact the ecosystems in which they live - resilience has to be applied on integrated systems.

The ISDR (2004) defines resilience as

“...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”.

KLEIN ET AL. (1998), focusing on coastal zones, define coastal resilience as

“...the self-organising capacity of the coast to preserve actual and potential functions under the influence of changing hydraulic and morphological conditions. This capacity is based on the potential dynamics of morphological, ecological and socio-economic processes and the demands for these processes made by the functions to be preserved”.

Based on these thoughts, CARPENTER ET AL., (2001) describes the following three conditions of resilience:

- The amount of change the system can undergo and still retain the same controls on function and structure,
- the degree to which the system is capable of self-organization, and
- the ability to build and increase the capacity for learning and adaptation.

DOVERS & HANDMER (1992) distinguish between the *reactive* and *proactive* resilience of a society. A society acting reactively tries to make the system resistant to change, whereas a proactive approach accepts the inevitability of change and tries to create a system that is capable of adapting to new conditions. With that, DOVERS & HANDMER (1992) show the determining difference between ecological and social resilience: social resilience is not just affected by an initial perturbation, but also includes the human capacity of anticipation and learning.

Resilience can thus be considered the opposite of vulnerability, as vulnerability increases in direct proportion to decreasing resilience. (HOLLING, 1995, KLEIN ET AL., 2002). “Vulnerability comes from a loss of resilience” (HOLLING, 1995:8). The amount of resilience a system possesses relates to the magnitude of disturbance required to fundamentally disrupt the system, causing a dramatic shift to another state of the system, which is in turn controlled by a different set of processes [2].

As the vulnerability of a system increases in direct proportion to decreasing resilience, determining the degree of resilience of coastal zones complements vulnerability assessment. Assessing the vulnerability without taking into account its resilience would lead to a much overestimated susceptibility of the investigated area. With high resilience a system is able to cope with disturbances it wouldn't without resilience.

Although considerable theoretical discussion about resilience exists and the concept is widely accepted by scientists, it has not been realised to integrate the concept of resilience into an operational tool as part of vulnerability assessment or risk management. Yet, coastal planners already develop practices to enhance resilience, often without really defining these as resilience.

TIMMERMANN (1981) was the first who brought resilience of societies and their recover from the occurrence of a hazardous event in the context of climate change.

In climate change research, a few projects are dealing with managed retreat (KLEIN, 1998) or measures to enhance the awareness of risk which contributes to natural and social resilience. KLEIN ET AL. (2002, 2004) investigate the meaning of resilience for the vulnerability of coastal mega-cities to weather-related hazards, concluding that resilience is desirable for coastal mega-cities if it is not seen as an equilibrium state but focuses on the functioning of systems. Furthermore, they conclude that taking up the original meaning of resilience - bouncing back to the original state after the occurrence of a disaster - is impossible for socio-economic systems such as mega-cities and even not desirable. This is due to the fact that this original state was struggled by a disaster because of its vulnerability and its lack of resilience (KLEIN ET AL., 2002, 2004).

Resilience is often used in conjunction with *coping capacity* and *adaptive capacity*. The distinction between these two terms is not quite clear. Often they are not distinguished distinctly.

As coping strategies come from hazard research, they imply that people make adjustments to extreme events occurring today. The aim of coping capacity assessment is to evaluate the possibilities of decision makers, planners, and inhabitants to mitigate effects of coastal hazards.

Here coping capacity is defined as

“...the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster”. (ISDR, 2004)

Coping strategies tend to be short-term responses in abnormal periods of stress. If a system copes successfully, it might revert to its pre-hazard state (FOLKE ET AL., 1998).

Adaptation as discussed in the climate change community means action on more long term scales. It does not occur instantly, but is a slow process of learning that aims at reducing the system's vulnerability to hazards happening in the future. Adaptive capacity is

“...the ability to plan, prepare for, facilitate and implement adaptation measures”. (ISDR, 2004)

ADGER & KELLY (2002) argue that all societies have an adaptive capacity and that they have been adaptive at all times. However, it is evident that the ability to respond is differently distributed among people.

DAVIES (1993) distinguishes coping as acting to survive in the prevailing rules system whereas adaptation involves changing the institutional arrangements and the livelihood strategies (e.g. migration or intervention by the state).

Successful coping does not necessarily equal adaptation, although lessons learned from a hazard event may result in the implementation of adaptation measures designed to increase the coping capacity of a system to similar future hazards (ADGER ET AL., 2004:68). People may also react differently when they are faced with the next hazard. This is referred to as autonomous adaptation (KLEIN ET AL., 1998). Autonomous adaptation refers to the success of existing coping measures (ADGER ET AL., 2004).

While the vulnerability of a system to climate change is associated with anticipated hazards in the medium and long term and so will depend on the systems ability to adapt, vulnerability associated to climate variability that may occur in form of singular or episodic extreme events will be related to the existing short term capacity of a system.

Seeing coping capacity as a more short term and adaptive capacity as a more long-term process they have similar contents. Capacity building in general includes:

- early warning systems
- training and public awareness programs
- participation
- emergency response management
- recovery resources
- increasing capacity and synergies for sustainable management
- networking and communication
- educational programmes

Beside coping capacity and adaptive capacity, recovery is a category of resilience. Recovery means as system's return from the situation of disastrous flooding to a situation in which adverse impacts of flooding have been overcome. This does not mean that the system's returns to the former situation because coastal systems are always changing. More, returning to a

former situation is not always useful, because it was this former situation that has made the system vulnerable. Recovery differs in time and degree among social groups. A community is considered recovered when the main characteristics that describe welfare and human life are back to normal (DE BRUIJN, 2005). Recovery is strongly dependent on vulnerability. Under the same conditions, households may recover differently due to different health, skills or education. Recovery therefore depends on physical factors such as the duration of the flood impact, and economic factors such as the availability of money to recover in form of reconstruction and the help that can be received from outside. Lastly it depends on social factors like the political structure or the health status.

Resilience as well as coping capacity and adaptive capacity have been discussed widely in the literature, but there are only a few examples of how to assess and measure it. There are some proposals, which are assumed to relate to resilience to climate change impacts, but their reliability has to be evaluated.

5.4 Indicators in vulnerability assessment

Applying integrated vulnerability assessment requires a methodology which allows a weighting, comparison and a linkage of data from different disciplines. Therefore a step back from the rich detail of micro scale assessment studies and a simplification is required. This data harmonisation is best achieved by using indicators and even more distant proxies as they are nominally countable or ordinally-scaleable.

To design a framework, which ideally can be widely applied, in developed countries as well as in developing countries, to all coastal hazard and which is easily to change and use, in this work an indicator-based framework was chosen. The need to develop indicators to evaluate vulnerabilities and risks is especially important for developing countries, where data is not available. Furthermore these countries need a strategy to invest scarce funds to maximize the results related to risk reduction. As outlined before, the use of indicators is a simplification, which is not as detailed as assessing all data relevant for vulnerability. But the results of vulnerability assessment are not useable for decision makers and coastal planners, if the assessment causes costs and time that are not justifiable and cannot be updated regularly.

Therefore in this work indicators are selected to assess vulnerability and resilience aiming for application across scales and different socio-economic conditions.

So far, indicatorsystems are most widely applied in environmental science focussing on sustainable development. Examples for global indicatorsystems are the UN Commission on Sustainable Development (CSD Indicators, 1995) or the World Bank indicators (expanding the measure of wealth).

The most important national-level aggregate index relating to human welfare is the Human Development Index (HDI) developed by the UNDP (1991). The HDI is an aggregate measure of well-being based on education, health status, income, and inequality. DOWNING ET AL. (2001) propose the HDI as a reasonable measure of “present criticality” which is equivalent to current vulnerability. The HDI gives meaningful information on aspects of development, but it does not include aspects of environmental sustainability.

Another index developed by the UN is the Human Poverty Index (HPI) comprising: probability at birth of not surviving to age 60, people lacking functional literacy skills, long-term unemployment and population below 50% of median income (%). The HPI is applied for use in developing countries.

An example of a composite index of human and environmental vulnerability is the environmental Vulnerability Index (EVI), developed by the South Pacific Applied Geosciences Commission (SOPAC). The purpose of the EVI is to represent the vulnerability of small island developing states (SIDS) to a range of natural and anthropogenic hazards, based on 47 indicators of vulnerability. These indicators include 27 representing risk, 7 of “intrinsic resilience” and 13 of “environmental integrity or degradation”. To date the EVI has only been applied to a limited number of SIDS.

The United Nations Environment Programme (UNEP) Division of Early Warning and Assessment (DEWA) and GRID-Geneva have developed a Disasters Risk Index (DRI) under the Global Risk and Vulnerability Trends per Year (GRAVITY) project. The DRI is a mortality calibrated index, measuring the risk of death in disaster (the historical vulnerability), employing data from 1980-2000. The DRI is the first global assessment of disaster risk factors through a country-by-country comparison of human vulnerability and exposure to three critical natural hazards: earthquake, tropical cyclones, and flooding, and the identification of development factors that contribute to risk. The DRI has been developed with a global level of observation and a national level of resolution and is defined for 249 countries.

The DRI can be adapted to identify vulnerability of different social groups and due to the fact that the index is calculated using the OFDA- CRED EM-DAT database which is maintained on a permanent basis in conjunction with national agencies, the index can be re-evaluated on a yearly basis. This feature can be used to monitor the evolution of vulnerability and risk as a function of time in a relatively simple fashion, as data is readily available.

The MUNICH RE (2003) has developed a method to calculate risks associated with various hazards for megacities around the world. The calculation of vulnerability involves the combination of three parameters, one which is hazard-dependent while the other two are hazard-independent. The parameters are:

- Structural vulnerability: related to the building classes most predominant in the city;

- Standard of preparedness / safeguards: associated with the existence of building regulations, town and country planning with respect to hazards; and
- General quality of construction and building density.

Furthermore, BROOKS ET AL. (2005), MOSS ET AL. (2001) as well as ADGER ET AL. (2004) developed indicator sets of vulnerability and adaptive capacity to climate variability on a national level.

This work is based on literature review regarding the use of coastal indicators at the global, regional, national and local level and is intended to provide a contribution to the evaluation of measurable variables addressing vulnerability and resilience towards coastal hazards.

Indicators lack the degree of detail of directly measured single values, but rather they are used as representatives of concrete correlations. These correlations are not indicated exactly but they show at an early point of time changes in a system which than can be investigated more in detail. In so doing, indicatorsystems function as an early warning system towards changes and risks.

Constraints when using indicators to quantify composite vulnerability are the lack of consensus between disciplines how to quantify vulnerability and the availability of data.

For an integrated risk assessment the optimal compability of components is important to include ecological, economic and social concerns.

The DPSIR indicatorsystem is a framework which can help with this integration by connecting social (driving forces as a motivation for risk awareness and handling), economic (pressures, economic activity), ecological (state and impact as environmental conditions) and political indicators (response) (cf figure 5-4).

The objective of this DPSIR approach is to clarify multisectoral inter-relationship. This environmental framework can also be applied on coastal risk and vulnerability indicators. Coastal zones are exposed to human and natural stress (drivers), which increases if changes in system components undergo. These pressures cause imbalance on the coastal system. The state of the system is affected by changes such as population growth, urbanisation, degradation of habitats, changes in land cover or land use. This disequilibrium results in a number of perceived impacts that affect the natural processes, the use of resources and protection, and the socio-economic activities that take place in coastal zones. These impacts can be of different magnitude and intensity, duration (permanent or temporary), capacity to return to its original condition (reversible or irreversible), and spatial distribution (homogeneous or heterogeneous). The impacts are a function of the coastal systems vulnerability.

These spontaneous or planned policies - response measures and strategies (mitigation, adaptation- could be regarded as the interference in the natural processes or in the socio-economic activities.

The integration of indicators for vulnerability and resilience in an indicatorsystem like the DPSIR framework is ambivalent. The advantage of the DPSIR framework is that it is compatible to many other frameworks used in organisations because they are designed in close connection to the PSR framework.

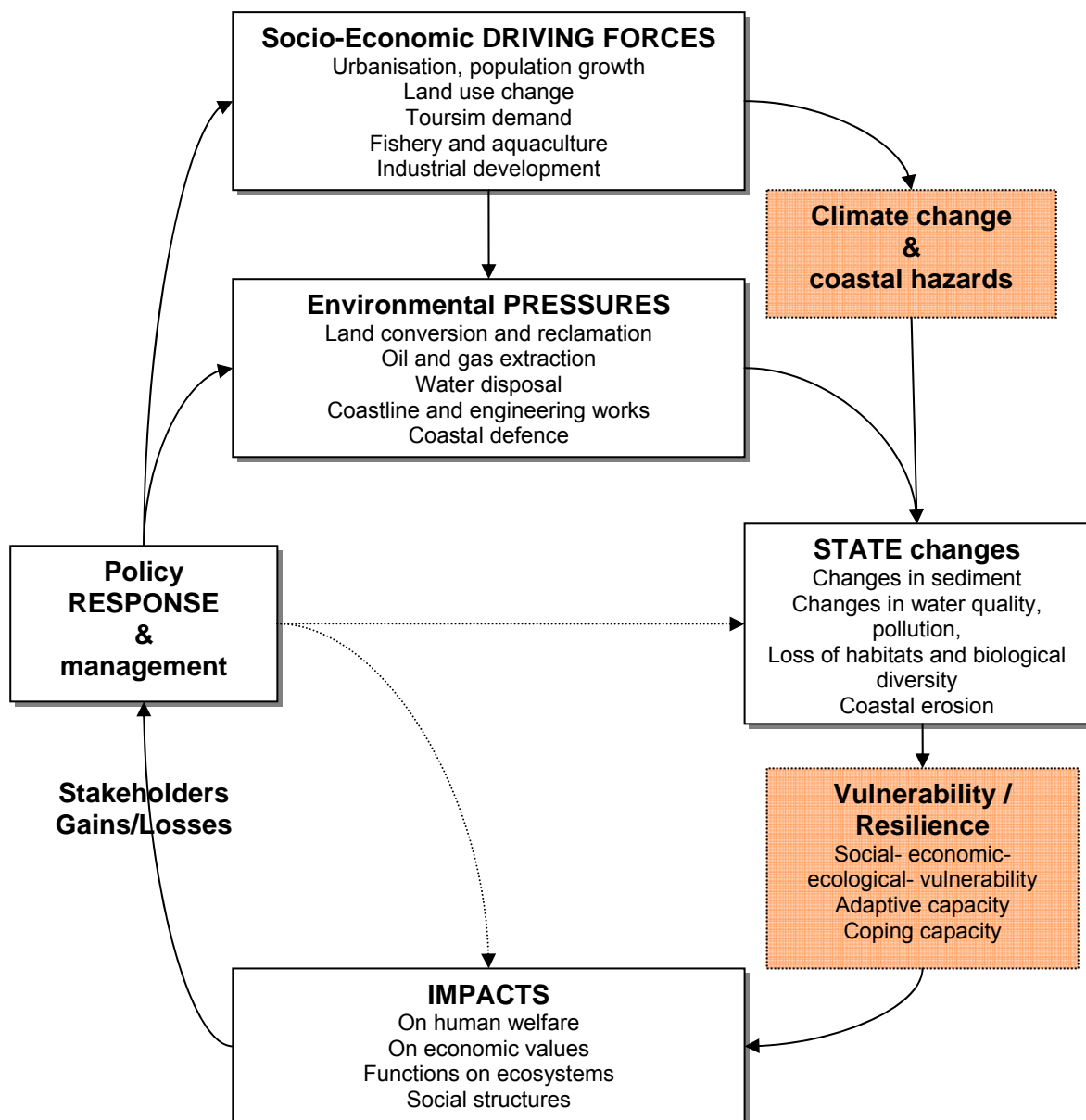


Figure 5-4: The DPSIR framework in the context of coastal vulnerability

Thus the adaptation of the DPSIR model in the context of coastal vulnerability associated with natural hazards is not straightforward because of two constraints:

- The pressure must encompass not only those social factors such as poverty, population growth, and migration, but the intrinsic hazards like sea-level rise or floods,
- Only response strategies are incorporated in the framework, but not preparedness or precaution activities.

Integrating these two issues the framework of coastal vulnerability and resilience can be incorporated in the DPSIR framework (cf. table 5-3)

Table 5-3: Framework for Vulnerability in relation to the DPSIR framework (according to Fleischhauer, 2004:254)

	Driving forces	Pressures	State	Impact	Response
Hazard exposure	Climate change	Causation and impacts on natural hazards	Hazard potential by natural hazards	Impacts on a systems due to the magnitude of a hazard	Mitigation of causation and impact factors of natural hazards
Vulnerability	Global change (socio-economic development)	Causation and influencing factors to enhance the damage potential (vulnerability)	Damage potential	Damage and demolition	Reducing the damage potential to natural hazards
Resilience	Global change (socio-economic development)	Restraints for an increasing resilience	Potential to be prepared and react	Reaction and recovery	Strengthen of resilience
TV/Total risk	Global change including climate change	Causation and impacts on natural hazards	Spatial, place specific risk potential	Total damage and adverse effects	Reduction of causations and influencing factors of natural hazards

In the following indicators should be selected that are able to reflect the specific risk in coastal regions.

The indicators to be chosen have to be selected carefully; they have to be structured and threshold values have to be defined. It is only then possible to combine selected indicators and correlate them with each other. Complex issues such as integrated assessment require the consideration of several indicators which can be combined to (key) indicator sets. Indicators steadily have to be changed and monitored, and data quality has to be steadily improved.

The selection of indicators has been made according to the framework in figure 5-5.

Indicators are developed to monitor advances made with respect to specific goals. So, in the beginning of the process goals have to be defined for which the indicator is needed (cf. figure 5-5)

1. The design of indicators is based on their expected use. For example, sustainable development indicators are used to monitor the state of the environment, and to monitor the success of different measures. In reference to coastal vulnerability assessment, the goals include the reduction of vulnerabilities and the strengthening of resilience with respect to specific benchmarks.
2. The definition of the scope and the indicatorsystem is crucial because it decides whether the indicatorset can be applied in risk management and decision making, later on. The needs of politicians and decision makers, their perceptions and capacities to understand and interpret the results have to taken into account. As a result of this process one should obtain the temporal and spatial scale of the indicatorsystem, and the number of indicators used.
3. In a third step the selection criteria for indicators have to be defined.
4. Finally the potential indicators are identified.
5. From these indicators a key set of indicators has to be chosen along certain criteria.
6. This final set can now be analysed, and
7. performance in terms of the preestablished criteria can be verified.

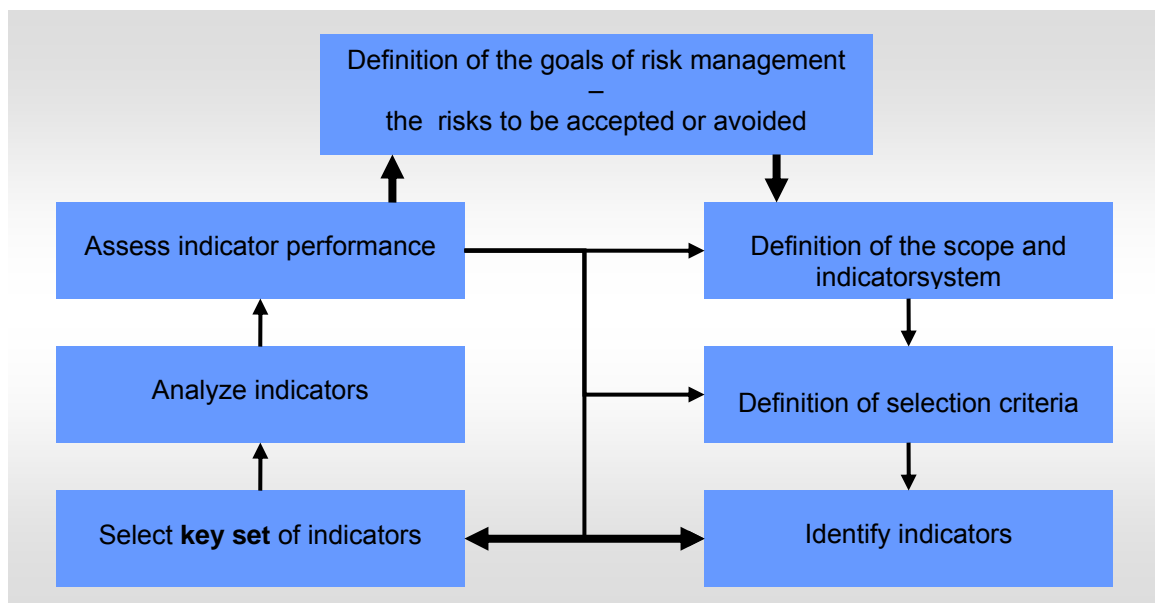


Figure 5-5: Development of indicators

In the following chapters step three to six is described methodologically for coastal vulnerability assessment. The indicators were selected along the criteria described in chapter 3.4.3 which belong to the overall selection criteria:

1. Policy relevance and utility for management
2. Analytical correctness
3. Feasibility

According to these criteria a range of possible indicators for social vulnerability, economic vulnerability, and ecological vulnerability as well as ecological and social resilience are selected with help of a literature review.

5.4.1 Indicators for social vulnerability

The spectrum of indicators of social vulnerability to coastal hazards is very big. Contrary to droughts or famine coastal hazards occur all over the world in developed as well as in developing countries, in urban as in rural areas. Thus, to define indicators that are suitable for all coastal regions is hardly possible due to very different social conditions.

In table 5-4 indicators for social vulnerability are developed to be used for coastal vulnerability assessment.

These indicators are assigned to six groups:

1. Demography
2. Health
3. Education
4. Governance
5. Cultural and personal attitudes
6. Personal welfare

These groups summarize the main categories of social vulnerability. Not every indicator is useful to be applied in every region. Rather the most suitable indicator(s) of one group may be chosen according to the regional specification (e.g. developing or developed country) and the hazard specification.

Indicators for demography reflect the structure of society and the population at risk. These indicators refer to how many people might be harmed or being at risk of losing their lives in case of an emergency (e.g. flooding). Health indicators indicate the preexisting weakness of a society and their ability to withstand negative impacts. Education indicators stand for the development of a society. School enrolment and literacy are essential for involvement in social networks and even towards the degree of poverty. Governance indicators indicate political stability and freedom. The absence of freedom weakens a society and abrogates networking as well as processes of policy and decision making. Cultural and personal attitudes refer to the individual vulnerability. Personal welfare indicates poverty and welfare and the individual possibilities to reduce its own vulnerability.

Table 5-4: Indicators for social vulnerability to coastal hazards

Class	Variable	Proxy	Source	
	Settlement	Population at risk	12	
	Resource pressure	Population density	4,22	
	Resource pressure	Urban growth	4	
	Resource pressure	% urban population	5,6, 16	
	Dependence on agriculture	% rural population	2,5, 16,18	
	Coastal squeeze	Population growth	5,4	
Demography (DEM)	Structure of society	Mortality rate		
	Structure of society	Birth rate	6,1, 16	
	Structure of society	% of population under 5 years old	6	
	Structure of society	% of population over 65 years old	6	
	Structure of society	Gender specification (% females)	7,6	
	Structure of society	Family structure (% with children)	7	
		Nutritional status	Average calorie supply per capita	1,2, 19,20
		Food availability	Food production index	16
		Quality of infrastructure	% of pop. with access to adequate health service	1,2, 17,18
		Quality of infrastructure	% of pop. with access to safe water	1,2, 17,18
Health (H)	Burden of ill health	% Population with special needs (disability)	2,7, 17	
	Health status	Life expectancy	1,16, 2,18	
	Health status	Childhood mortality rate	6,18	
	Health status	Immunization rate	18	
	State support for health	Public health expenditure (% of GDP)	2	
	State support for health	Nursing home rents per capita	6	
	State support for health	Number of hospital beds	16	
	State support for health	Number of physicians (per 1000 inh.)	16	
Education (EDU)	Entitlement of information	Illiteracy rate	1,2, 16,18	
	Entitlement of information	School enrolment (% girls)	18	
	Entitlement of information	% of pop. > 25 y. without high school diploma	6	
	Entitlement of information	Language skills		
	Entitlement of information	% of scientists and engineers	16	
	Education commitment	Education expenditure as % of GNP	18,2	
	Labour force	% of civilian labor force employment	6	
	Labour force	% females in civilian labor force	6	

	Conflict	Internal refugees 1000/pop.	
	Conflict	Index of corruption	4, 12
	Political welfare	Local government debt to revenue ratio	
	Investment in adaptation	Rule of law	4
Governance (GOV)	Influence of polit. process	Political rights	2, FH
	Participation	% members of networks, organizations	
	Participation	Voice and accountability	2
	Investment in adaptation	Economic freedom	12
	Investment in adaptation	Political stability	2, 4, 12
Cultural and personal attitudes (CUL)	Cultural attitudes	Ethnicity	7
	Cultural attitudes	Religion	12
	Investment in adaptation	Trust in responsible authorities	
	Preparedness	Access to information and knowledge	11
	Preparedness	Flood experience	
	Preparedness	Risk perception, awareness	
Personal welfare (WEL)	Poverty	Income per capita	5, 6,
	Poverty	% owing health insurance	
	Poverty	Access to resources	5, 10
	Poverty	% owing house insurance	
	Poverty	% of per capita social security recipients	
	Poverty	Average number of people per household	
	Poverty	Residence type, (% renter-occupied housing units, % mobile homes)	6
	Inequality	Gini Index	10, 12 18

Sources: (1) MOSS ET AL. (2001); (2) BROOKS ET AL. 2005 ; (3) UNDP (2004); (4) ADGER, 2004; (5) CUTTER ET AL., 2000; (6) BORUFF ET AL., 2005); (7) JHC, 2002; (8) ICAM; (9) EUROSION; (10) ADGER, 1999; (11), CUTTER, 1996; (12) DE LA VEGA-LEINERT ET AL. (2005); (16) WB – WORLD BANK; (17) WHO – WORLD HEALTH ORGANIZATION; (18) HDI- HUMAN DEVELOPMENT INDEX/UN; (20) UNO/GRID;

5.4.2 Indicators for economic vulnerability

Economic vulnerability indicators (cf. table 5-5) can be divided in four major groups:

1. Capital value at loss,
2. Land at loss,
3. Labor force, and
4. Economic activity

Capital value at loss and land loss refer to the monetary damage potential. The values of the elements of risk determine vulnerability, as high monetary values indicate a high vulnerability. Indicators of labor force describe the working and employment situation, indicating a risk of loss of jobs. Indicators summarized to economic activity represent a broad field of economic variables such as trade relations, dependence on resources, or economic welfare. They indicate the strength and the financial resources of a society to adapted, to bear, and to buffer disasters.

Table 5-5: Indicators for economic vulnerability to coastal hazards

Class	Variable	Proxy	Source
Capital value at loss (CV)	Capital value at loss	private buildings / m ²	6
	Capital value at loss	manufacturing factories/ m ²	6
	Capital value at loss	commercial establishments/ m ²	6
	Capital value at loss	Cars, boats	13, 14, 15
	Capital value at loss	Fixtures	13, 14, 15
	Capital value at loss	Cattle	
	Capital value at loss	Stock value	13, 14, 15
	Capital value at loss	Assets	13, 14, 15
	Capital value at loss	Drainage systems, water management	
	Capital value at loss	Underground engineering	
	Capital value at loss	Coastal defense works	
	Cultural loss	Number cultural goods , World heritage sites	
	Infrastructure	Traffic areas (% railroads, airports, harbors, roads)	2, 13, 14, 15
Land at loss (LL)	Area of land loss	% Forest area	
	Area of land loss	% Agricultural area	
	Area of land loss	% Settlement area	
	Area of land loss	% area of land owned by the public	9
Labour force (LAB)	Labor force	% employed in primary extractive industries	6, 2, 16
	Labor force	% employed in transport and tourism	6

	Labor force	% employed in service occupation	6
	Labor force	% Unemployment	23
	Dependence on tourism	Rate /seasonal variations in employment in tourism	
	Dependence on agricult.	Agricultural production index	2, 16
	Dependence on aqua- cul	Aquaculture production	8
	Economic welfare	GVA from all industries / m ²	
	Economic welfare	Amount of shipping traffic	8
	Dependence on tourism	tourists per km of coastline	8
	Dependence on tourism	Tourist arrivals / departures	8
	Dependence on tourism	Coastal recreation visitor days	8
Economic activity (EA)	Dependence on tourism	Tourist added value	12
	National wealth	GDP per capita	
	Trade relations	Supplying industries	
	Trade relations	Economic openness (im/export as % of GDP)	24
	Trade relations	Export concentration index	24
	Trade relations	Export diversification index	
	Trade relations	Peripherality	24
	Dependence on extern.	Dependence on imports	24
	Dependence on extern.	Dependence on foreign sources of finance	
	Dependence on extern.	Total dept service	4

Sources: MOSS ET AL. (2001); (2) BROOKS ET AL. 2005 ; (4) ADGER, 2004; (6) BORUFF ET AL., 2005; (8) ICAM; (9) EUROSION; (12) DE LA VEGA-LEINERT ET AL. (2005); (13) REESE ET AL. (2003); (14) HAMANN & KLUG (1998); (15) COLIJN ET AL. (2000); (16) WB – WORLD BANK; (23) ILO: INTERNATIONAL LABOUR OFFICE ; (24) BRIGUGLIO

5.4.3 Indicators for ecological vulnerability

Ecological indicators are widely applied in environmental science focussing on sustainable development (e.g. DIERßEN & HOFFMANN-MÜLLER, 2004)

Indicators of ecological vulnerability can be grouped into two groups:

1. Ecological value
2. Environmental pressure

Indicators of ecological value describe the uniqueness of the coastal ecological system. The uniqueness is a value, which is not clearly measurable in monetary terms but indicates a range of ecological functions which are at risk.

Environmental pressure refers to indicators of environmental stress and degradation. The capacity of a system to withstand is limited, if degradation of natural habitats is reduced (cf. table 5-6)

Table 5-6: Indicators for ecological vulnerability

Class	Variable	Proxy	Source
Ecological value (EV)	Environmental stress	% coastal habitats (coral reefs, wetlands etc.)	9
	Uniqueness	% of protected and rare species	8
	Uniqueness	% of alien species	8
	Environmental stress	Forest change rate	2,20
	Environmental stress	% forest cover	2, 4, 20
	Environmental stress	% protected land	2, 4, 20
	Env. soundness	Degree of sedimentation and reproduction	
	Env. soundness	Change in coastal erosion	9
	Env. soundness	Amount of nutrients	
	Environmental pressure (ENV)	Environmental stress	Amount of coastal infrastructure
Environmental stress		Annual tourists	
Environmental stress		Population density	
Environmental stress		% limited natural resources	
Environmental stress		% unpopulated land area	2, 4, 22
Environmental stress		% land managed	1, 19
Sustain. resources		Groundwater recharge per capita	20, 2
Sustain. resources		Water resources per capita	2, 4, 20
Erosion		% of agricultural areas on slopes	
Env. degradation		% deforestation	
Env. degradation		% land and soil degradation	
Env. degradation		% fertilized use	1, 16
Env. degradation		Degree of eutrophication	
Env. degradation		Waste disposal	
Env. degradation		Degree of pollution in flood water	
Env. soundness	Affected area by flooding in the last 10 years		

Sources: MOSS ET AL. (2001); (2) BROOKS ET AL. 2005; (4) ADGER, 2004; (8) ICAM; (9) EUROSION; (16) WB – WORLD BANK; (20) UNO/GRID; (22) CIESIN

5.4.4 Indicators for resilience

Indicators of resilience are partly very close to or alike the ones of vulnerability. Indicators for resilience can be grouped into two main groups (cf. table 5-7)

1. Socio-economic resilience
 - a. Preparedness and early warning capacity (ability to self organize)
 - b. Adaptive capacity
 - c. Coping capacity
 - d. Recovery
2. Ecological resilience

Indicators for socio-economic resilience intrinsically could be sub-grouped as in 1 a, b, c, d. However as many indicators are overlapping and can not clearly be allocated it is abstained from that here.

Socio-economic indicators for resilience encompass proxies for preparedness, mainly describing peoples awareness and involvement in management and planning processes. Indicators for coping capacity and adaptive capacity differ in their time scale. While indicators for coping predominantly refer to the ability to cope with disasters, indicators for adaptive capacity indicate a more long-term capability of a society to learn and steadily to adapt to changing conditions. Indicators for recovery give information about the ability of a society to overcome a disaster and return to wealthy conditions.

Ecological resilience indicators refer to natural systems ability to buffer adverse effects and the degree of renewable capacity.

Table 5-7: Indicators for coastal resilience

Class	Variable	Proxy	Source
Socio-economic Resilience (SORES)	Awareness of flood risk	Risk perception	
	Awareness of flood risk	Flood experience	
	Preparedness	% of houses protected against flood impacts	
	Public Participation	% of persons involved in disaster management	
	Public Participation	% Member of social networks	
	Public Participation	Number of Flood Action Groups	
	Early warning capacity	Number of radios (per 1000 inh.)	16
	Early warning capacity	Existing warning and protection structures	
	Early warning capacity	Number of telephone lines	
	Political soundness	Decision making frameworks	
	Economic Freedom	GDP per capita	
	Economic freedom	Gini coefficient	1, 16

	Human resources	% illiteracy	1
	Incidence of poverty	Income	
	Coastal squeeze	Degree of urbanization	
	Conflict	Political stability, (absence of warfare)	24
	Health status	Life expectancy	
	Health status	Population with special needs	
	Health status	Access to sanitation	
	Health status	Access to clean water	
	Health status	Calorie supply per capita	
	Structure of society	Fragmentation index	
	Structure of society	% of pop > 65 years	
	Structure of society	% of pop < 5 years	
	Structure of society	Gender (% female)	
	Structure of society	Ethnicity, Religion	
	Coping capacity	Individual social integration (family, clan, etc.)	
	Coping capacity	Ability to transfer production to other locations	
	Coping capacity	Energy supply	
	Coping capacity	Technical & transport capacities and resources	
	Coping capacity	Strength and cohesion of civil society	
	Welfare	% population in the workforce	1
	Recovery	Financial reserves of households, community	
	Recovery	Substitutability of lost items	
	Recovery	% of people with insurance	
	Recovery	External support	
	Recovery	Sources of income	1
<i>Ecological Resilience (ECOSRES)</i>	Environmental stress	% of ecologically intact area (land /waters side)	
	Ecological potential	Renewable natural capacity, natural resources	1, 19
	Env. pressure	Degree of human intrusion (% land managed)	1
	Env. pressure	Population density	1, 16

Sources: (1) MOSS ET AL. (2001); (16) WB – WORLDBANK; (19) UNDP –FAO; (24) BRIGUGLIO (2004)

5.5 Composite vulnerability index

Several indicators for social vulnerability exist in literature, focusing on general risks of climate change, droughts, or food supply. Here indicators for composite coastal vulnerability and coastal resilience have been developed. These can be selected and combined to build a place-based total vulnerability index (TVI, cf. figure 5-6). This composite vulnerability index is defined as a means to combine selected parameters from social, economic and ecological vulnerability as well, as resilience to produce a single indicator. Such a procedure is analogous to the construction of indices such as the HDI.

To get a Total Vulnerability Index (TVI) it is advisable to design sectoral indices first. According to the vulnerability and resilience framework these sectoral indices are the Social Vulnerability Index (SVI), the Economic Vulnerability Index (ENVI) and the Ecological Vulnerability Index (ELVI). Indicators have not only to be weighted within these sectoral indices but also between sectoral indices. If the SVI or the ENVI is more important to determine vulnerability is strongly depending on the characteristics of the area of investigation. In regions where population is sparse, ecological vulnerability is determining total vulnerability. In cities in developing countries the social vulnerability is more relevant for the amount of total vulnerability, while in cities in the developed world the economic vulnerability is most important.

The weighting of the specific indicators has to be predefined in close relation with politicians, stakeholders and coastal managers. The weights have been assigned to each indicator via suggestions emanating from such an expert group

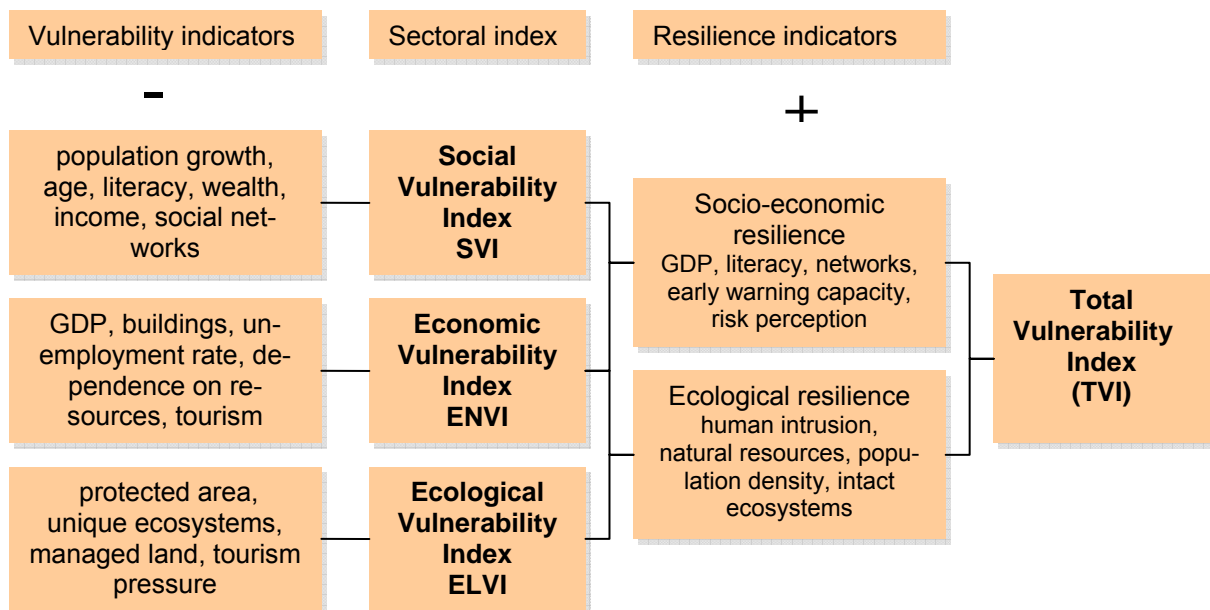


Figure 5-6: Generation of a Total Vulnerability Index (TVI)

Using these aggregated indices one has to keep in mind the weakness in relation to the development of indices as combination of indicators:

- Subjective choice of variables, related to subjectivity associated with choice of variables and computations of variables used to calculate the index.
- Measurement problems occur for certain countries or systems, associated with the absence of data for certain variables; or in relation to different methods which may be applied in various countries to compile and process data.
- Inaccuracy in averaging and weighting, associated to the combination of several indicators.
- Aggregation problems, related to specific problems which may arise when aggregating data at the regional or national level from data at the local or community level.
- Political aspects, regarding the fact that a given indicator or index might create problems of “political” nature, or increase the level of tension among stakeholders.

Although a composite vulnerability index (or Total Vulnerability Index, TVI) is an aggregated simplified value, it has the advantage of giving a clear number describing the degree of vulnerability. The TVI can be updated on a yearly basis to track changes in vulnerability, if all data are available.

5.6 Key set of indicators

According to figure 5-5 in the following step five and six is conducted, i.e. selecting key indicators and analyzing them.

The identification of exposure and hazards leads to the selection of indicators that target specific conditions of vulnerability. It is rare that one indicator will be relevant, at least to the same degree, for many people at risk and all hazards.

Indicators are not designed to provide a full picture on all risk issues, but they reveal trends and draw attention to changes that require further analysis. It is one of the main challenges of indicator studies to find reliable data (PARRY & CARTER, 1998). Whether an indicator is useful or not is very much depending on a particular context. A careful selection process is needed to determine which indicators may be relevant in the given context. A key set of indicators should not only give information on the development in specific areas, but also give a general impression of the state of the environment by reducing a large quantity of data to a simple form.

The lists of indicators created in the previous chapters are not intended to be complete, but have to be individually used or even supplemented.

The level of an indicator is determined by guidelines and data. Guidelines describe which information shall be indicated and which criteria are used to select and aggregate data. Different

indicators have to be developed for different regions, because differences in development, cultural, and political structures as well as different biophysical conditions form a different basis of assessment. Furthermore, the weighting of the indicators has to be adaptable to site-specific requirements. While some regions are subject to tremendous social pressure, in other regions the natural conditions are more dominant. In developing countries, social pressure is much more important than in developed countries. Here, indicators for wealth and health such as calorie supply per capita or illiteracy are more fundamental. In the developed world, e.g. in the Netherlands or in Germany, the impacts of sea level rise or storm surges are much more a function of economic characteristics. The best indicator is not meaningful if data are either completely available, false, or difficult to assess. Thus, measurability and data quality are the most important criteria for the selection of indicators.

The choice of indicators is also dependent on the purpose of the vulnerability assessment. A vulnerability assessment in a region which is very exposed to frequently recurring hazards, e.g. hurricanes in the Caribbean, needs different indicators from those for coastal vulnerability to ASLR in Europe. Therefore, the application of identical indicators for every coastal region is nearly impossible

While biophysical factors are measurable and documented with increasingly good data, social variables are not that easily measurable because they have strong qualitative characteristics and differ strongly even on small scales. The difficulty to assess social data as well as quantitative information on resilience is one reason why it was neglected in most VA studies so far. In climate change research this was additionally hindered by the problem of making social analysis in the long run. As social vulnerability and resilience are essentially determining the characteristics of a disaster, it is indicated to measure them so that they become a part of risk management planning.

It is clear that the most sophisticated vulnerability assessment would have to take the full spectrum of indicators into account and would also have to use the most detailed data. However, in reality a methodology that requires the assessment of too much data will never be used because of limited resources, either in time and money or in data availability. It is thus more the question which indicators can be produced and which ones would the enduser need.

Once the indicators have been chosen, the question remains as to how the indicators should be constructed and how they prove to vulnerability on different scales. The appropriate weighting to apply to the different indicators has to be found. The question is whether any weighting procedure should be applied at all, and whether or not composite indicators should be constructed.

In table 5-8, a key set of coastal vulnerability and resilience indicators - derived from the lists in chapter 5.4 - is presented that reflects a set of generic indicators for coastal vulnerability assessment. Even if regions strongly differ from each other, an assessment should include indicators concerning:

- Social vulnerability
 - Demography
 - Health
 - Education
 - Governance
 - Cultural and personal attitudes
 - Personal welfare
- Economic vulnerability
 - Capital value
 - Land at loss
 - Labor force
 - Economic activity
- Ecological vulnerability
 - Ecological value
 - Environmental pressure
- Resilience
 - Socio-economic resilience
 - Preparedness
 - Early warning capacity
 - Coping capacity
 - Adaptive capacity
 - Recovery
 - Ecological resilience

When choosing key indicators from the extensive amount of indicators in social, economic and environmental, science an accurate selection has to be done. Questions that should be kept in mind when choosing indicators are:

- What is the aim of the indicator?
- On which spatial scale should it work?
- On which time scale should it work?
- Are the mechanisms of aggregation suitable?
- Is a chosen indicator compatible with the other indicators?

- Can the indicators be gained with a justifiable effort?

The listed key indicators in the context of vulnerability to natural hazards were selected to the following criteria:

Policy relevance

- Validity
- Sensitivity to changes
- Relevance

Analytical correctness

- Scientific quality
- Cross-scale applicability

Feasibility

- Data availability
- Measureability
- Justifiable concerning cost-benefit
- Ability for updating and monitoring

Table 5-8: Key set of indicators

	Class	Variable	Proxy
Social vulnerability	DEM	Settlement	Population at risk
	DEM	Resource pressure	Population density
	DEM	Structure of society	Age structure (% population > 65 and < 5 years)
	DEM	Structure of society	Gender (% females)
	H	Nutritional status	Average calorie supply per capita
	H	Health status	Life expectancy
	H	Burden of ill health	% pop. with special needs
	H	Quality of infrastructure	% pop. with access to adequate health service
	EDU	Entitlement of information	Illiteracy rate
	EDU	Entitlement of information	School enrolment
	EDU	Labour force	% of civilian labour force employment
	GOV	Participation in decision making	% Members of organizations
	GOV	Conflict	Index of corruption
	GOV	Investment in adaptation	Political stability
	CUL	Cultural attitudes	Religion
	CUL	Preparedness	Personal flood experience
	WEL	Poverty	Income per capita
	WEL	Poverty	Access to resources
	WEL	Inequality	Gini Index
	Economic vulnerability	CV	Capital value at loss
CV		Capital value at loss	manufacturing factories/m ²
CV		Infrastructure	Traffic areas
LAN		Area of land loss	% agricultural area
LAN		Area of land loss	% forest area
LAB		Dependency	% employment in primary extractive industries
LAB		Dependency	% employment in transportation and tourism
LAB		Labour force	% unemployment
EA		Agricultural self sufficiency	Agricultural production index
EA		Dependence on tourism	Tourist added value
EA		Prosperity	GVA from all industry
EA		Prosperity	GDP per capita
EA		Trade relations	Supplying industry
EA		Trade relations	Economic exposure index
EA		Dependency	Dependence on foreign resources

Ecological vulnerability	<p>EV - Uniqueness - % key coastal habitats (e.g, coral reefs, wetlands) EV - Uniqueness - % of protected and rare species EV - Uniqueness - % of protected land</p> <p>ENV - Erosion - % of agricultural areas on slopes ENV - Environmental stress - Amount of coastal infrastructure ENV - Environmental stress - Annual tourists ENV - Environmental stress - Population density ENV - Sustainability of water resources - Water resources per capita ENV - Environmental degradation - % deforestation ENV - Environmental degradation - % land and soil degradation ENV - Environmental stress - % land managed</p>
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Resilience	<p>SORES - Awareness of flood risk - Risk perception SORES - Preparedness - % of houses protected against flood impacts SORES - Public Participation - % member of organisations SORES - Public Participation - Number of flood action groups SORES - Early warning capacity - Number of radios SORES - Early warning capacity - Existing warning / protection structures SORES - Economic freedom - GDP per capita SORES - Inequality - Gini Index SORES - Human resources - Illiteracy SORES - Poverty - Income per capita SORES - Conflict - Political stability SORES - Health status - Calorie supply per capita SORES - Structure of society - % pop < 5 years and > 65 years SORES - Coping capacity - Technical & transport capacities and resources SORES - Coping capacity - Strength and cohesion of civil society SORES - Recovery - % population in the workforce SORES - Recovery - Financial reserves SORES - Recovery - % of people with insurance SORES - Recovery - External support SORES - Recovery - Source of income (dependence)</p> <p>ECORES - Environmental stress - % of ecologically intact area ECORES - Ecological potential - Renewable capacity, natural resources ECORES - Environmental pressure - Population density ECORES - Environmental pressure - Degree of human intrusion</p>
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Selection of key indicators for social vulnerability

The **population at risk**, or the total coastal population in the flood prone area, is the most widely applied indicator for vulnerability assessment to natural disasters. The population at risk is defined as the number of people experiencing flooding in a typical year (HOOZEMANS ET AL., 1993; BAARSE, 1995). As the loss of human lives is not measurable in monetary terms, quantitative results are gained. This number is estimated by multiplying the total number of

people living in an area potentially affected by flooding by the probability of flooding in any year, as determined for each risk zone. The assessment of the population in the area of investigation is crucial as loss of life still is the most threatening consequence of disasters. The advantage of the use of the population as an indicator is that it is easily to access all over the world. Even in the case of scenario based assessment – as for example the impacts of future climate change – , it can provide reliable results, while other social indicators often are not calculable in the long run.

The **population density** gives information about the resource pressure and consequently about the access of resources. With increasing environmental pressure resources are getting scarce, i.e. water and food resources, land, infrastructure, and service. Furthermore, with limited resources, in case of an emergency, a dense population is less able to cope.

Information about the structure of a society is needed, but often lacking. This includes the **age structure** (people < 5 years and > 65 years) as well as **gender-specific** data. Women and men may see very different problems and solutions simply because the gender division of labor situates them differently in a society's economy. The same is true with respect to women's and men's different social networks and personal coping skills (ISDR, 2005:68). The distinction of gender is more or less significantly depending on regional cultural settings. Oftentimes, this is closely related to customs, ethnicity, and religion. As the women's self determination is strongly suppressed in many cultures, women in these regions are not involved in planning, policy, and management; they are often less educated or illiterate. These circumstances handicap them in handling of and getting prepared for disasters. This is similar for persons who need help and advice and are not able to act autonomously. Children and old and/or sick people are therefore more vulnerable than others. Especially the elderly are thus vulnerable to flooding not only because they are elderly but also because they are more likely than others to be in poor health prior to the flood. Hence, the age profile of the populations at risk can serve as an indicator for the health status.

A healthy society is less vulnerable because it is better able to cope. For example, calorie intake and sanitation are predictive indicators of health status, while life expectancy is diagnostic of health status and of the efficiency of health care.

Indicators reflecting the health situation report whether a society is vulnerable to living in poor conditions, which in turn will make them increasingly vulnerable to climate change impacts such as flooding, temperature, and precipitation changes. The **average calorie supply per capita** is an outstanding indicator in developing countries, while it is negligible in developed countries. It gives information about a society's or group's exposure famine and malnutrition. The factors make them vulnerable and less able to cope in emergency situations. Even **life expectancy** and the **percentage of population with access to adequate health service**

indicate the wealth of a society and thus its resistance. A high **percentage of people with special needs** weakens a society due to the burden of ill health.

The status of education reveals information about development and entitlements. Literacy is an important indicator for the development, especially in developing countries. **Illiteracy** is still common in many rural parts in the developing world. Usually those parts of the world that are most often subject to natural disasters. Illiterate people are inferior because they are not equally informed about news and politics and are not able to take part in community processes like literate people may do. They hamper planning, adaptation and management, and further development of societies. Children that are not able to go to school (**school enrolment**) are disadvantaged. Illiteracy increases vulnerability to a specific hazard, because people are not able to read warnings posted in newspapers and information material about imminent threats. At the same time the lack of literacy skills normally limits the chances to reach an economic position that enables people to improve their situation of vulnerability. A literate population will be better able to lobby for political rights which in turn will allow it to demand accountable and effective government. A small **percentage of civilian labor force employment** in a region weakens networking processes and capabilities.

The governance indicators emphasize the ability of citizens to **participate** through **networks and organisations**. Active involvement of the public and cohesion in society antagonize vulnerability. **Political stability** and the absence of corruption (**corruption index**) and warfare are making societies less vulnerable. Government effectiveness and accountability as well as political rights are of importance for administrative functioning. Where such rights exist, governments are more able to address vulnerability.

Cultural attitudes such as **religion** or **ethnicity** are crucial in the implementation of administrative and governmental decisions. Especially in emergency situations cultural attitudes can hamper processes like evacuation. A study in Bangladesh (SCHMUCK, 2003) showed that due to cultural rules, women are more exposed to flooding because in case of evacuation they refuse to use evacuation buildings together with other men.

Poverty is an important aspect, particularly in developing countries. It is directly linked to **access to resources** (ADGER & KELLY 1999), which affects both vulnerability and coping capacity to extreme events. Poorer people live in more hazardous areas where the infrastructure is marginal in case of an extreme event as well as the social security. The access to resources even plays a crucial role in the case of recovery. Access to resources in turn is based on social and economic relations (BLAIKIE, 1994:48). Poverty can be measured by

income per capita. Another indicator that expresses the degree of inequality in terms of income, but also of inequality in general (e.g. health) is the **Gini coefficient**, which is a commonly and widely applied indicator. The lower the number here, the more equal is the distribution of income.

Selection of key indicators for economic vulnerability

The capital value at loss – including private and public **buildings, traffic areas, and manufacturing buildings** – as well as the land at loss – including **agricultural and forest area** – indicates the values in a region which will be harmed or lost in case of flooding or erosion and thus the economic worth. This category can be assessed in monetary terms. They can either be assessed by carrying out a field survey, using remote sensing data, or by relying on pre-existing data sources. Where data is not available, indicators can help to make an assessment. The capital values in a region are much more than just buildings, factories and traffic areas, e.g. cars. However, these are the most expensive ones, and thus should face priority.

Aside from tangible values for economic vulnerability the **labor force** and the **rate of unemployment** are of importance. This is especially true in the case of a strong dependency on special sectors, which are harmed by flooding and have a long time of recovery.

More difficult to assess – because not easily to measure – are the dependency and the prosperity of a region. The **agricultural production index** and the **tourist added value** give information about dependency on agriculture and tourism. A region strongly dependent on tourism, for example, will suffer intensively from damages, flooding and beach erosion as consequences of hurricanes, storm floods, or extreme events such as tsunamis. This suffering will not only occur because of the loss of beaches and infrastructure (hotels), but also because of the perceptual component, including the fear of tourists leading to their absence from the region in the future.

The **gross value added (GVA)** from the economic sectors and producing industries as well as the **GDP per capita** indicate the prosperity of a region.

The dependence of trade relation (**economic exposure index, dependence on foreign resources**) makes regions more vulnerable and less self sufficient.

Selection of key indicators for ecological vulnerability

Indicators for ecological vulnerability are an expression of the ecological value as well as the environmental stress of the coastal system. The ecological value can be derived from the **percentage of key coastal habitats, protected species, protected land, and the forest cover**, which determine the **ecological uniqueness of an area**. The loss and harm of ecological habitats is not only of natural relevance but also of relevance for coastal societies. Close human-environmental relations exist, which will be disrupted by loss of ecological values. As an example, coastal habitats such as coral reefs, mangroves, or dunes are important features of natural coastal protection. In countries that do not have the resources for elaborated coastal defense structures and even with the regard to the shift toward soft protection and managed retreat, these natural features are of outstanding importance. Thus, for example in the aftermath of the Asian tsunami, investigations were started to assert that the wave impact was worse in areas of mangrove degradation due to depletion.

The ecological vulnerability of the coast is intensely increasing with coastal squeeze caused by **infrastructure, tourism, population density, and the percentage of managed land**. Especially sandy beach coasts and small islands are subject to intensive tourism and thereby also to waste, utilization of water resources, hotels, traffic, and diving activities stressing coral reefs. At the same time, these coastal stripes are more vulnerable to extreme events such as hurricanes or tsunamis because in the surroundings of extended beach resorts, coasts are characterized by a large accumulation of oftentimes unprepared tourists. Furthermore in these regions the economic damage potential is very high.

More, indicators for **land and soil** as well as **forest degradation** show the ecological vulnerability, as degraded land is more vulnerable because of absent buffering capacities. Especially in arid environments, the sustainability of water resources, estimated by the **water resources per capita**, indicate vulnerability.

Selection of key indicators for resilience

As outlined in Chapter 5.1, vulnerability and resilience are balancing each other. Consequently, indicators for resilience are in many cases the same as for vulnerability. For example, **income** as an indicator for poverty is indicating both vulnerability and resilience. A high average income per capita is making a society less vulnerable and to the same degree more resilient and vice versa. The same is the case with indicators such as **GDP per capita, Gini Index, illiteracy, political stability, calorie supply per capacity and the age structure of the society**.

Indicators of socio-economic resilience and of ecological resilience can be distinguished. While the ecological or natural system has quite good capabilities to withstand and to recover from adverse impacts if natural processes are not further disrupted by human interventions, the socio-economic system is less capable.

The indicators of social resilience can be grouped into (i) preparedness indicators including risk perception, risk awareness, participation, or early warning capacities, (ii) coping and adaptive capacity, and (iii) recovery indicators. The **flood experience** and the **perception of risk** are indicators for social resilience. This is based on the assumption that people who were aware of the risk, with which they live or who have recently been subjected to a coastal (flood) disaster and who are sufficiently informed are able to react in better and faster ways in case of an emergency and are more open for the development of adaptation strategies. The **percentage of houses protected against flood impacts** is an indicator because target oriented measures of protection help to reduce the damages of buildings and loss of fixtures considerably. The early warning capacity can be measured by the presence of **radios** and pre-existing **warning structures** (e.g. evacuation plans).

The **resources concerning transport capacities** as well as the **strength of civil societies** enable decision makers to organize and plan.

The ability to recover is an important indication for resilience, especially in regions that are subject to recurring hazards such as hurricanes. A high frequency of disturbance and recovery requires the development of strategies that make recovery successful and at the same time help to prevent for futures impacts. The ability to recover can be measured by **financial reserves, percentage of people with insurance, the degree of external support, and the source of income**. A region that has a high percentage of people working in the tourism branch, for example, will be much more affected and less resilient to sea-level rise and extreme events than others.

CLARK (1998) discusses even the role of insurance as an indicator. He argues that it is two-fold. On the one hand, private persons who have insured their houses are personally less affected by the disaster. On the other hand, insurance could act to reduce coastal resilience because people rely upon their insurance neglecting measures or activities to strengthen their preparedness.

Despite many attempts uniform vulnerability indicators that may be broadly applied to coastal hazards and by that systematic vulnerability profiles can be generated have not been developed yet.

These selected key indicators are predominantly generic ones, i.e. chosen to be applied to a large range of coastal sites. Nevertheless, the vulnerability at a specific site can be dominated

by special circumstances. In some countries for example indicators such as HIV/AIDS incidence or warfare are very important. In countries or regions with active war, totally different conditions have to be assumed, as for example governments are not able to work as usual, or infrastructure is interrupted. The vulnerability of such a region is much higher than it would be as compared to without war. Conflicts make regions extremely vulnerable because the adaptive capacity is reduced.

As FOLKE ET AL.⁴ acknowledges, “the world is not a set of Chinese boxes”, scale is all-important in evaluating, and comparing vulnerability of specific units to potential changes in climate. An action that is successful for one individual, organization, or level of government may not be classed as successful by another. For adaptation on household level other factors are relevant than for adaptation on state level. While on household level socio-economic factors like health or education are of importance, on state level the adaptation processes are determined by national wealth or the effectiveness of governments. There is an increasing conscience of the importance of cross-scale linkages, but no concrete results on how to link global changes to political responses at the local/regional scale as well as scientific assessments to decision-making across scales are gained so far. It is not always possible to transfer the results from one scale to another. Things may be homogenous at an aggregated scale and heterogenous at a finer scale.

Thus for the selection and use of key indicators, their spatial scale must be taken into account. Most indicators are conceived for the national level. Others can be useful at smaller scale, either regional (e.g., at the level of coastal counties) or local (e.g., a coastal strip or small community). About the actual scale indicators can be used has to be decided due to the specific area of investigation and the related hazard exposure.

In table 5.9 a proposal is made how to address indicators to coastal vulnerability and resilience assessment. In the table the four types of coastal hazards are chosen:

- Storm surges and episodic flooding,
- Tsunamis,
- SLR and inundation, and
- coastal erosion

The key indicator groups are classified according to their most feasible assessment scale with regard to the specific hazard.

⁴ <http://www.uni.bonn.de/i NDP/wp02main.htm>

Table 5-9: Indicators according to scale

	Storm surges, episodic flooding	Tsunamis	SLR and inundation
Social vulnerability			
DEM	Regional	Local	National
H	Regional	Local	National
EDU	Regional	Local	National
GOV	Regional	Local	National
CUL	Regional	Local	National
WEL	Regional	Local	National
Economic vulnerability			
CV	Local	Local	Local
LAN	Local	Local	Local
LAB	Local	Regional	Local
EA	Local	Regional	Local
Ecological vulnerability			
EV	Regional	Local	Regional
ENV	Regional	Local	Regional
Resilience			
SORES	Local	Local	Local
ECORES	Regional	Regional	Regional

National 
 Regional 
 Local 

The scale indicators should be assessed on differs among different types of hazards. This is due to the different impact characteristics. Sea level rise and related inundation is a slowly occurring process affecting the whole coastline, although regional differences occur. Tsunamis or other episodic floodings in contrast occur suddenly, very local and with a much more intense impact. Thus according to the specific hazard the key indicator classes are proposed to be assessed as follows:

Storm surges and episodic flooding: Indicators of social vulnerability, like demographic parameters (DEM), health (H), education (EDU), governance (GOV) and personal welfare (WEL) are most easily gained on national level as country statistics are available at this level. Especially in developed countries, it can be assumed that these data are quite homogenous throughout a country so that the national level is appropriate. Developing countries are often characterized by discrepancies making it necessary to gain regional data on social vulnerability to episodic flooding.

As storm floods have a huge impact on material values, economic vulnerability, especially capital value at loss (CV) and land loss (LAN) have to be assessed on local level. Labor force (LAB) an economic acitivity (EA) are for the most determined by regional conditions. So is even the ecological situation (vulnerability and resilience). Social resilience (SORES) has to be assessed on a very local level because a lot of subjective personal attitudes are decisive for social resilience, e.g. risk perception, houses protected against flood impacts or the number of radios.

Tsunamis: As tsunamis are very local and unpredictable hazards most of the indicators have to be assessed on local level. In the context of tsunamis social indicators and indicators for social resilience are arbitrate as the natural vulnerability or the exposure does not give any clear advice on the dimension of Tsunami impacts because no clear prognosis if a Tsunami wave is 3 metres or 30 metres high can be made in the run up to an event. Thus social vulnerability indicators (demographic parameters (DEM), health (H), education (EDU), governance (GOV) and personal welfare (WEL)), indicators for social resilienc (SORES) and capital values at loss (CV)/ land loss (LAN) have to be assessed on local level. Economic vulnerability indicators (LAB and EA) are measuring vulnerability outover the area directly affected and thus are feasible on regional level. Ecological (EV, ENV) vulnerability and resilience (ECORES) are related to coastal types which extend regionally.

Sea-level rise and permanent inundation: These hazards occur slowly and are predictable- although not detailed on local level due to a lack of local scenarios. As SLR affects the whole coastline social indicators for vulnerability (demographic parameters (DEM), health (H), education (EDU), governance (GOV) and personal welfare (WEL)), can be gained on national level. Economic vulnerability (capital value and land at loss (CV, LAN) indicators are needed on local level as values lost and flooded are locally specific and so are indicators for social resilience (SORES), i.e. preparedness and adaptation measures to be decided upon. Environmental conditions (EV, ENV, ECORES) are related to regional coastal stripes and even economic acitivity (EA) and labor force (LAB) affected by sea-level rise is of regional relevance.

This is a generalized approach to scale related indicator-based vulnerability assessment. The reason for a cross-scale application is that an assessment only on local level - which indeed would be most effective- is not operable in all coastal regions due to the lack of resources and even the reliability of local scenarios for global processes. Hence, if it is absolutely necessary local indicators should be applied; the others should be gained through up-scaling. It is important to keep in mind that all these considerations are depending on data availability and quality. Although methodological necessary, it is not possible to assess local data in certain situations. Here an upscaling is necessary while the integrative approach covering indicators from social,

economic and ecological vulnerability and ecological and social resilience should not be disclaimed.

5.7 Risk perception

Risk perception refers to the awareness of risk of people living in flood-prone areas. Risk perception and risk awareness can thus be related to resilience. Societies or individuals are assumed to be more resilient, if they are aware of potential risks they are subjected to. Furthermore it can be influenced, i.e. improved, by management activities such as information dissemination. Yet, risk perception has been neglected in former risk and vulnerability assessment studies. First approaches to assess the perception of risk have been made in the context of risk management and disaster reduction.

Thus, one focal point of this thesis is the evaluation of the meaning of risk perception for resilience and vulnerability as well as risk management.

Scientists and decision-makers who assess and develop strategies to reduce the vulnerability of coastal zones to natural hazards and to improve disaster preparedness have to consider aspects in addition to quantitative measurable determinants such as inundation depth or the number of people affected. Whether a hazard has negative impacts on coastal societies or turns into a disaster depends to a great extent on human behavior. The human behavior in turn depends not on facts, but on perception, experience, and knowledge. The daily, "intuitive" perception and evaluation of risks is the basis for the individual, subjective assessment. Consequently, perception and evaluation of risk is prototypical for human behavior in dangerous situations. This also applies to the perception and handling of risks of natural hazards. In order to determine the vulnerability of a region and to develop effective information and communication strategies of natural risks, the perception and evaluation of these risks and influencing factors should be known (PLAPP, 2001). SMITH (2001:72) reveals that "it is clear that risk assessment and risk perception have to be combined in the attempts made by governments and others to reduce hazards". Successful risk management is not only the task of policy makers and coastal planners, but it is also strongly influenced by the people living in the prone area, their perception, and awareness, their decisions and behavior concerning the natural risk.

In the following an overview of the scientific background is given. Furthermore the results of an international survey in the North Sea Region are presented and analysed.

5.7.1 What is risk perception?

Risk perception refers to the intuitive risk judgements of individuals and social groups in the context of limited and uncertain information (SLOVIC, 1987). These judgements vary due to different levels of information and uncertainty basing on different intuitive behaviors.

Risk perception is

“...the subjective appraisal based on intuitive judgement, personal experience, and acquired information that people make about the characteristics and severity of a risk.”

The handling of risk primarily has the objective to prevent or reduce risks or losses. Therefore, certain strategies or concepts, which are developed with regard to natural hazards within the risk management, are mandatory. That again implies several decisions. These decisions and the resulting actions are shaped by individual and collective perceptions of risk. Decisions about risk management are not only the task of authorities and professional managers. It is also necessary, though often neglected, to actively involve the people living in the exposed areas. “Their risk perception is a fundamental base for their decisions and behaviour concerning natural risks and their management of natural risks. Consequently, the risk perception of the inhabitants of a community has been taken into consideration concerning disaster management planning on community level. For the development of effective information strategies on protective measurements (risk and communications policies), the risk perception of the targeted group and as well influences on risk perception should be known” (PLAPP, 2001:2).

In the context of risk perception, the first step is the identification of the risk and, subsequently, its evaluation. That means the process of perception can be subdivided into two parts: the perceptual phase and the valuation phase. The first phase is an extensive unconscious process, where possibilities and problems are identified, analysed, and then verbalized, categorized, and classified. The capacity of reception and processing as well as the situation and the cultural pattern of thoughts have a selective effect and lead to an automatic selection. In the second phase, risks are evaluated and options and alternatives for action are measured. These perception and valuation phases can hardly be separated within the day-to-day practise, because these processes are happening rather unconsciously. Hence, only the term risk perception or risk evaluation is used, even though both phases are meant.

In classical risk research, there are three approaches to risk perception.

- The axiomatic measurement paradigm according to STARR (1969),
- the socio-cultural paradigm, and
- the psychometric paradigm.

All of them were developed and applied mainly in the context of controversial public discussions and debates on technical and environmental risks in the USA since the Mid-Seventies. Studies following the axiomatic measurement paradigm, adopting the statement of STARR (1969): "How safe is safe enough", have focused on the way in which people subjectively transform objective risk information, i.e., possible consequences of risky choice options such as mortality rates or financial losses and their likelihood of occurrence, in ways that reflect the impact that these events have on their lives. The approach focuses on the relation between a socio-economic benefit of a situation and the corresponding risk. According to STARR, the acceptance of a risk is increasing when the benefits are increasing. Based on historical data about accepted risks, a comparison with actual calculated risks is made (*revealed-preference method*). This comparison with past data is one of the most important critical points of this approach.

Studies within the socio-cultural paradigm have examined the effect of group- and culture-level variables on risk perception. They placed affiliations with social ways of life and corresponding worldviews in the center of their theoretical concept of risk perception. The most influential cultural theory is termed "The Cultural Theory of Risk". This Cultural Theory is based on the work of DOUGLAS & WILDAVSKY (1982) and argues that views of risk are produced and supported by social structures. It proposes that there are four basic *ways of life* each corresponding to a particular social structure and a particular view on risk. They are called *cultural biases*, and are defined by their levels of *grid* and *group*. Grid refers to the degree to which people are constrained in their social role. Group refers to a feeling of belonging or solidarity.

- High group and high grid produces a *hierarchist* way of life, characterized by a reliance on authority and regulation. Hierarchists fear crime, delinquency, and other risks that would disrupt the careful ordering of society.
- Low grid and high group produces an *egalitarian* way of life, characterized by voluntary associations in which all members are equal. Egalitarians focus on low-probability. Yet, catastrophic risks such as nuclear power, because fear of disaster keeps members in line.
- Low grid and low group produce an *individualist* way of life, characterized by competition in the market. Individualists fear anything that would impair the functioning of the market, such as war.
- High grid and low group produces a *fatalist* way of life, characterized by a feeling of lack of control of the world. Fatalists do not fear risks, as they do not think they can prevent them.

The psychometric paradigm (FISCHHOFF ET AL., 1978) is most germane in this context. Research within the psychometric paradigm has identified people's emotional reactions to risky

situations that affect judgements of the riskiness of physical, environmental, and material risks in ways that go beyond their objective consequences. The aim of this approach is unveiling the cognitive structure of risk using psychophysical scaling and multivariate analysis techniques to produce quantitative representations of risk attitudes and perceptions. Contrary to STARR (1969) data are not gained indirect from historical sources, but are assessed empirically (surveys, factor analysis, cluster analysis). Instead of the revealed preference method the expressed preference method is used (SLABY & URBAN, 2002).

Focal points in this approach are (KARGER, 1996:31):

- Determination of the noticed level of the risk,
- analysis of the cognitive structures of the risk,
- comparison of the risk perception for different sources of risk,
- determination of the factors of influence and characteristics on the risk perception,
- analysis of comparative risk judgements, and
- determination of risk – benefit relationship.

Several studies have proven that risk perception, and respectively risk evaluation, is influenced by different factors. The identified factors which make up the whole stimuli set can be assigned to three dimensions: risk criteria, personal attributes, and environmental settings. Concerning the first dimension through several studies SLOVIC ET AL. (1985) could identify two risk criteria, which have a significant influence on the individual risk perception: dread risk and familiarity.

Dread risk	
controllable	not controllable
not dreadful	dreadful
no risk of a global disaster	risk of a global disaster
consequences not deadly	consequences deadly
benefit equally distributed	benefit not equally distributed
damage for an individual	damage for many
no risk for future generations	high risk for future generations
easily to reduce	hardly to reduce
risk decreases	risk increases
voluntary	involuntary
Familiarity	
perceivable	not perceivable
familiar to the concerned	not familiar to the concerned
direct impact	delayed impact
old risk	new risk
explored	not explored

Figure 5-7: Dominating factors and features for risk evaluation
(Source: Weichselgartner 2001: 34)

Aspects which affect the dread risk are for example the possibilities to control, voluntarily deal with, and reduce risk; (un-)familiarity is for instance determined by scientific clarification or the direct effect (cf. figure 5-7).

Dread risk is the most often investigated criteria. It describes the estimated damage dimension which people associate with risk. This especially applies to the risk evaluation of so called lays. Dread risk is thereby assessed comparatively independent from the probability. This distinguishes non-professionals from professionals, where latter attach a much higher importance to the probability. Contrary to these results other studies pointed out that people insure themselves rather against more frequent minor losses than accidents with heavy losses, but low frequency.

The familiarity of a certain risk – in terms of name recognition – is directly connected to dread risk. A new, unknown risk such as genetic engineering raises fears, because people have to become acquainted with it and new knowledge must be acquired. Since familiarity is not necessarily dependent on the individual knowledge, it is not classified as a people's characteristic (JUNGERMANN & SLOVIC, 1993; 1997; SLOVIC, 1987).

SLOVIC (1987) describes exposure in terms of the number of affected people as further risk criteria. The greater the personal exposure is valued, the higher is the general assessment. Effects of adaptation or repression, socio-demographic factors, and experience with damages possibly have a significant influence on the appraisal of the exposure. Within the comparison of different flood affected areas, it could be detected that people in frequently inundated areas assess the hazardousness lower than people affected for the first time.

Tremendous differences concerning the assessment of the threat of various risk sources between so called experts and lays partly exist. The danger of inundation is often underestimated by the population, while it is viewed as rather threatening by the experts.

The WBGU (1999) identifies the occurrence probability, the damage potential, the perceptibility, temporal aspects, the terminableness of the impacts, direct and indirect consequences, and the irreversibility of the consequences as the perceived risk attributes. Subject to these risk attributes, damaging events have different announcement effects, whereas the event, which is related to a unknown and dreadful risk has a much higher announcement effect than familiar ones. This effect can result from the (hypothetical) risk due to the ignorance of possible risks (JUNGERMANN & SLOVIC, 1993:104). It is experienced as especially threatening.

Other studies stated that the individual accident rate affects the estimation of the own risk of accident. If it is categorized as low, the disaster potential is decisive for the risk evaluation and the personal attribute concernment corresponds with the risk of accident.

Knowledge, experience, and the mental attitude about valuation is of vital importance concerning the personal attributes. For the individual, RENN (1993) defines risk evaluation as the following personal attributes which influence the assessment additionally:

- personal attitudes and interests
- voluntariness
- possibility of personal control
- nativeness of risk source
- reliability about consequences
- reversibility of consequences
- eventuality of disaster
- justice of benefit and risk distribution
- possibility of extensive consequences
- impact on future generations
- sensual perception
- familiarisation of risk
- experiences with techniques and nature
- balance between beneficiary & bearer of risk
- confidence in public control

Beyond these factors considered as relevant for risk perception, also cultural-sociological aspects are of importance. The cultural system of the receptor and the associated moral concept as well as the social integration into the society is of importance for perception. Different studies have shown that not only cultural specific differences in the valuation of risk, but there are also different subcultures or groups within a society which have varying perception and valuation patterns. Thus the differences within one country are often greater than between different countries (ROHRMANN, 1995).

Among risk and personal attributes, the environmental conditions complete the set of stimuli (DEUTSCH, 2002). The spatial vicinity has an important influence on the risk evaluation. People who live close to technical objects rank the associated risks and the expected drawbacks much higher (NIMBY - Not-in-my-backyard). This factor corresponds with the assessment of the personal dismay. Furthermore the political, economical, and social conditions (war, recession, crisis) have effects on the risk attributes. The represented factors and concomitants of the risk evaluation are just a range of possible impacts. The influences as a whole cannot be charted in a model.

5.7.2 Risk perception, communication and information

The perception of risk varies with the social influences. Thus, it is obvious that communication is of great importance. Risk communication concerns all communication processes which refer to identification, analysis, evaluation, and management of risks as well as the associated interactions amongst all parties (JUNGERMANN ET AL., 1991). Communication about risks, i.e. what is communicated when and from whom, is important for the perception of individuals, for risk management, and in the range of prevention.

What kind of information is of importance for the inhabitants of a flood prone area and how does it have to be conveyed to achieve the proposed effect? What is more recommendable, to inform the people by means of a presentation in the town hall or by a brochure with hints about the emergency case? In order to develop an effective risk communication, it is considered helpful if one can revert to the risk perception of the target group (PLAPP, 2003).

Risk communication, risk perception, and the behavior concerning potential risks and damages are regarded as a unit. Moreover, the process of acceptance can be partly influenced by means of communication. This is especially a particular issue on the political and administrative level. Risk communication can enhance the public awareness of hazards, and sensitise the risk perception, but it can also contribute to the uncertainty of the public (RENN & ZWICK, 1997). It is assumed that an improvement of the communication process can solve a number of social problems, such as inappropriate risk perception, resistance to accept technique or unwanted risky behavior.

Benefits and risks are conveyed to the social recipients through science, policy and mass media. Even though the influence of the mass media is not unessential, it is often overrated. A conclusion on the effect and relevance of mass media reports is not provided within the communication research. Whether the communication via media results in risk acceptance or aversion remains unacknowledged (*chicken-egg-question*).

The following assumptions about the different cohesions exist: (WBGU, 1999:175):

- the media influence the standard of knowledge and their acquisition of the recipients,
- the media affect the selection of problematic topics (*agenda setting*),
- the media have influence on the recipients opinion and position,
- the media affect the image of the actors, and
- the media have influence on the capability to deal with risks and cope with them.

Therefore, it is to be considered that it is extremely difficult to separate media influences from inter-personal communication. Different studies determined that the press coverage of the

media is often distorted or incorrect (DUNWOODY & PETERS, 1993). This again requires a specific acceptance.

The term *acceptance* comprises all social and political coherences. Definitions in the literature vary from “pure obedience” up to “political participation”. The following definition of acceptance appears to be most appropriate in this context:

“The affirmative or tolerable attitude of a person or group to normative principles or regulations. Concerning the material field it is the positive attitude to the development and distribution of new technologies or products. The attitude results in a corresponding behavior. A lack of acceptance can lead to a change of official standards or influence social-political decisions” (BROCKHAUS ENZYKLOPÄDIE, 1986).

In other words acceptance is the chance to get the explicit or implicit consent of a group or person for specific concepts, measures, proposals, or decisions. Acceptance always refers to intended or already performed actions. Traditionally, the term risk assumes that only the state is responsible for political action. The population can either refuse or accept this. In the meantime, the term is more related to political acceptance. Hence, acceptance of national communication would only be achievable through a participation of the population in risk communication and management. This has been neglected especially in coastal defense and disaster management, where the scientific-technical approach was dominating.

5.7.3 Risk perception of natural hazards

The risk perception and valuation of natural hazards, is now illustrated against the theoretical background.

In natural hazard research three schools dealing with the social meaning of natural hazards exist

- the *Vulnerability school*, considering the reasons for social susceptibility to a disaster
- the *Disaster school*, considering the acquaintance of humans with an actual disastrous event, and
- the *Chicago school*, considering the acquaintance of humans with the threat of natural hazards.

Vulnerability research as described above, analyzes the vulnerability of social groups due to economic, social, and cultural structures in the area of investigation. Existing vulnerability approaches do not give any clues for risk perception.

The Chicago School, established by Gilbert White, Ian Burton, and Robert Kates after the 2nd world war, developed a descriptive decision model following the cognition that the knowledge of individual human behavior enables risk management.

The work of the Chicago school has the following subjects:

- estimation of population at risk
- development of adaptation strategies, and
- investigation of risk perception

TOBIN & MONTZ (1997) differentiate various factors which determine the perception of natural hazards (HIDAJAT, 2001). These are illustrated in figure 5-8.

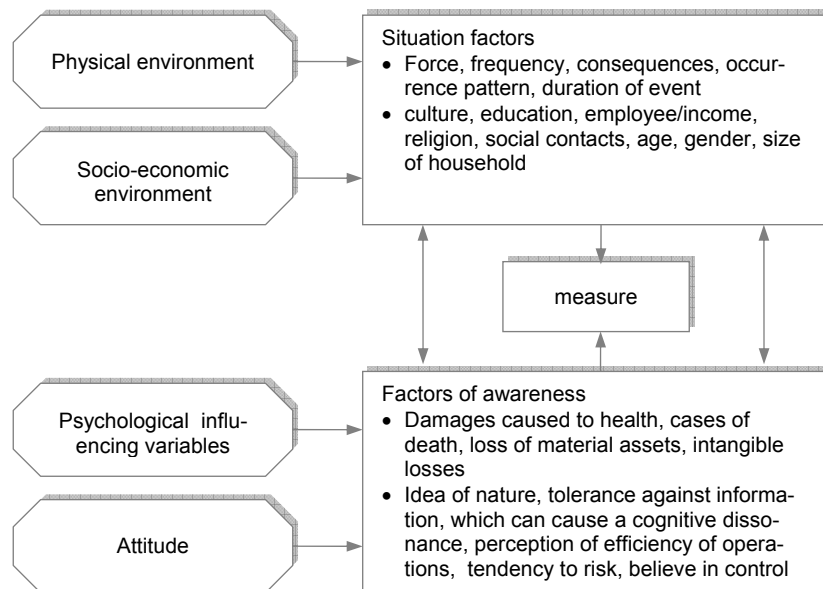


Figure 5-8: Influencing factors of perception (Source: TOBIN & MONTZ, 1997:149)

The authors differentiate between two groups of influence factors: situation factors, which result from the physical and socio-economic framework and awareness factors, which include psychological aspects and attitudes.

People have problems when thinking in probabilistic terms. Numerous natural hazards studies have shown, that people overestimate and underestimate event probabilities due to different cognitive information processes. They also interpret information in different ways to facilitate the handling of the uncertainty. SMITH distinguishes three different basic types of perception models (SMITH, 2001:70):

Determinate perception

The arbitrariness of occurrence of disastrous events prompt people to put the events in specific orders (e.g. iterative cycles or regular intervals).

Dissonant perception

The denial of hazard is the most negating form of perception. Past events are regarded as exceptional coincidences. Consequently it is judged as unlikely that they will occur again. The complete denial of events is a way to deal with the everyday threat.

Probabilistic perception

Hazards are identified and perceived; the events are categorized as arbitrary and accepted. The acceptance is connected with a handover of the responsibility to a higher level such as the government or god (*act-of-god-syndrome*).

BURTON ET AL. (1978) develop a concept of intervals to determine the connection between perception and decisions for handling (cf. figure 5-9). First, when reaching a level of perception, handling is taking place.

Level of risk	Decisions for handling
5	Escape from hazard situation
	<div style="border: 1px solid black; width: 80%; margin: 0 auto; padding: 2px;">Level of retreat</div>
4	Assessment of hazard situation demanded
	<div style="border: 1px solid black; width: 80%; margin: 0 auto; padding: 2px;">Level of acceptability</div>
3	Hazard reduction demanded
	<div style="border: 1px solid black; width: 80%; margin: 0 auto; padding: 2px;">Level of action</div>
2	Hazard accepted
	<div style="border: 1px solid black; width: 80%; margin: 0 auto; padding: 2px;">Level of perception</div>
1	Hazard not realised or agonized

Figure 5-9: Concept of intervals (Source: HIDAJAT, 2001:8, adapted from BURTON ET AL., 1978)

On the first stage humans react and do not notice the hazard, in order to lead a productive life due to their vital basic need. If a hazard is realized, it is often displaced, weakened, or even denied. The damage is accepted and felt as fate. At the level of perception, the hazard is somewhat conscious, which contains a possibility of damage.

On the second stage, the negative effects are recognized and classified as important, but the reaction remains passive and no countermeasures are taken. If the risk is accepted, one learns to live with the danger. Rather a well-known evil is tolerated than to admit an uncertain outcome. If the action threshold is crossed, the need for intervention and hazard reduction awakes. This includes coping, but not preventing yet. With excess of the mobility threshold, a fundamental examination of the hazardous situation is demanded. Smooth measures are no longer sufficient, but fundamental improvements or acceptable alternatives must be compiled. As a last step the escape occurs, if the risk cannot be reduced sufficiently. However, this step is rare, since the connections to the residence and the social environment are extraordinarily strong. The behaviour patterns described here hardly show up in the described minglingness and isolate. One always determines a mixture of different kinds of behavior, depending on numerous influencing factors.

5.7.4 Risk perception of storm floods in the North Sea Region

To investigate the role of the perception of risk to storm floods and coastal flooding, a study was carried out in the North Sea Region by the author.

Along the North Sea coast, vast low-lying areas are threatened by recurring storm flood events and are thus at risk of being flooded. Approximately 16 million people live in flood-prone areas protected by coastal defense. Important economic centers like the harbors of Rotterdam or Hamburg, as well as many tourist facilities, are situated in this region. During the severe storm flood disaster in 1953, more than 2,000 people lost their lives in the Netherlands, Belgium, and the United Kingdom. Even the *Hamburg-flood* in 1962 claimed a death toll of 340. Without coastal management and defense measures, the people living in the North Sea Region would be exposed to an unacceptable level of risk. To maintain present safety standards despite increasing natural and socio-economic pressures, long-term investments are mandatory. Social and scientific conditions in the areas at risk have to be determined when establishing an effective management process.

Against this background, the national and regional authorities in the North Sea Region initiated the multilateral Interreg IIIb project COMRISK (Common strategies to reduce the risk of storm floods in coastal lowlands). This was done in 2002 with the aim to improve risk management in flood prone areas in the North Sea Region by means of a transfer and evaluation of knowledge and methods as well as pilot studies.

It is assumed that people who are aware of the risk of flooding will probably accept this and could help to reduce it. Further, it is assumed that an aware coastal population might react faster and in a better organized way in case of an emergency. As awareness decreases with

time passed by after the last event and in order to maintain an adequate level of public awareness, it is necessary to further inform the people and to develop respective instruments, e.g. information tools, flood warning systems, or public participation processes in risk management.

To investigate the role of perception and participation in terms of risk management and coastal flood defense planning a study was carried out by the author in the framework of the COMRISK Subproject 3: "Public Perception and participation in coastal defense planning". Besides the perception of risk, the study also investigated the level of information, the level of preparedness, and the level of participation in the coastal defense and risk management planning process from the view of the public as well as the view of experts (KAISER ET AL., 2004).

In the following, the results of the public survey on risk perception, information, and preparedness are presented.

5.7.4.1 Methodology

Information about risk perception cannot be gained from historical considerations, but has to be assessed empirically. The empirical instrument for the survey was a standardized questionnaire containing twelve questions about risk perception, nine questions about participation, and three questions concerning demographic information. A total of 2000 questionnaires were distributed, 400 in each of the five study areas. They were translated into Dutch, Danish, and English, so that they could easily be filled out by all local participants. The questionnaires were distributed to randomly selected households with prepaid return envelopes. The entire inquiry was designed taking into account important aspects of Dillman's Total Design Method (DILLMAN, 1978). This method delivers a set of procedures, which should lead to a maximum success of a mail survey, e.g. guaranteed anonymity, avoiding delicate questions, prepaid return-envelopes and a serious letter with official logos. Detailed information on the project accompanied the mailings in order to raise the awareness of the participants of an existing problem that is important and significant to them, and that their support is needed to find a solution.

Assuming that the perception of the risk of storm floods is different within and between the areas of investigation, representative results are to be expected from this approach. Different regional conditions, historic and actual disasters, and the degree of participation as well as the flow of information were taken into account when comparing the results.

The following questions sum up the main topics required for an analysis:

- To what extent are storm surges considered a threat / risk?
- To what extent is risk accepted?
- What are the regional distinctions of risk awareness?
- How can risk perception be improved?

The returned questionnaires were analyzed with SPSS.

The public perception was investigated in Oostende/ Belgium, Ribe/ Danmark, St. Peter-Ording /Germany, Gemeente Sluis /The Netherlands, and in Skegness/ United Kingdom (cf. figure 5-10).



Figure 5-10: Area of investigation

(Source: KAISER ET AL., 2004: 27, adapted from JORISSEN ET AL., 2001)

Belgium - Oostende

In Belgium, approximately 3% of the land surface is flood-prone (MINVENW, 2001:8). The city Oostende is situated at the Flemish coastline. Morphologically speaking, the area is a sedimentary plain. This means it consists of sandy banks in the shallow sea, sandy beaches, and dunes. Behind the dunes, low-lying polders dominate the landscape. Oostende is the largest urban settlement on the Belgian coast, characterized by tourism and the town's infrastructure as a transportation hub. The Flemish coast has been affected by severe storm floods in the past, with the disaster in 1953 being the worst. For coastal protection measures in the recent past, e.g. beach nourishments in Oostende, safety levels for a 1,000-year-period were used as well as a 1:1000 years breakthrough probability of dunes. In Oostende,

an improvement of coastal protection is urgently needed and planned, but discussed controversially.

Denmark - Ribe

Approximately 4% of the country is low-lying area beneath 5m NN. The community Ribe is situated at the southern Danish Wadden Sea coast, located at the Ribe Å. Although the town has a distance of 6 km from the sea, it belongs to the flood-prone area. Tourism is important for this ancient trading town. Compared to the other study areas, Ribe is not a typical beach resort. Here, the historic town itself, the landscape, and the Wadden Sea are of interest to tourists. From Esbjerg – south to the German border – some 100 km of dikes protect the low-lying marshland areas against flooding. The dike safety in Denmark is standardized to a safety of 50 years. Where it is economically justifiable, it is set higher, e.g. to 200 years in Tønder and to 1000 years in Thyborøn. Several storm surge events hit the Danish coast in the past; the last flooding that took human lives occurred in 1923. Since the 1970s, the dikes protecting the low-lying towns Ribe and Hojer have been reinforced repeatedly and two new dikes have been built. Since the 1970s, the frequency of storm surges has been much higher than earlier in the 20th century (MINVENW, 2001:3).

Germany - St. Peter-Ording

The flood-prone area of the four German states at the North-Sea – Niedersachsen, Bremen, Hamburg and Schleswig-Holstein – covers as many as 11.240 km² (17.5% of the total area). Due to the land reclamation during the last centuries, most of the North Sea coastline is divided into flood units, so-called *Koerge*. The beach resort St. Peter-Ording is situated at the North-Sea coast of Schleswig-Holstein. A (partly interrupted) sea dike protects the municipality. Sandbanks run parallel to the coastline, creating the sandy beach and dunes in St. Peter-Ording as a kind of a natural sea-defense. The Hinterland is a low lying terrain with 0 - 2.5 m NN. For the safety-levels of dikes, a return-period of 100 years is minimum. In addition, the highest regionally recorded water or storm surge level is taken into account. In 1962, a severe storm flood in the German Bight killed 350 people in Germany, most of them in the city of Hamburg (MINVENW, 2001:8). For the most parts of the German North-Sea coast, however, the highest storm surge occurred in 1976. Because dikes were raised and enforced following the 1962 flood, no major damages were suffered during these peak flood levels of 1976.

The Netherlands - Gemeente Sluis

The 25.000 km² flood-prone area in the Netherlands covers about two-thirds of the entire country (MINVENW, 2001:6-1). Sixty percent of the Dutch population and economy are situ-

ated in this vast and densely populated area. Effective coastal protection is essential for the existence of the nation. Thus, protection against flooding is an important national issue and a political task embedded in the constitution. Failure of flood defense structures would have devastating human and economic consequences for the entire country. In 1953, the Netherlands experienced the country's worst flooding in modern times, with a death toll of 1,835. Since then, the Netherlands have implemented the highest safety level in Europe with a range from 2,000 to 10,000 years (expressed as return periods). In Zeeuws Vlaanderen, the safety level is 4,000 years. The southern part of the coastline between the Belgian border and Hoek van Holland consists of estuaries of the rivers Rhine, Meuse, and Scheldt. The tourist settlements in Gemeente Sluis are situated in the western part of the province Zeeland. The study region is protected by a sea-defense dike near Cadzand/ Cadzand-Bad and high dunes at Breskens.

United Kingdom - Skegness

Five percent of the United Kingdom is at risk of flooding by the sea. The low-lying areas at the coast are spread over numerous regions. In most of the regions, e.g. in estuaries, there is a danger of coastal flooding as well as riverine flooding. Skegness is a touristic beach resort, located at the North Sea coast of Lincolnshire, south of the Humber estuary and north of the bay *The Wash*. The coastline between Mablethorpe and Skegness is a retreating coast with sandy beaches and coastal defense structures, sand dunes, clay embankments and seawalls, providing flood protection for the low-lying area. In the severe storm flood in 1953, multiple dike and dune breaches at the Lincshore coast led to the loss of 41 lives. The current coastal defense strategy is to stabilize the coastline through beach nourishment. Along the coastal frontage between Mablethorpe and Skegness, 24 km of coastal defenses provide flood protection for over 20,000 ha of low-lying land (EA, 2002).

5.7.4.2 Results of the survey on risk perception

In the following, the most important results of the survey on risk perception in the North Sea Region were discussed. For the total results of the study, see also KAISER ET AL. (2004).

For the interpretation of the results, some constraints have to be made: Although the interpretation of the results aims at an (international) European comparison, the results reflect local situations rather than representing national issues, so that an international comparison must be limited. The areas of investigation are only partly comparable, because they were chosen by the international project partners with regard to political situations. Although they are all flood prone areas with sea-side tourism, they differ significantly in size and structure. Compared to other surveys, 2,000 questionnaires are an enormous amount. Nevertheless, with this kind of

investigation it has to be taken into account that only a very small part of the population made up for the results.

In total, 411 questionnaires (20.6%) of a total of 2000 were returned. The return rate was similar in all countries, except for the UK. 20.5% to 27.5% of the questionnaires were returned in Belgium, Denmark, Germany, and in the Netherlands, while in the UK, the return rate was only 11.3%. Two thirds of the respondents (64%) were male and belonged to the age group of 30-60 years.

In the survey on public risk perception, the inhabitants were asked a total of 12 questions (cf. questionnaire Annex A).

R 1: Have you ever experienced a storm flood?

R 2: Have you ever experienced a coastal flooding (defense breaching)?

R 3: Do you know the year when a storm flood disaster occurred in xxx in the past?

R 4: How high do you estimate the probability of a coastal flooding in xxx?

R 5: Could your dwelling be hit by the floodwater in case of a coastal flooding?

R 6a: Have you taken personal measures to be generally prepared for a storm flood?

R 6b: If yes, what kind of measures did you take?

R 7a: In your opinion, is there sufficient protection against storm floods in xxx?

R 7b: If *no* how, in your opinion, could the safety in case of a storm flood be improved?

R 8a: Do you know what to do in case of a coastal flooding?

R 8b: If *yes* what exactly can you do to protect yourself in case of a coastal flooding?

R 9: How well have you been informed about the basic risks of a storm flood by the responsible authorities?

R 10a: Do you know how to get precautionary information about your own protection in case of a storm flood?

R 10b: If *yes*, where do you get the information from?

R 11: Do you feel personally endangered by a sea-level rise, inducted by the global climate change?

R 12: How high do you estimate the influence of a sea-level rise on the danger of a storm flood in xxx?

D 1: How long have you lived in xxx?

D 2: Age

D 3: Gender

The most relevant questions are discussed in the following.

Question R2: Have you ever experienced a coastal flooding (dike breaching)?

As the personal experience has strong influence on the perception of risk and the behavior of the concerned, the question about the people’s experience is of importance. It is supposed that people who have experienced a coastal flooding before are all the more aware of the risk. Figure 5-11 (cf. table 5-10) shows that in total 29% of the respondents experienced a coastal flooding or dike breaching. This question correlates strongly with the last storm flood disasters in the Netherlands, Belgium and the UK (1953) and in Germany (1962), especially among the age group who experienced these flood disasters. Although smaller dike breaches happened in Denmark in the recent decades, 70% of the respondents did not mention them. The reason for this may be that the town of Ribe is situated some 6 km behind the coastline and that the town itself had not been affected by these dike breaches. In Skegness, due to low storm surge frequency, only 18% experienced an extreme event.

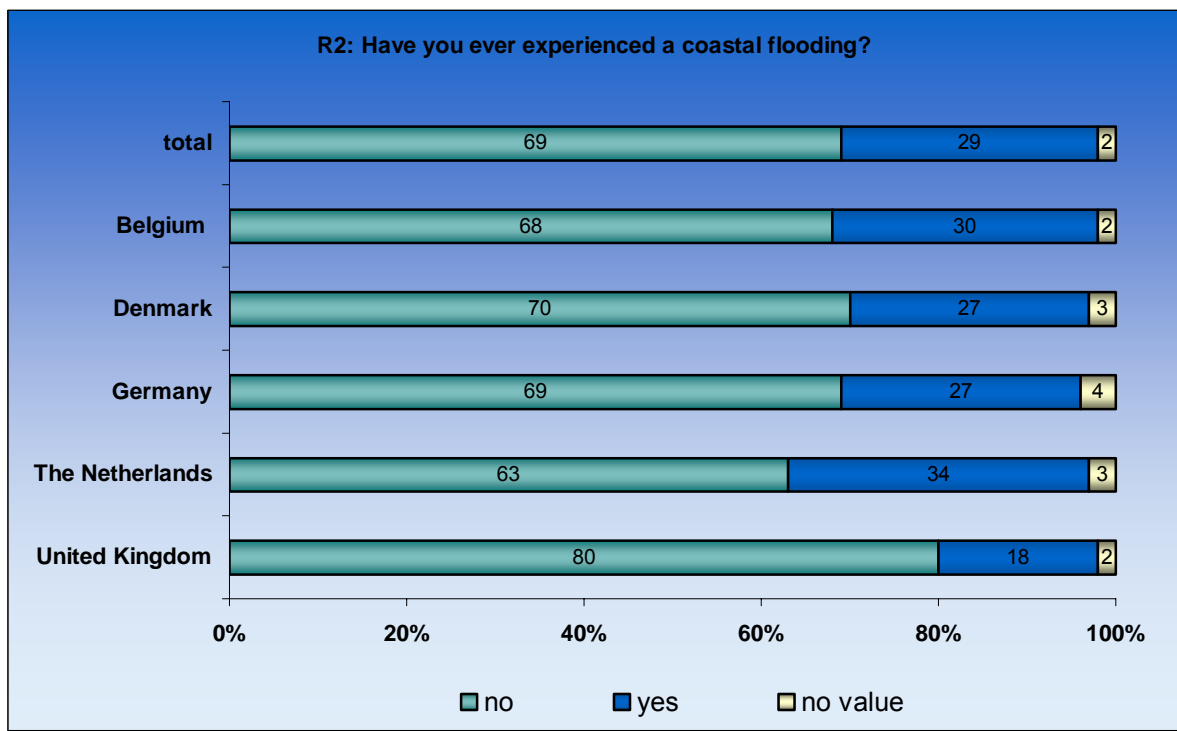


Figure 5-11: Question R2: Have you ever experienced a coastal flooding (dike breaching)?

Table 5-10: Experiences with coastal flooding (dike breaching) in the different study areas

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
no	68	70	69	63	80	69
yes	30	27	27	34	18	29
not valid	0	0	0	0	0	0
no answer	2	3	2	1	1	2

Question R4: How high do you estimate the probability of a coastal flooding?

In all countries, there are quite homogenous results concerning the estimation of the probability of coastal flooding (cf. figure 5-12, table 5-11). In total, 33% of the respondents estimate the probability of a coastal flooding high or very high. In the international comparison, Belgium differs from the others with 42% considering the probability of a coastal flooding high or very high. This result obviously arises from the general coastal defense situation in Oostende, where the sea dike is in the phase of renewal, while at the time of the survey it was overtopped regularly by water, leading to a flooding of the city. There is also a widespread discussion and dissatisfaction with the coastal defense situation in Oostende, both of which are assumed to have considerable influence on the survey.

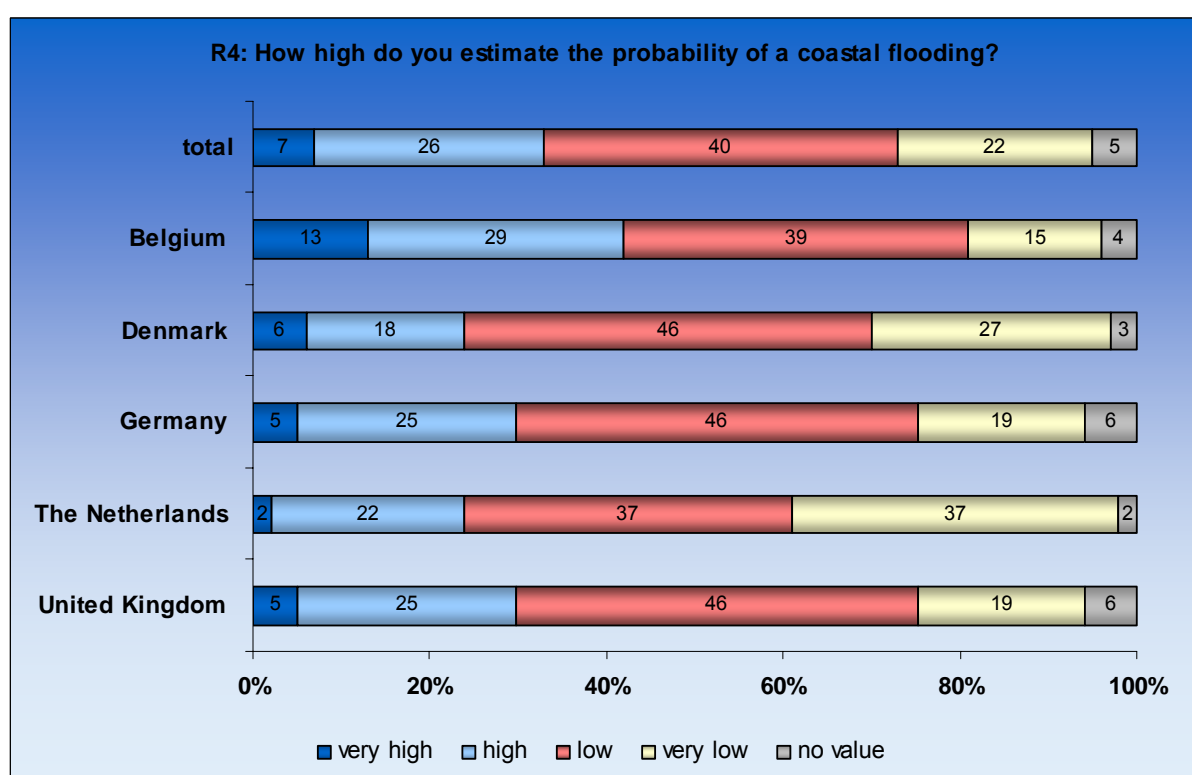


Figure 5-12: Question R4: How high do you estimate the probability of a coastal flooding?

Table 5-11: Estimation of flood probability in the different study areas

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
very high	13	6	5	2	5	7
high	29	18	25	22	25	26
low	39	46	46	37	46	43
very low	15	27	19	37	19	22
not valid	0	0	1	1	1	1
no answer	4	3	5	1	5	4

A cross table of question R4 and R12 reveals a correlation between the estimation of the probability of a coastal flooding and an estimation of the influence of a sea-level rise on the danger of storm floods (cf. figure 5-13). People who thought that the probability of a storm flood is high or very high also stated that the influence of sea level rise is high or very high. This leads to the assumption that these people are aware of the risks and consequences of a climate change and sea-level rise.

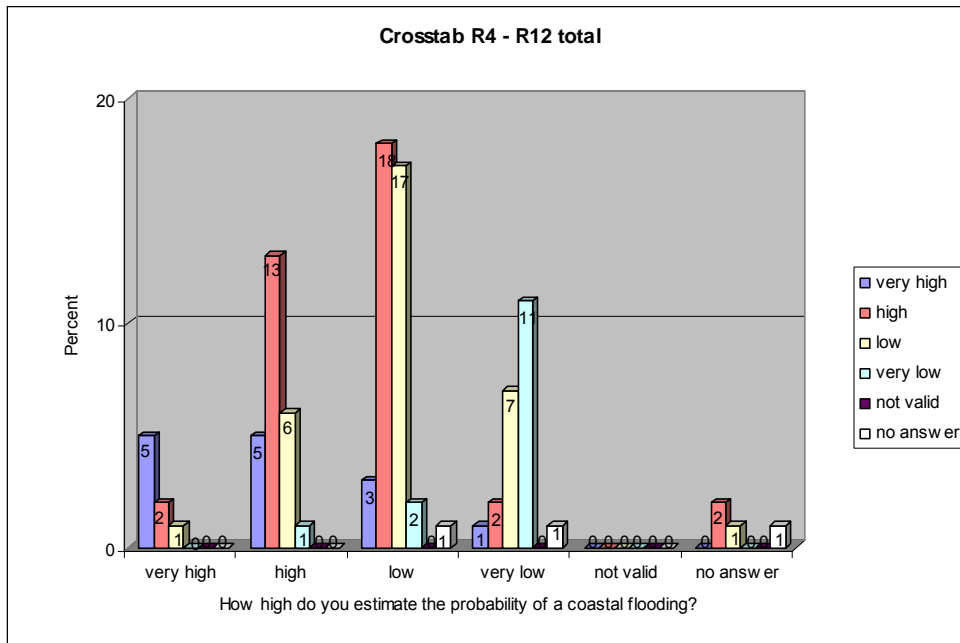


Figure 5-13: Cross table R4: How high do you estimate the probability of a coastal flooding and R12: How great do you estimate the influence of a sea-level rise on the danger of a storm flood?

Symmetric Measures: Interval by Interval Pearson's R: 0.316
 Ordinal by Ordinal Spearman Correlation: 0.502
 N of valid cases: 411

The study at hand did not confirm correlations between risk perception/ awareness and socio-demographic factors and personal experience as they are supposed by other researches. The statement that individual experience does influence the assessment of the probability could not be confirmed. There was also no significant correlation between age and risk estimation or gender and individual risk perception. Hence, it could not be affirmed that women have a higher risk estimation and elderly people a more intensive risk perception.

Question R5: Could your dwelling be hit by the floodwater in case of a coastal flooding?

In total, 30% of the respondents supposed that their house could not be hit by the floodwater in case of a coastal flooding (cf. figure 5-14, table 5-12). This appears a high ratio consider-

ing that all the respondents actually live in the flood-prone area below 5 m NN. This ignorance arises essentially from the absence of concrete spatial information about risk. Only in the Netherlands, 90% of the respondents are obviously informed about the risk, with which they live in their area.

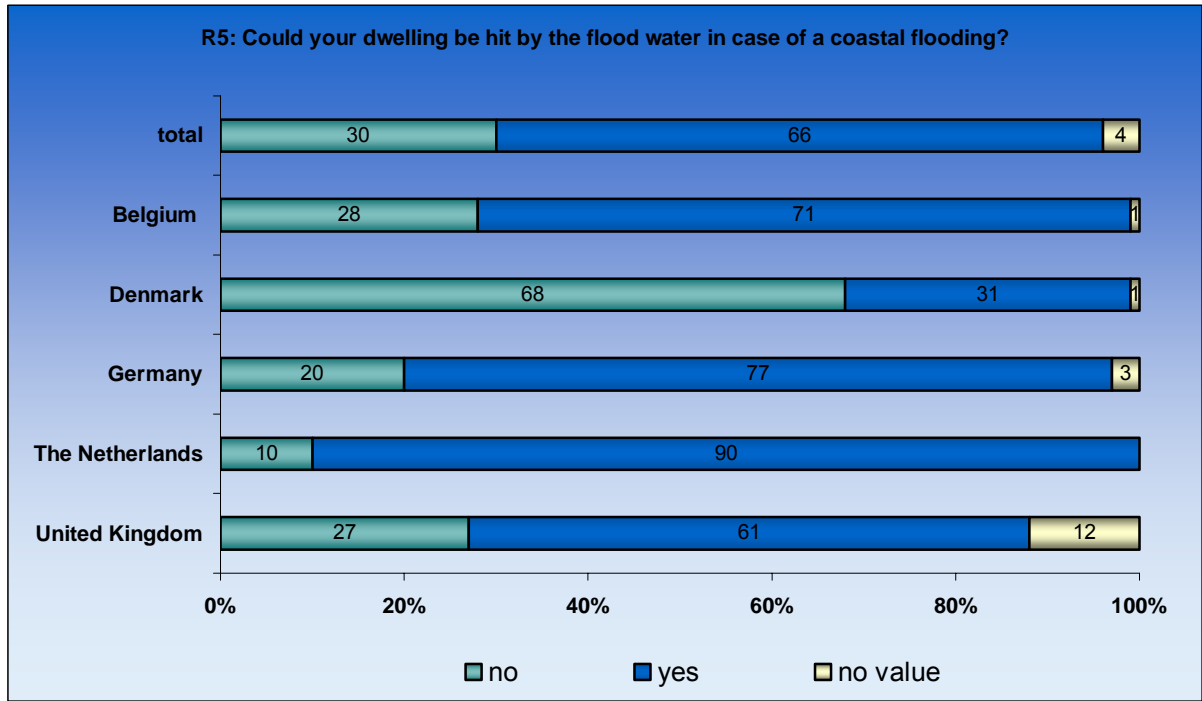


Figure 5-14: Question R5: Could your dwelling be hit by the floodwater in case of a coastal flooding?

Table 5-12: Estimation if own dwelling could be hit by flooding in the different study areas

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
no	28	68	20	10	27	30
yes	71	31	77	90	61	66
not valid	1	1	0	0	2	1
no answer	0	0	2	0	9	3

The survey for Denmark reveals some remarkable results. In Ribe, 68% of the respondents believe that they do not live in the flood prone area and their house could not be hit by the water, although the whole Ribe-area lies lower than 5m NN. The map in figure 5-15 – showing the flood-prone area below 5 m – is distributed by the *Stormflodsberedskabet* via internet and also as a leaflet to the households. Although the authorities spread this information and corresponding flood maps to the households, a large part of the citizens is not aware of living in a flood prone area. This implies that people are poorly informed about the elevation of their homes. More, the distance from the coastline distracts them from recognizing that they live in the flood-prone area. A map such as the one distributed in Ribe is revealing another prob-

lem: Obviously, many citizens are unable to read or interpret a map appropriately. This was confirmed by the questionnaire itself. People were asked to mark the location of their homes with a cross in a map. It turned out that many crosses were far away from the correct location. This leads to the conclusion that people often have difficulties to read and understand maps.

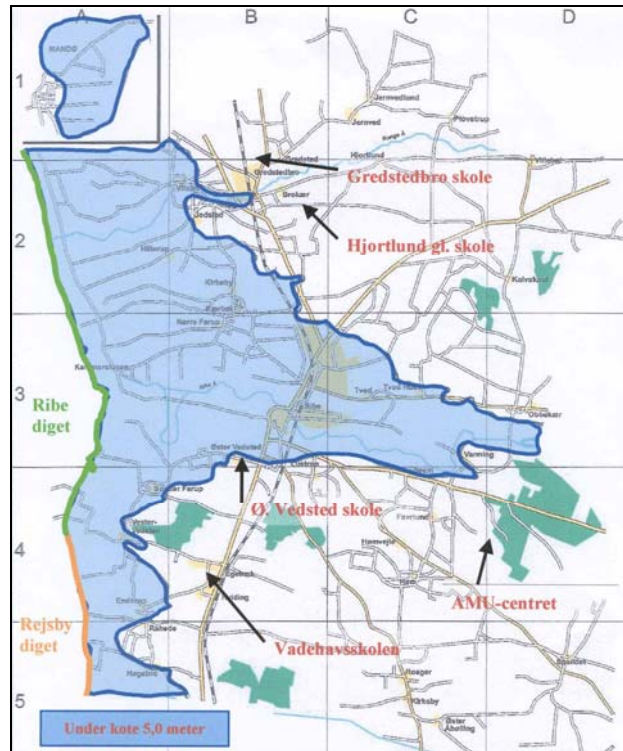


Figure 5-15: Flood prone area in Ribe
(Source: <http://www.ribekommune.dk/page522.asp>)

The information that people have about the risk of storm floods in their own region appears to be insufficient to prepare them for a possible disaster. Apparently, people know about the risks, but are not fully aware of the consequences or do not know what to do or how to prepare appropriately. Information may not be understood or reflected concerning all details.

Question R6a: Have you ever taken personal measures to be generally prepared for a storm flood?

There is a large gap between risk perception and the resulting actions which people take. Only 7% of the respondents answered yes to the question whether they would take protective measures (cf. figure 5-16, table 5-13). A cross table of questions R2 and R6 respectively the assumption, that personal experience would influence the degree of preparedness, does not show any correlation. This emphasises the results of earlier studies (BAKER & PATTON, 1974; MOLINE, 1974). The experience of a dike breach or the awareness of living in the flood-

prone area does not automatically lead to precautionary actions. This missing willingness to act is due to the so called probabilistic risk perception. Although the danger is recognized and perceived, the event is considered to be arbitrary and therefore accepted. This acceptance is correlated with a transfer of charge to another responsible entity (Act of God-Syndrome).

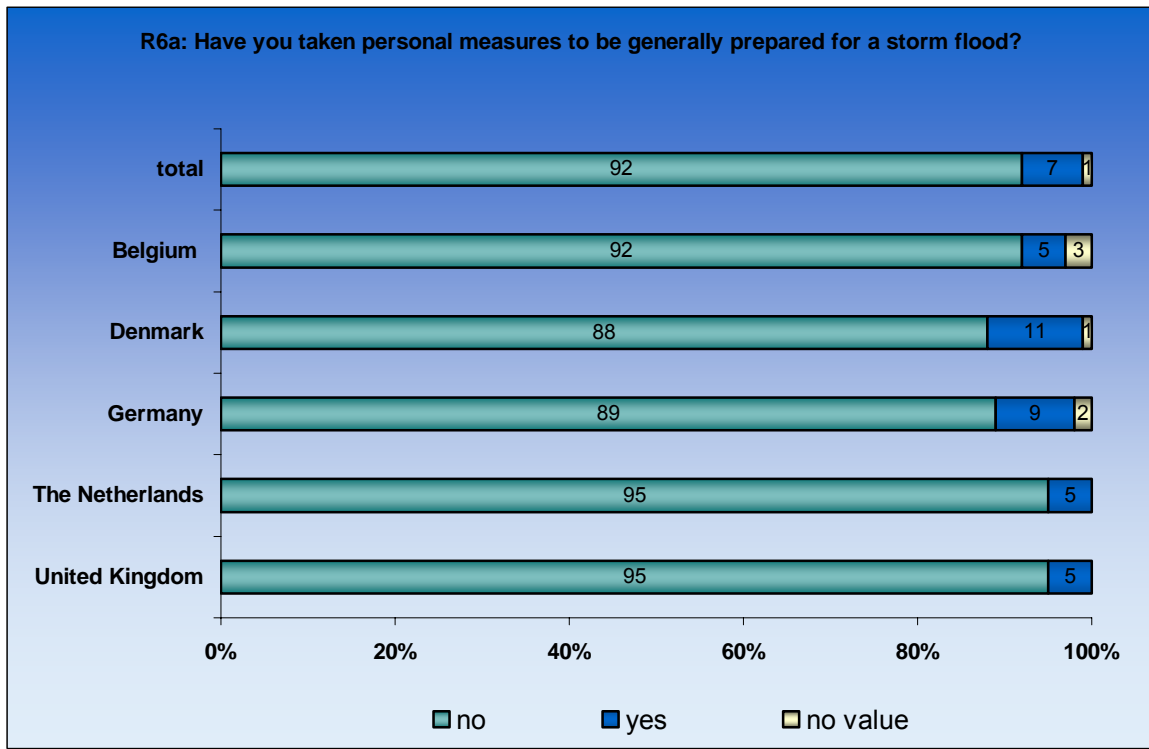


Figure 5-16: Question R6a: Have you ever taken personal measures to be generally prepared for a storm flood?

Table 5-13: People who are generally prepared for a storm flood in the different study areas

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
no	92	88	89	95	95	92
yes	5	11	9	5	5	7
not valid	1	0	0	0	0	0
no answer	3	1	2	0	0	1

A cross table (cf. figure 5-17) of question R4: How high do you estimate the probability of a coastal flooding? and R6a: Have you taken personal measures to be generally prepared for a storm flood? shows that 90% of all persons who estimated the probability of a storm flood very high do not take any personal measures. Knowledge about a risk does not automatically lead to comprehensive understanding. SJOBERG (1999) confirms this; he notes that differ-

ences in perception cannot be explained by lack of knowledge alone rather perception is influenced by difficulties in understanding probabilistic processes, biased media coverage, and misleading personal experiences.

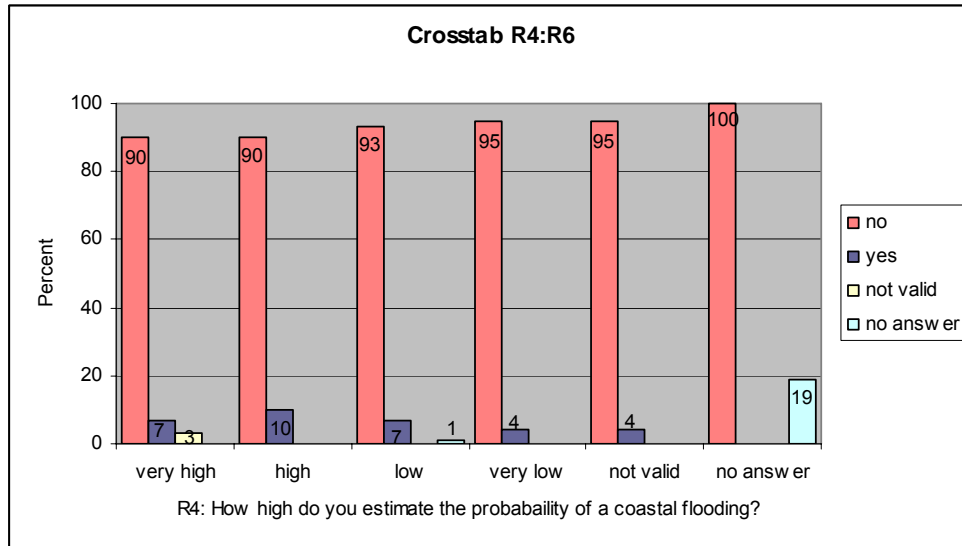


Figure 5-17: Cross table: R4: How high do you estimate the probability of a coastal flooding? and R6: Have you taken personal measures to be generally prepared for a storm flood?
 Symmetric measures: Interval by interval Pearson's R: 0.321
 Ordinal by Ordinal Spearman Correlation: -0.014
 N of valid classes: 411

Another result of the survey shows that a large part of those people who experienced a coastal flooding before do not take any personal measures. This is due to the motivational decay: as time passes, people tend to forget, personal experience loses its significance. BAUMANN & SIMS (1987) mention that oblivion begins as early as about 6 months after an event. This leads to the fact that after 15 years, the remembrance is vanished in a way that decisions are no longer influenced by former experience.

Question R6b: If you answered yes in question R6a, what kind of measures have you taken to be prepared for a storm flood?

The answers to question R6b show, that of those 7% who take personal measures the most mentioned "settlement outside the flood-prone area", "protection of the building", and the "availability of emergency equipment" (cf. figure 5-18). As question R6b was an open question, the results were categorized afterwards. Individual answers such as "insurance" reveal the misinformation of some respondents, because insurances do not cover natural disasters. The lack of information is further highlighted by the fact that many respondents who actually live in flood-prone areas do not think they do.

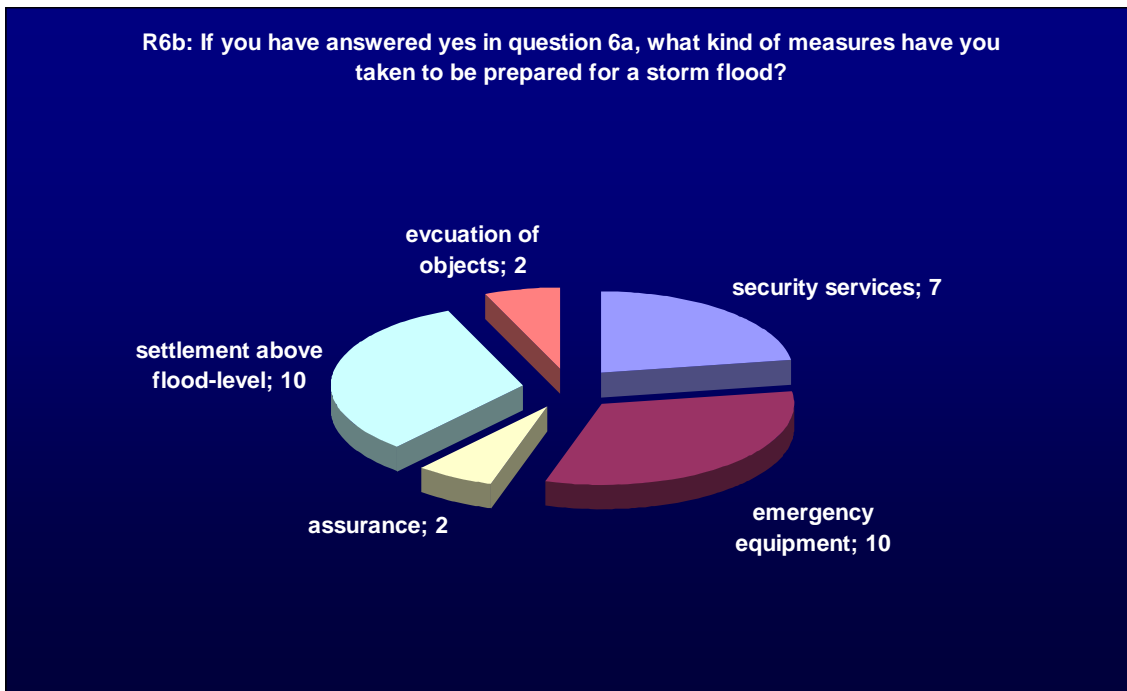


Figure 5-18: Question R6b: If you answered yes in question R6a, what kind of measures have you taken to be prepared for a storm flood?

Question R7a: In your opinion is there sufficient protection against storm floods?

56% of the respondents in Belgium and 45% in Germany and the Netherlands believe that they are not sufficiently protected against storm floods (cf. figure 5-19). In Denmark, 93% of the respondents are satisfied with the protection. This satisfaction may be caused by the fact that 68% of the respondents (falsely) think, that they do not live in a flood prone area (cf. figure 5-19, table 5-14). This feeling of safety may be emphasized by the fact that the storm surges in recent years spared the town of Ribe. In Oostende, 56% of the people were not satisfied. From the comments given at the end of the questionnaire, it became clear that there is a controversial discussion about the coastal defense situation in the town of Oostende.

The contentedness of the inhabitants with the coastal defense situation relates to the trust in the authorities and politics.

The trust in actual politics and authorities in turn is crucial in case of an emergency and when targeted advice is decisive about the dimension of a disaster. Yet even in the long run, mutual trust is of importance for planned adaptation and to afford sustainable development. The evaluation of the actual coastal defense situation is of course strongly related to a sufficient information level of the society.

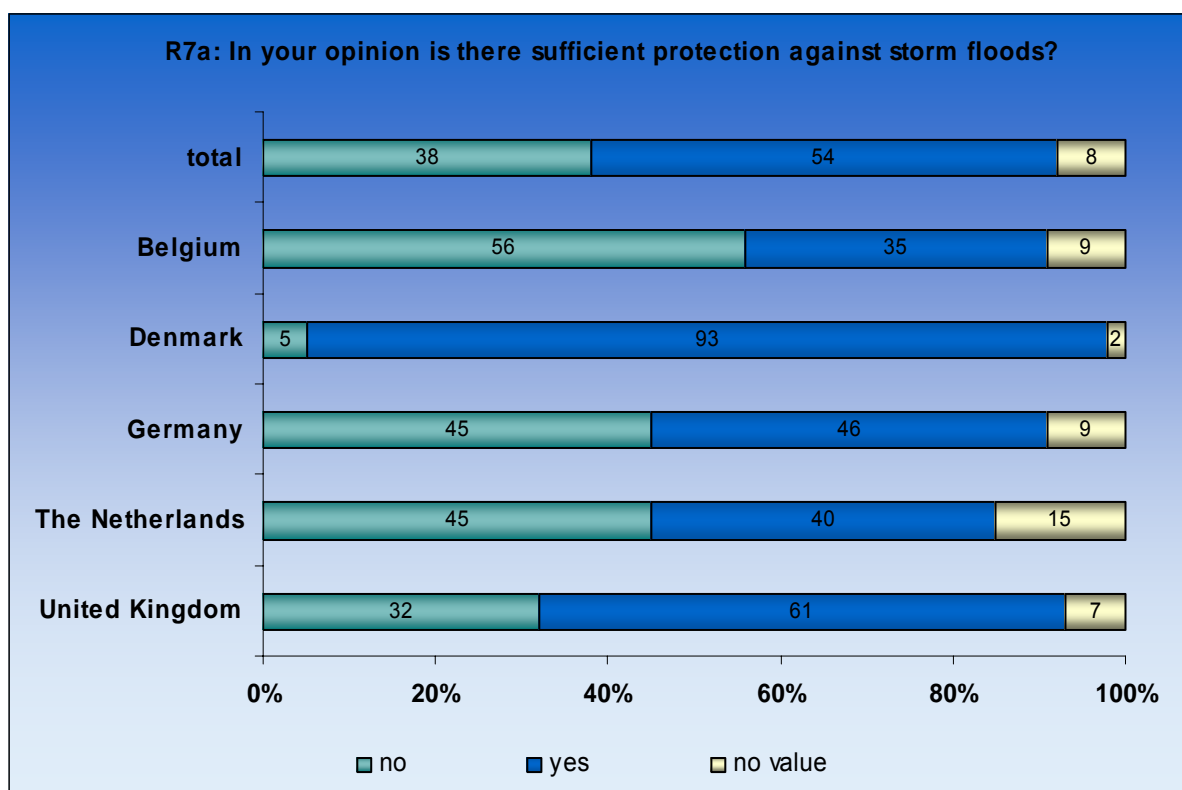


Figure 5-19: Question R7a: In your opinion, is there sufficient protection against storm floods?

Table 5-14: Country specific satisfaction with protection against storm surges

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
no	56	5	45	45	32	38
yes	35	93	46	40	61	54
not valid	2	0	4	0	0	1
no answer	7	2	5	15	7	7

Question R7b: If you have answered no in question 7a, in your opinion, how could the safety in case of a storm flood be improved?

Most of the respondents who had answered no in the previous question asked for more information or an improved disaster plan. Especially in Belgium and in the Netherlands, people seek more and better information than they receive. It must be noted that this question was open, i.e. the respondents had to give their own answers. The answers were grouped and categorized afterwards (cf. figure 5-20, table 5-15).

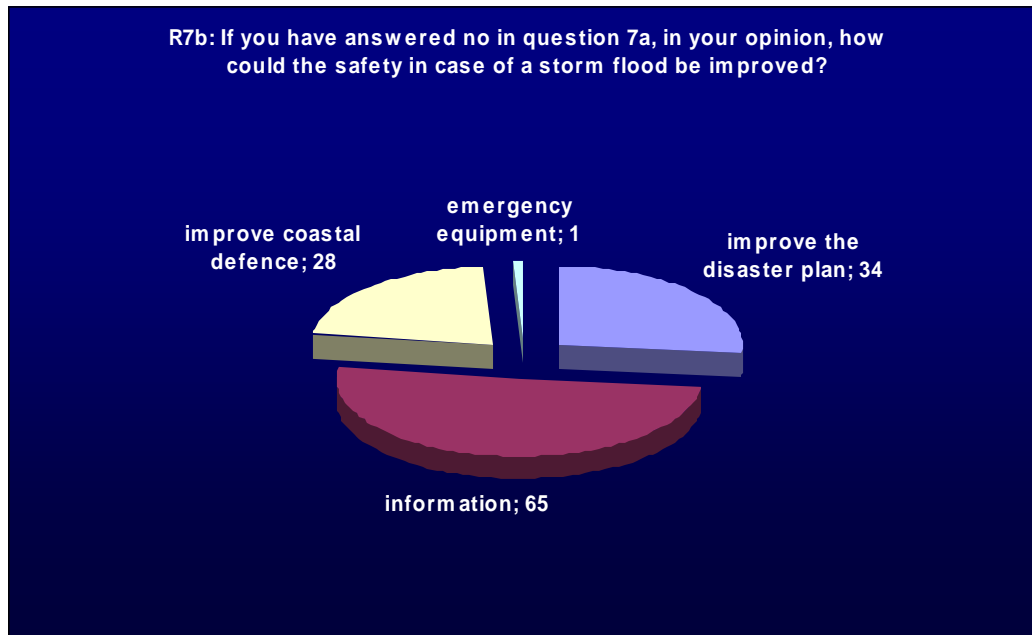


Figure 5-20: Question R7b: If you have answered no in question 7a, in your opinion, how could the safety in case of a storm flood be improved?

Table 5-15: Country specific statements about options to improve safety

answer	Belgium (freq.)	Denmark (freq.)	Germany (freq.)	Netherlands (freq.)	United Kingdom (freq.)	Total (freq.)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
improve the disaster plan	12	0	11	8	3	34
information	28	3	11	20	3	65
improve coastal defense	18	1	4	2	3	28
emergency equipment	0	0	0	1	0	1
no answer	52	85	59	51	36	283

Question R8a: Do you know what to do in case of a coastal flooding?

Almost two third of the respondents said they do not know how to react to a flood event. It is obvious, that concerning this matter, there is an information deficit not only with regard to possible reactions in case of an emergency, but also with regard to flood risk, personal concernment, as well as personal preparedness.

With 78%, Belgium has the highest percentage of people not knowing what to do in case of a storm surge. Germany (65%), the United Kingdom (64%) and the Netherlands (56%) follow closely behind. The only region, where a majority of the people feels sure about what to do in case of a coastal flooding is Denmark (cf. figure 5-21, table 5-16). The fact that 66% of the people in Ribe answered yes, probably reflects the effect of the information distributed to the

households through leaflets. These brochures contain a map of the flood-prone area and instructions how to behave in case of a coastal flooding. This information, however, has to be improved, keeping in mind that 68% of the people mistakenly believed that they do not live in a flood-prone area.

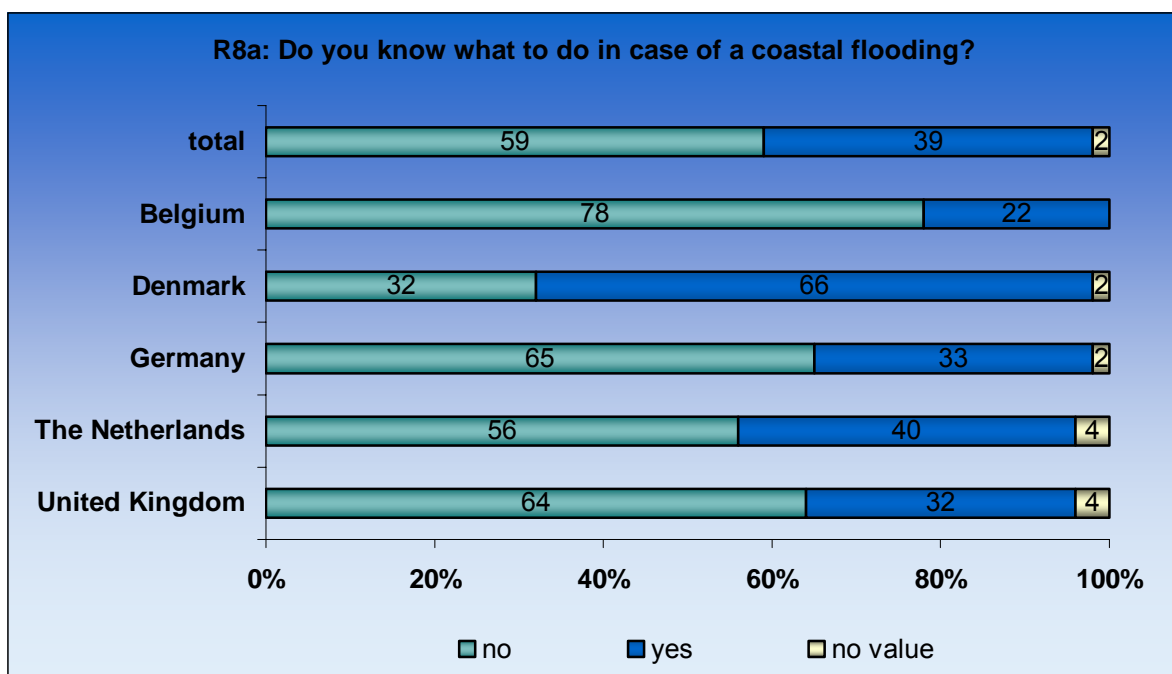


Figure 5-21: Question R8a: Do you know what to do in case of a coastal flooding?

Table 5-16: Country-specific statements about the preparedness

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
no	78	32	65	56	64	59
yes	22	66	33	40	32	39
no answer	0	2	2	4	4	2

Question R8b: If you have answered yes in question R8a, what exactly can you do to protect yourself in case of a coastal flooding?

This additional question revealed that most of people who know what to do in case of a coastal flooding stated “leaving the area” as the preferred option (cf. figure 5-22), followed by “go to higher floors” and “wait for help/warning”.

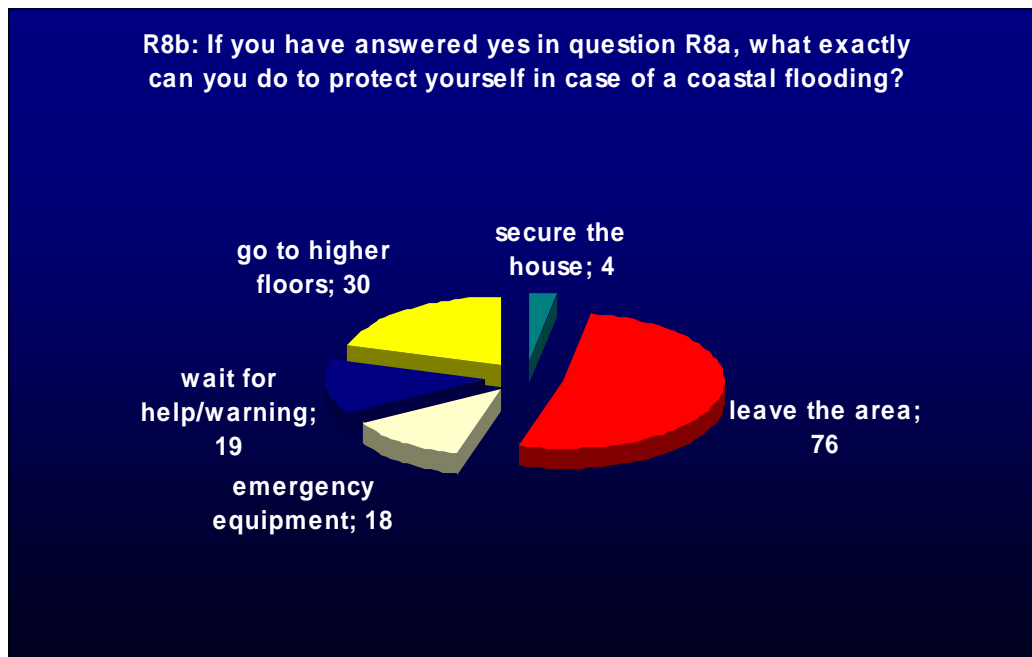


Figure 5-22: Question R8b: If you have answered yes in question R8a, what exactly can you do to protect yourself in case of a coastal flooding?

Question R9: How well have you been informed about the basic risks of a storm flood by the responsible authorities?

As R9 (cf. figure 5-23, table 5-17) reveals, in total nearly two third of the interviewees state that, in their point of view, the information they received from the authorities is not sufficient. Although the authorities in all five regions provide some kind of information, it can be assumed that this is not comprehensive enough or cannot be communicated in a comprehensible way. Denmark is the only region where the trend of the answers is positive. In Ribe, 79% of the respondents feel well or very well informed. In the other countries, more than half of the respondents feel informed insufficiently – especially in Belgium, where 86% of the respondents were not satisfied with the information level provided. This significant difference might be the result of a rather broad information policy in Denmark. On the other hand, the low percentage of people (14%) in Belgium who feel well or very well informed might reflect the ongoing public discussion of coastal protection measures. Controversial discussions often lead to discord and uncertainty among the people concerned.

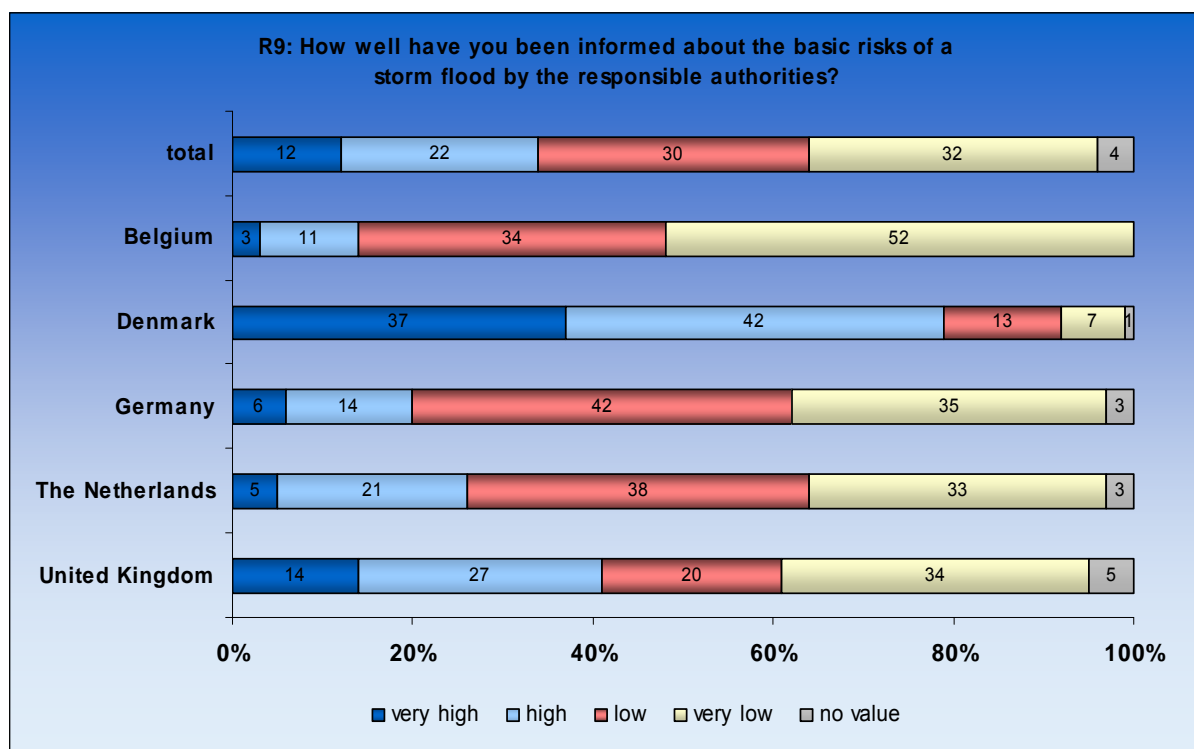


Figure 5-23: Question R9: How well have you been informed about the basic risks of a storm flood by the responsible authorities?

Table 5-17: Assessment of authorities' information policy in the different study areas

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
very high	3	37	6	5	14	12
high	11	42	14	21	27	22
low	34	13	42	38	20	30
very low	52	7	35	33	34	32
not valid	0	0	0	1	0	0
no answer	1	1	3	2	5	4

Question R10a: Do you know how to get precautionary information about your own protection in case of a storm flood?

The answers to this question confirm the tendency mentioned above. The only country, where the majority (65 %) answered yes is Denmark. In total, 60% of the respondents do not know where to obtain information. Especially in Belgium, a lack of information is stated by a vast majority of 84% (cf. figure 5-24, table 5-18).

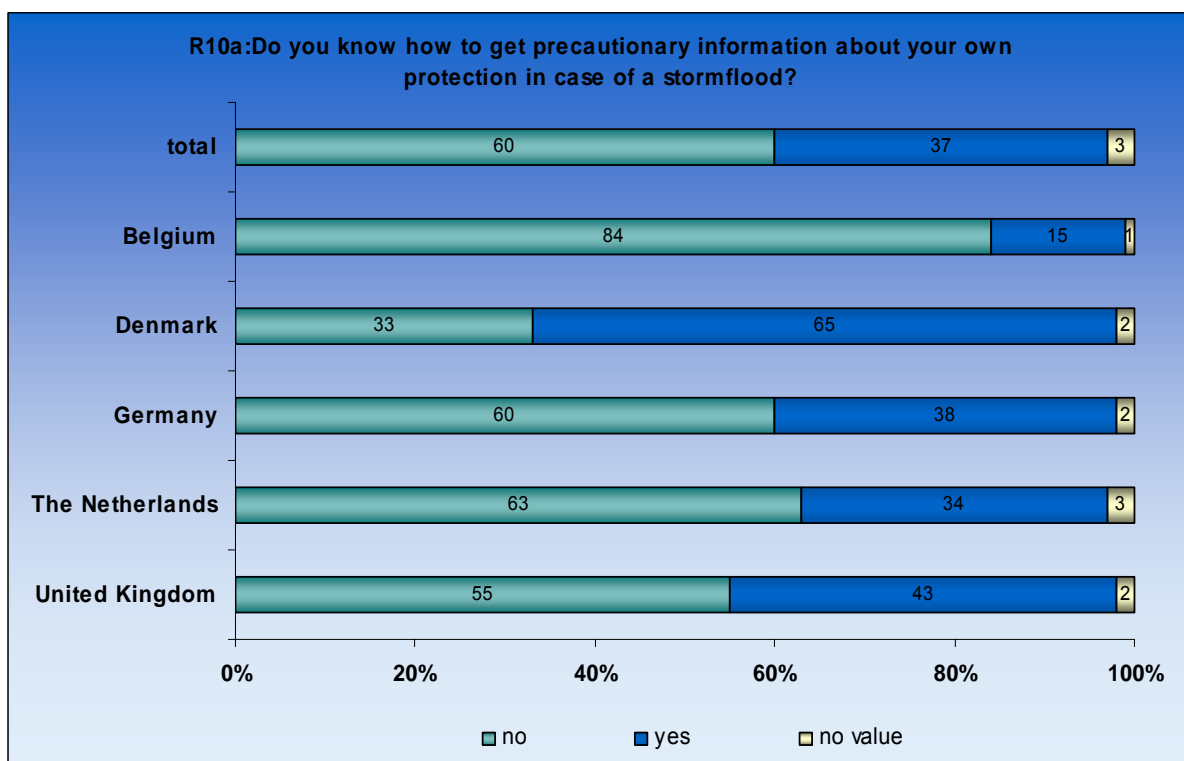


Figure 5-24: Question R10a: Do you know how to get precautionary information about your own protection in case of a storm flood?

Table 5-18: People’s knowledge how to get information about self-protection in the different study areas

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
no	84	33	60	63	55	60
yes	15	65	38	34	43	37
not valid	0	1	1	0	0	1
no answer	1	1	1	2	2	2

Question R10b: If you answered yes in R10a, where do you get the information from?

The results in figure 5-25 show that the most relevant sources of information for the people are radio and television broadcast. *Authorities* and *prevention/fire brigade* play a less important role. The internet was not mentioned as a commonly used source of information. It appears, however, that some respondents who marked “authorities” might use the websites of local or regional governments in order to obtain information. Radio and TV might be useful to inform about flooding in general and contribute to raise the awareness, but they are definitely not the appropriate tool to obtain information about precise protective measures. This is

again a sign of an information deficit. In spite of these findings, the internet opens up more possibilities to inform people in the future.

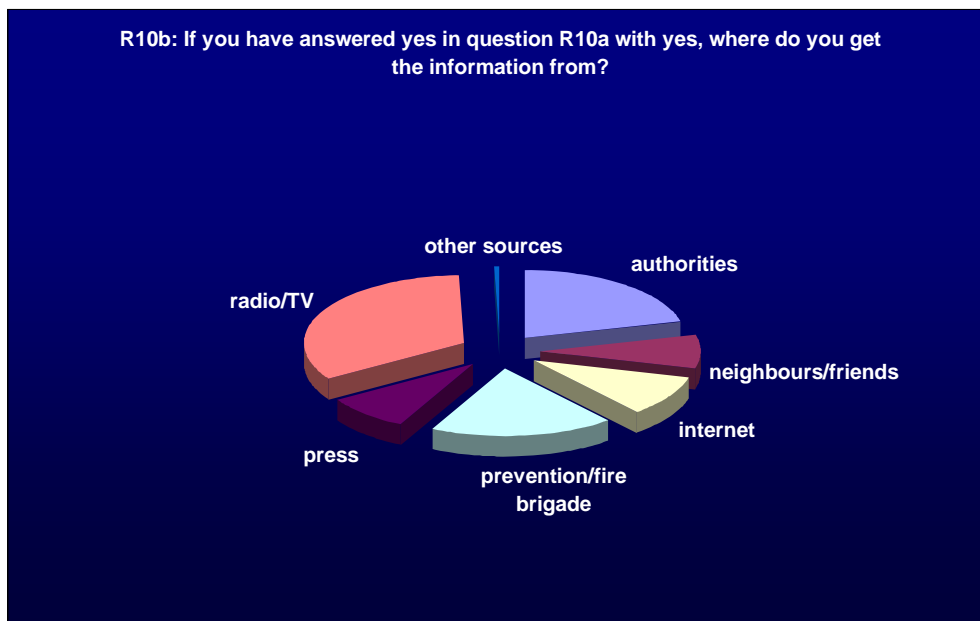


Figure 5-25: Question R10b: If you answered yes in R10a, where do you get the information from?

Question R11: Do you feel personally endangered by a sea-level rise, induced by the global climate change?

The answers to question R11 reveal that 36% of all respondents feel at risk by a sea-level rise, caused by global climate change. This indicates that at least a part of the people seems to be well informed about the actual climate change discussion. The greater part is either not aware of the risks and consequences of climate change, seeing the risk as something that lies in the far future, or trusts in coastal defense structures and activities (cf. figure 5-26, table 5-19).

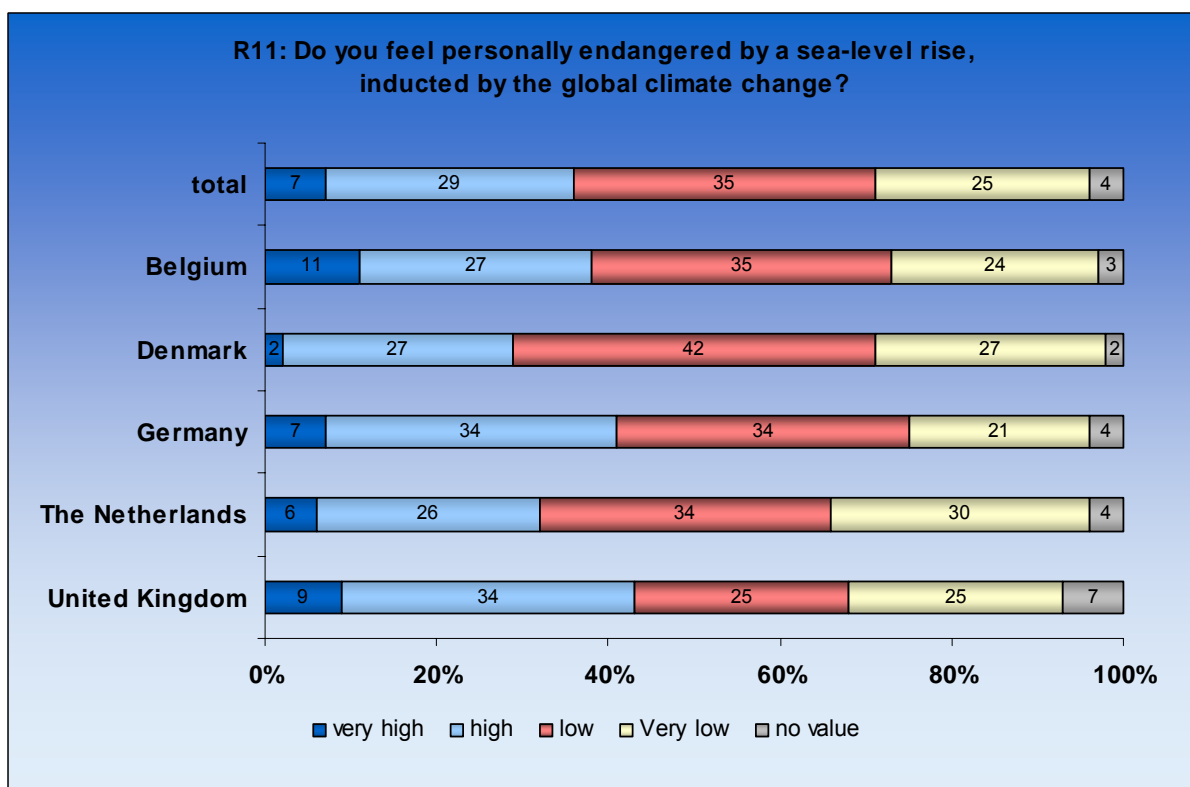


Figure 5-26: Question R11: Do you feel personally endangered by a sea-level rise, induced by the global climate change?

Table 5-19: Estimation about personal risk of sea-level rise in the different study areas

answer	Belgium %	Denmark %	Germany %	Netherlands %	United Kingdom %	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
very high	11	2	7	6	9	7
high	27	27	34	26	34	29
low	35	42	34	34	25	35
very low	24	27	21	30	25	25
not valid	0	0	2	1	0	1
no answer	3	2	2	3	7	3

Question R12: How high do you estimate the influence of a sea level rise on the danger of a storm flood?

In total, 50% of the people interviewed estimate the influence of sea-level rise high or very high, with a very high percentage (60%) in Germany. In the Netherlands, however, a majority of the respondents (57%) consider the SLR influence low or very low. To a certain extent, the high safety standards in coastal defense in the Netherlands (based on a 1-in-10,000 year flood event) may explain this deviation (cf. figure 5-27, table 5-20).

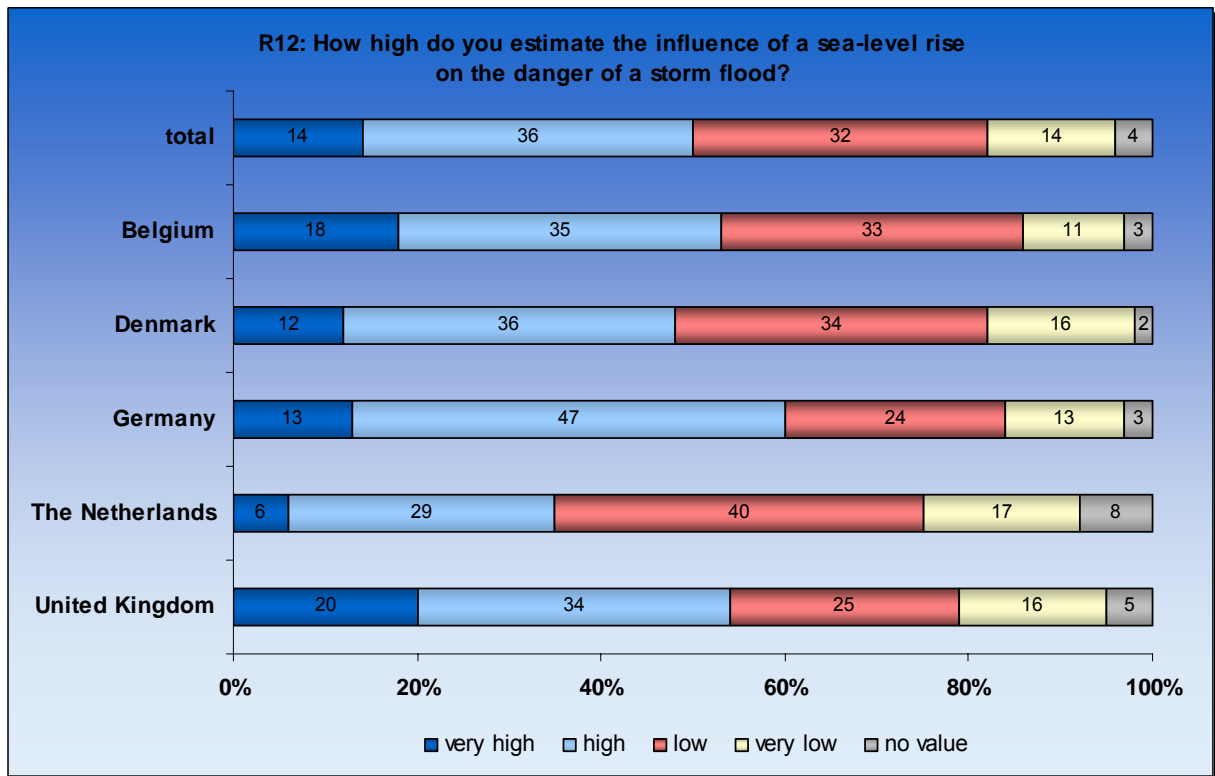


Figure 5-27: Question R12: How high do you estimate the influence of a sea level rise on the danger of a storm flood?

Table 5-20: Country specific estimation about influence of sea-level rise on risk of storm surges

answer	Belgium (%)	Denmark (%)	Germany (%)	Netherlands (%)	United Kingdom (%)	total (%)
	n = 110	n = 89	n = 85	n = 82	n = 45	n = 411
very high	18	12	13	6	20	14
high	35	36	47	29	34	36
low	33	34	24	40	25	32
very low	11	16	13	17	16	14
not valid	0	0	2	2	0	1
No answer	3	2	1	8	5	3

Analyzing the results of the public survey on risk perception and information, it can be concluded that the perception of risk is not well developed in the whole North Sea Region and has to be improved. Concerning the comparison of the five countries, the results are very homogeneous. However, in some aspects they show some significant differences.

As there were different spatial conditions in the areas of investigation, some constraints had to be made. These are important to keep in mind when interpreting the results. These differences are due to political and planning conditions.

One precondition which was different in the areas of investigation is the size and structure of the community. St. Peter-Ording, Gemeente Sluis, and Skegness are tourist resorts with sandy beaches and dikes/sea walls, which are dominated by sea-side tourism and a high percentage of seasonal inhabitants. Ribe lies at the Wadden Sea Coast, without beaches, 6 km from the sea (although flood prone). Oostende is a big town, with complete infrastructure and sea-side tourism. These differences were taken into account by not interviewing tourists as “part time citizens”, because they might have a different awareness concerning flood risk. Only households with permanent inhabitants were selected.

The most decisive difference among the areas of investigation was on political and planning level, because the areas were selected with regard to national demands. The survey revealed for example, that the results in Oostende were strongly influenced by ongoing public debates on coastal defense, causing significant problems comparing the data from Belgium with the other areas. The strongly diverging, somehow “freakish” results of Oostende indicate a temporarily increased level of awareness and emotions among the inhabitants, leading to answers expressing their discontent with the situation.

It is supposed that people, who have experienced a severe storm flood, are all the more aware of the risk, which also implies a different risk perception. This assumption could not be confirmed. In total 62% of the respondents experienced a storm flood before – with a wide range from 83% in Denmark to only 11% in the UK. These different experiences do not fit with the perception results. Thus, in these particular study areas no correlation between the personal experience and the perception could be observed.

It turned out that a huge information deficit exists in three main categories, partly due to lacking information given by the authorities, and partly due to disregard or misinterpretation by the inhabitants. First of all, many people are not aware of the risk, not to mention the possible consequences. 67% of the public estimates the flood risk low or very low and 30% of the respondents thought that their house could not be hit by the floodwater in case of a coastal flooding (questions R4 & R5). This appears to be a high ratio considering that all the respondents actually live in the flood-prone area. Furthermore, the majority (60%) do not know how they can protect themselves or their property against flooding and where they can get information concerning this matter (question R10a). The third category is concerned with the case of emergency. In total, 59% of the respondents said they do not know what to do in case of a flooding event (question R8a).

Regarding the people who stated to be informed, it turned out that the information was wrong or insufficient. Hence, the proportion of appropriate informed people is in fact lower than the quoted rate.

The survey reveals that despite knowledge about risks and climate change, the level of information is not sufficient to inform people in the right way. People demand for more information from the authorities. This information should comprise information about the actual risk, possibilities to personal preventive measures, as well as guidelines on how to behave in case of an emergency.

A general conclusion that could be drawn from the survey at hand is that risk management in the North Sea Region is increasingly confronted with a loss of trust by society as well as disenchantment with politics. Trust in the authorities is important, especially in case of an emergency where target-oriented and quick action is necessary, so that information politics and an involvement of stakeholders and the public in the risk management process will be indispensable.

5.8 Conclusions

In chapter 5.1, an integrated framework covering the full range of impact categories of coastal vulnerability has been outlined, facing the challenge to merge natural and social science. According to this framework, a system's vulnerability is a function of exposure (natural vulnerability). Its social, economic, and ecological characteristics and its socio-economic and ecological resilience all have to be evaluated to determine the total vulnerability and to estimate the residual risk that has to be managed.

In this thesis a special focus is on the evaluation of the role of risk perception as an indicator for the resilience of the social system.

The results of the study in the North Sea Region showed that there exists a vulnerability factor with regard to risk perception. Risk perception strengthens the resilience of a society as it is influencing the degree of preparedness and pro-active activities.

A lack of risk perception and awareness may lead to disastrous effects above average.

The perception of risk makes people act in specific ways before, during, and after a disaster, and even with regard to long-term sustainable management. A lack of risk awareness influences the vulnerability of a coastal zone, either by people settling in flood-prone areas or by malpractice in case of an adverse event.

As the COMRISK project had the aim to develop trans-national risk management strategies, the investigation on risk perception to flood risk was the first one conducted with an international approach in the North Sea Region. The results of the survey, together with expert

judgement and literature review, lead to various general conclusions concerning risk perception.

The degree of risk perception is essentially defined by knowledge, information, and experience, as pre-experience enhances the awareness of problems and the readiness for corresponding action. Personal experiences with hazards often lead to the opinion that damages are avoidable through personal measures, whereas this is normally considered as a task for the responsible institutions and authorities. Furthermore experience is a function of time, especially in case of very rare events. Young generations often possess only minor knowledge about natural hazards, while elderly people have in most cases experienced at least one extreme event. The results of the survey in the North Sea Region show that personal experience with extreme events as well as the time passed since the event significantly influences the perception of risk. Contrary in the survey, an apparent correlation between the experience of a disaster and the behaviour concerning precaution against the risk of storm floods could not be concluded. Although people are partly aware of the risk or have experienced a coastal flooding, this does not improve their willingness to prepare themselves or take precautionary measures. Furthermore, the knowledge about risk does not automatically lead to a realistic estimation of personal concernment. No obvious correlation can be evaluated between the personal experience and the preparedness (question R2 & R6a), due to the fact that only 7% of the respondents have installed protective measures at all.

Comparable results were gained through a study on cyclone disaster preparedness in India after the cyclone in 1999, killing 10,000 people (THOMALLA & SCHMUCK, 2004). Even if people knew that a severe cyclone was approaching, they often did not react appropriately. Some misunderstood the warning and some mistakenly felt safe, because they did not consider their home to be threatened. Only a minority took countermeasures.

In recent times, the hurricane *Katrina* in New Orleans dramatically proved that the knowledge about hurricanes, their possible consequences, and even the forecast of the exact time of arrival do not automatically lead to adequate behavior of the concerned in case of a disaster.

There is a close correlation between risk perception and socio-demographic factors. Although this could not be verified in the case study in the North Sea Region, it is generally assumed that men and women behave differently. Also, the age of the perceiving person has a noticeable influence on risk perception. Older people perceive risks more intensely. They normally have a more comprehensive knowledge concerning the hazards, but are less willing to change their attitudes. In addition the assumption exists that younger people assess those risks higher which threaten their own life or property, whereas the older generation rather assesses global risks higher.

An essential feature in the perception of individuals and even societies are predominant cultural factors that lead to pronounced intercultural differences between societies and sub-civilizations within a society. Cultural values and differences strongly influence policy making and therewith the structure of planning and management processes.

Although integrated vulnerability assessment - including social, economic, and ecological features as well as a systems capacity, i.e. its resilience - is necessary to make a holistic and realistic estimation of the risks and the vulnerability of a region, there are some substantial constraints:

- Natural and social data are difficult to merge due to different data types and temporal scales. Despite increasing know how and technical possibilities there are still uncertainties in climate change prognosis and resulting impacts, especially on local level. Furthermore there are additionally by far more uncertainties about future socio-economic changes. The most climate impact prognoses are made in a time frame of about 50 to 100 years, a time frame in which societies are changing dramatically and in an unpredictable way.
- The availability of data is a limited for integrated assessment, because data are not available in the same quality and on the same scale. Often there is a total lack of data, or data are not easily assessable.
- Integrated assessment needs interdisciplinary know how. Different scientific disciplines are urged to merge different methods and conceptual thinking. More, they have to share the same "language", a problem that strongly inhibits common approaches.

Due to these constraints, the selection of indicators for a special purpose in a specific area is crucial, as the indicators must be comparable to weight them for index building. Nevertheless, it is meaningful to reduce the amount of indicators and instead to insure that all impact categories (social, economic and ecological) are involved and the resilience factor is taken into account. A differentiated consideration of the coastal functions requires integrative assessment because a sectoral perspective is insufficient as a coastal region rarely faces only one stress at the same time. Instead, an interdisciplinary approach is necessary to understand impacts on social, economic and ecological systems, to comprehend the functions and relations between them to finally get response strategies and management working successfully.

6 Operationalisation of risk management by quantitative vulnerability assessment – synthesis and outlook

The risks today's society is exposed to can not be eliminated, they have to be managed.

SMITH, 2005

As coastal risks are assumed to increase in the future, current hazard response and adaptation strategies have to be reviewed or changed. Heavy coastal disasters in the last years have shown that despite sophisticated scientific knowledge about natural hazards and their impacts, there are deficits in current risk management.

Since vulnerability is deciding upon whether and to what degree a natural hazard turns into a disaster it is the prior aim of hazard reduction strategies to reduce vulnerability. Vulnerability changes continually with time. Changes are related to those factors which can augment it, reduce it, or maintain it in that state.

In this thesis a conceptual framework is designed to define, characterize and evaluate vulnerability at different scales, from the local to the global level. It became clear that vulnerability needs to be understood in a wide context including interdisciplinary sectors and components.

Numerous existing approaches, methodologies, and tools to assess coastal risks provide clearly proof for the existence of coastal vulnerability and that it will increase under changing climate and socio-economic conditions. What is not that clearly answered by vulnerability assessment, however, is the question most central to the reduction of risks in coastal zones: *What is to be done and where?* Thus, this is the question that has to be answered to enable politicians and coastal managers to make decisions about response measures.

The FAO (2004) states, "the biggest improvement in risk management can be achieved by targeting on the vulnerabilities of the coastal communities". Thus to be useful, vulnerability assessment must produce information that can be used to initiate or optimize coastal risk management. As vulnerability assessment is predominantly scientifically based, whereas risk management is in the duty of governmental decision making, it is of importance to link vulnerability assessment to the prevailing administrative conditions and planning projects. Only in doing so, the outcomes can be translated into decision making.

Vulnerability assessment can bridge the gap between science and policy by a transfer of knowledge to promote an overall understanding of risk pathways and the issues of risk management.

6.1 Risk management

Risk management is a very expansible term which comprises all activities that enable a region or community to cope with risks. It is the process of using administrative decisions and operational skills to implement policies, strategies, and coping capacities to enable a system to function at present and in the future despite disturbances. This comprises structural and non-structural measures to avoid or to limit adverse effects of hazards and to promote sustainable development.

In coastal risk management, all information about the probability, the impacts, and the evaluation of a specific risk are combined to develop the necessary prevention strategies and measures. Many technical, administrative, and political interests are combined. So, it is required to involve a large range of aspects, interest groups, and information. It aims at either changing the flood probability, e.g. by a change in coastal defense measures or at reducing the flood impacts by capacity building, awareness raising, or changing land use.

Risk management to natural hazards is more complicated than to many other risks. The main characteristics of natural hazards that hamper management are (HOLLENSTEIN, 1997:55):

- Difficult to circumscribe: Natural hazards are permanent processes (e.g. erosion), which first become dangerous if intensity increases.
- Barely possibilities to control them on local level: The adverse impacts are the outcome of regional processes, which are influenced by global mechanisms.
- Difficult to determine the sources of hazards and risk: Natural hazards are of great spatial extension so that natural hazards are hardly to antagonize at the routes.
- Complex effects: natural hazards, due to dynamic and longlasting effects lead to impacts on values which are hardly to determine. Direct, mechanical impacts are better known.
- Place-based: Every space and region has its own natural and human elements which are difficult to compare with regard to risk management strategies.

So far, adaptation to flood risk has been dominated by the construction of technical measures such as dikes, sea walls, or beach nourishment. Now, it is increasingly recognized that technical measures alone will not be sufficient to protect future generations and to allow sustainable development. Not at least the flood disaster in New Orleans showed that technically high de-

veloped countries can be subject to sea defense failure and human malpractice. To guarantee a more holistic acquaintance with current and future risks there has been a shift from the technical and physical oriented adaptation and protection to integrated risk management. This integrated risk management includes more societal factors and has a close relation to policy making and coastal management.

According to CARDONA (2003) risk management involves:

risk identification (including individual perceptions, social representations and objective assessment), risk reduction (prevention/mitigation), and disaster management (response and recovery).

The UNDP (2002) distinguishes anticipatory, compensatory, and reactive risk management.

Anticipatory risk management means to ensure that future development reduces rather than increases risk, e.g. by reducing the probability of flooding by sea defense or by emergency strengthening.

Compensatory risk management comprises actions to mitigate the losses associated with existing risk, e.g. controlling development in flood prone areas, infrastructural measures such as flood-prone buildings and crisis management, including early-warning and evacuation plans.

Reactive risk management means ensuring that risk is not reconstructed after disaster events by means of capacity building, recovery, preparedness to restore land and infrastructure, and compensation of damages.

(cf. figure 6-1)

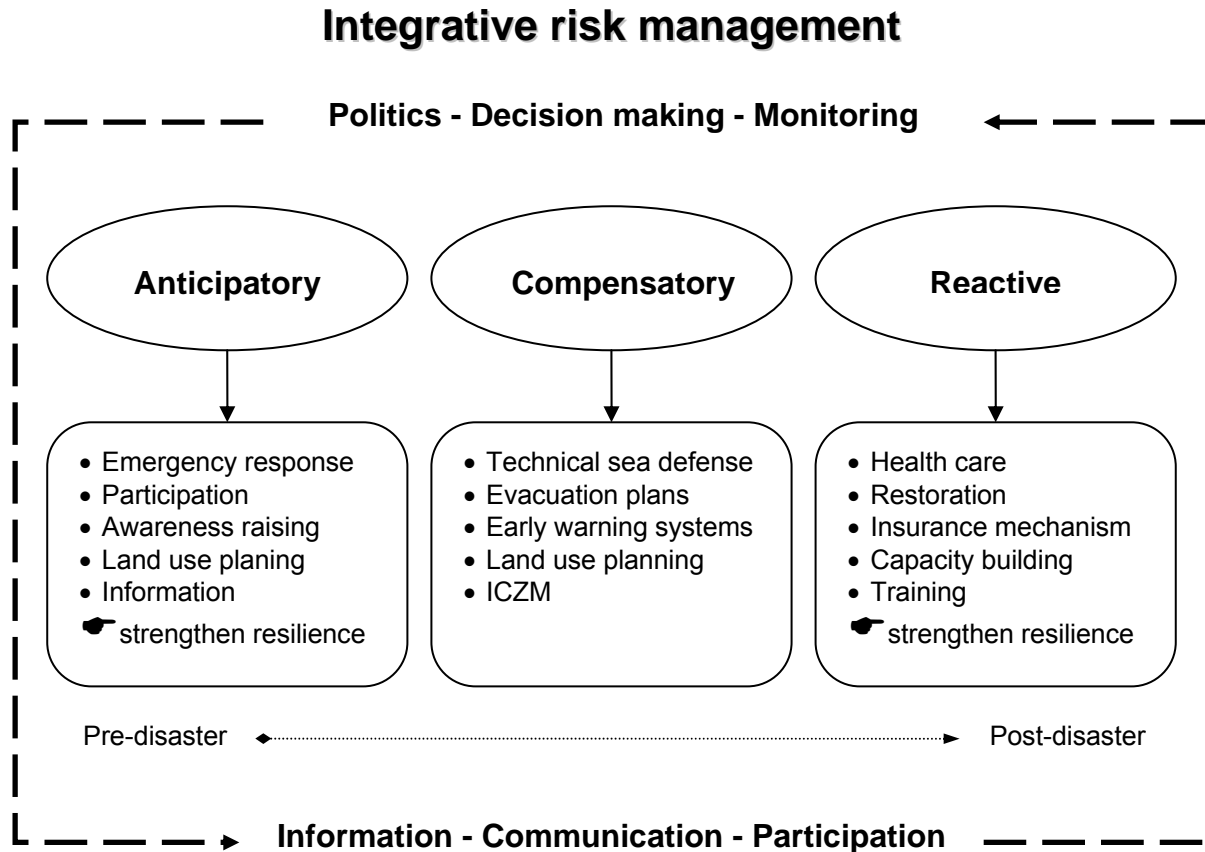


Figure 6-1: Integrative risk management

The aim of integrated risk management is not just to eliminate deficits in safety, but rather to incorporate the public actively in the management process. In so doing, the public is involved in the process of determining the acceptable risk. Risk management implies a renunciation from defensive hazard reduction to a more active and anticipatory handling. This means that complementary to “hard” coastal defense structures or structural management tools, integrative management strategies are developed, including also non structural management tools to mitigate the risk of coastal hazards.

Structural management tools include:

- engineering, dikes, and infrastructure,
- land use planning and management,
- building codes,
- insurance, and
- early warning systems.

Non-structural management tools include:

- communication, training, and information,
- programs to rise public awareness,
- active stakeholder involvement (participation),

- emergency response management, and
- plans for recovery, reconstruction and rehabilitation.

Both structural and non-structural tools comprise elements of pre- to post-disaster management. Preventive strategies in form of engineering and hard defense measures are adequate where the potential for disaster (e.g. storm surges) is very high. These structures are used to mitigate possible damages in form of “controlling” the sea by holding it back. Nevertheless there is always a remaining risk and a risk of failure, so that additional strategies such as early warning strategies have to be approved.

Apart from technical measures, a further preventive strategy is the strengthening of resilience. This means concretely to strengthen the people’s capacity to self-organize by means of adaptive and coping capacity. Capacity building programs teach the handling of disasters, the possibilities for adaptation, and the abilities to recover. A society that has a well developed capacity is better prepared and therefore more resilient.

Key elements of non structural risk management are thus information, communication, and participation. Here, the improvement of risk perception and the participation of the public in the planning process play a crucial role.

Participation means “the act of taking part or sharing in something” (The American Heritage Dictionary of the English Language). RENN ET AL. (1995) define participation as

“...forums of exchange that are organised for the purposes of facilitating **communication** between government, citizens, stakeholders and interest groups, and businesses regarding a specific decision or problem”.

The term participation obviously implies both **information** and active involvement.

There is no universal public participation method to support the decision-making in coastal management. Perhaps the best-known examination of public participation is *Arnstein’s ladder of citizen participation* (1969, cf. figure 6-2).

The crucial point of the Arnstein model is the idea that as involvement increases, there is a shift in power and resources to those involved in the participation. The model specifies eight levels of citizen participation that correspond to different purposes, ranging from manipulation of the public to citizen control of the decision making process.

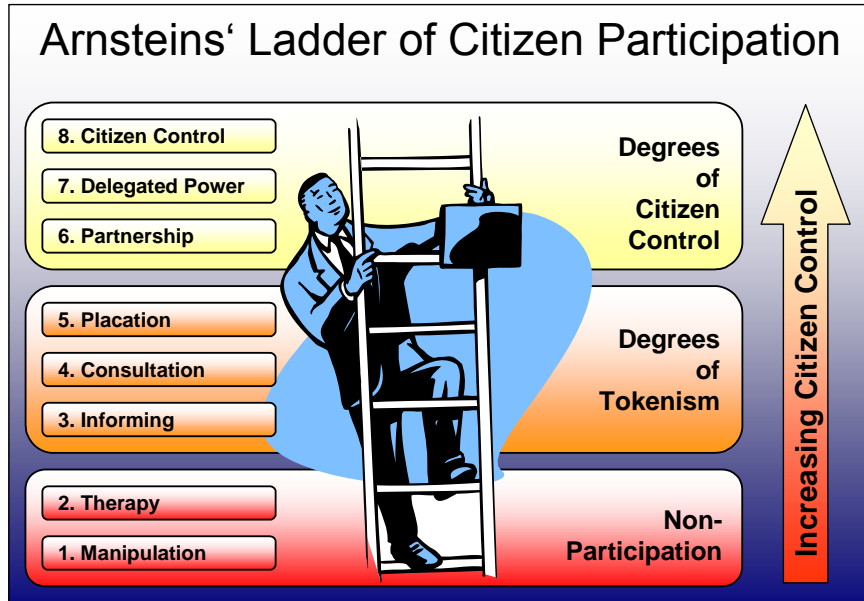


Figure 6-2: Arnsteins' Ladder of Citizen Participation (ARNSTEIN, 1969:218)

There is a range of theories of why participation might be important.

Participation is the key to sustainable development initiatives, since it will lead to:

- a greater sense of ownership on the part of the stakeholders,
- increased commitment to the objectives and outcomes,
- longer term social sustainability,
- increased self-help capacities, and
- stronger and more democratic institutions and partnerships.

The advantages are that the population participates in the development of their own environment. In the ideal case, the policy sullenness can be reduced through the experience of democratic procedures and the active involvement into the social system. This might improve the mutual trust between society and state and may also encourage people to permanently socio-politically engage themselves. In addition, participation can influence the quality of a planning process positively, because the authorities have to face the critical public. An accurate and fair participation allows a consensus. More, the participants identify with the results of the planning process. According to FÜRST ET AL. (2001), the responsibility is spread on a broad basis. This prevents people from pointing the finger in case of negative planning consequences. Another important aspect of participation is the gain of knowledge of all actors (FÜRST ET AL., 2001; HABEKOST, 1999). Besides the advantages, disadvantages ought to be mentioned. Most crucial deficits might include technically and organizationally excessive demands as well as the fear of conflicts on the part of the administration, a lack of communicative competence and independence of planning and administration, specific needs of af-

affected people which may not be recognized or interpreted correctly, and a long period between discussion and decision that might be discouraging.

There are manifold methodologies to help authorities or groups who seek participatory discussion with people. "Many have described it as a 'tool kit' of methods" (CUFF, 2001:17). Most of the methods are in fact quite simple in practice. Also, many of the techniques overlap in practice as elements from one technique are used in another. There is a vast number of participatory methods already described by TOOGOOD & CUFF (2000); WATES (2000); FAO (2004); ÖGUT (2004). Certainly, some methods are more appropriate for certain situations and certain types of stakeholder than others.

The meaning of participation in coastal flood defense was investigated in the North Sea Region in the framework of the COMRISK project (KAISER ET AL., 2004). A public and an expert survey were conducted in Belgium, Denmark, Germany, the Netherlands, and the United Kingdom to assess if participation is taking place and if it is wanted and used.

In this study, a range of participation tools were considered, compared, and evaluated concerning their practice in coastal risk management: Inquiry/survey, circular/leaflet, exhibition, press/local radio, internet, open council, discussion, excursion/field trips, referendum, advisory board, assembly, public hearing/meeting, ombudsman, project approval procedure, future workshop, citizen jury, working group, round table, workshop, citizen panel, strategic environmental assessment round table, mediation, consensus conference, cooperative discourse, advocacy planning, charrettes, open house, collaborative task force, nominal groups, focus groups, stakeholder analysis, information centers and field offices.

As the list of participation instruments is manifold and there are numerous differences between the countries, a selection had to be made for the investigation in the North Sea Region before compiling the most common instruments and those who actually exist in all five countries. A set of 21 more or less common instruments were identified. In an expert survey, these instruments were evaluated.

As a result figure 6-3 gives the most important information and participation tools for coastal defense.

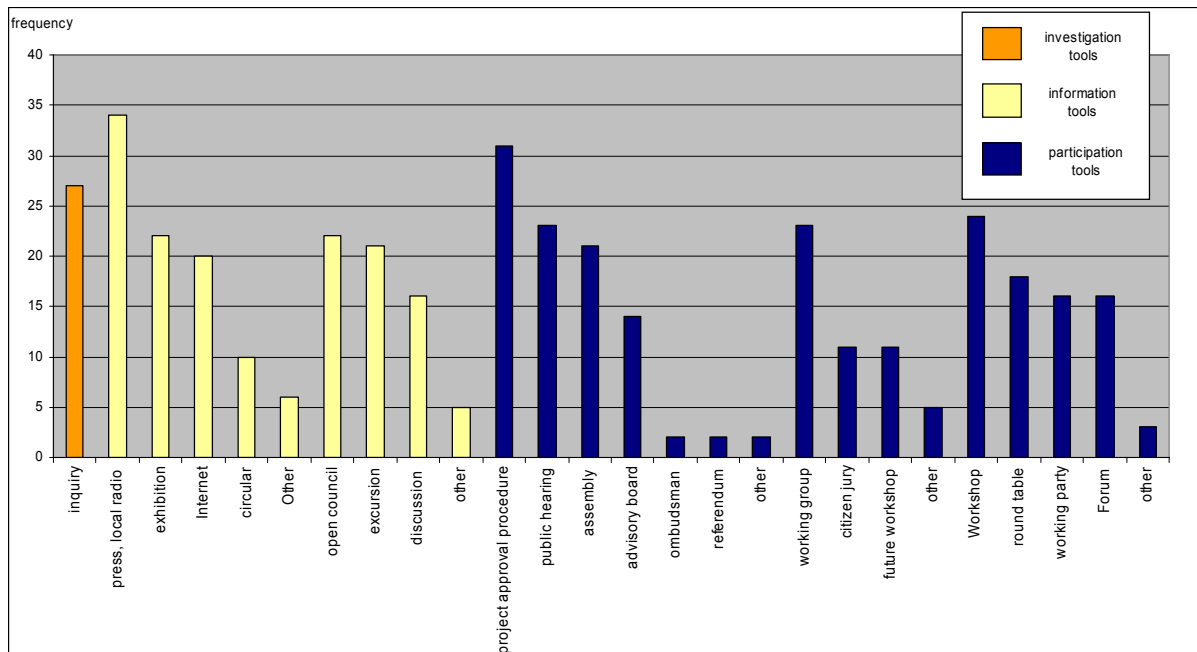


Figure 6-3: The most important tools respective formal and informal participation procedures for coastal defense ranked by experts in the NSR

These tools can be divided in investigation tools, information tools, and participation tools. Investigation and information can be defined as a form of participation, because they involve people in management planning by informing them and giving them the possibility to participate and to give their opinion. Concerning information tools or procedures, the press/ local radio was the most mentioned tool, followed by inquiries, public hearings, exhibitions, and open councils. The least named procedures were circulars.

Regarding participation instruments, project approval procedures were the most mentioned tools, followed by workshops and working groups.

In the survey, information and participation tools were assessed equally. Both were given high importance within coastal risk management. The local press and the project approval procedure were the most mentioned tools suited as participation instruments. However, others such as inquiries, public hearings, working groups or workshops were also named fairly often. Hence, there was not one single instrument recommended to be the most appropriate for coastal defense. The choice of the instrument has to be adapted to the circumstances. Instead of one instrument, a mix of instruments might be applied.

The valuation of the participation procedures, which have taken place in the regions, showed that both participation and information are almost consistently successful if implemented properly.

The public survey showed that 92% of the asked inhabitants in Oostende, Ribe, St.-Peter-Ording, Gemeente Sluis, and Skegness have never been in contact with public participation procedures, although a few were conducted in the regions. Those 8% who attended were satisfied and would do it again. There exists demand for participation, as 41% of the respon-

dents are interested in being involved in the planning process. However, only 6% would sacrifice a working day, 9% would work as a volunteer, and 50% would go to an information evening. The key results from the public survey were that people ask for more information. To get this information, most of them would go to information events instead of taking part in complex participation procedures. It was conspicuous that in total, 61% (homogenous in all countries) did not know about participation procedures and their possibilities to be involved. This indicated the lack of communication between the actors.

As capacity building includes learning, communication, training, and information, it constitutes several forms of public participation and involvement. Participation and information tools can help to improve risk awareness; they can help to teach people how to behave in case of an emergency. More, they can help to get people to accept governmental decisions concerning coastal defense necessities which might be in conflict with other coastal usages and functions.

So far, risk management has been dominated by technical measures. Non-structural management tools are not so widely established, but in recent times their importance has become more obvious and programs to establish these tools have started.

The investigation on public perception and participation conducted in the North Sea region was one step ahead to this.

Still, there is more engagement in supporting victims of a disaster than building up preparedness and capacities through reduction of vulnerability in a run up. SPERLING & SZEKELY (2005) mention that there is an imbalance between the official money spent in disaster relief and reconstruction in comparison to what is spent on disaster prevention. The UNESCO highlighted figures from its division of Basic and Engineering Science, which suggested that for every US\$100 spent by the international community on risks and disasters, US\$96 go to emergency relief and reconstruction, and only US\$4 is spent on prevention (SPERLING & SZEKELY 2005, related to UNESCO, 2005).

Participation, information, and communication are thus instruments that help to support prevention by awareness raising and involvement. These tools are dynamic and flexible, as even risk is dynamic, and therefore should never be stopped.

6.2 Linking coastal vulnerability assessment to risk management

As risk management is the final stage in which decisions are made, coastal defense is planned and established, and disaster management is evolved, the ones responsible for risk management are the end users of coastal vulnerability assessment. Thus scientists face the problem that they have to be scientifically credible and at the same time have to end up with clear

advice to decision makers about what to do. These requirements are difficult to fulfill by scientists; due to data constraints there always are gaps and uncertainties in the results of vulnerability assessment.

Vulnerability thus is a key concept in bridging understanding of and the response to climate change, risks and impacts of disasters.

One crucial problem in linking vulnerability assessment to risk management is the issue of scale. VA to climate change and SLR works mostly on large scales. Nevertheless, despite responsibilities, it is the local population that has to cope with the impacts and it is the local level where decisions are made about if and where money is spent for risk management efforts.

There are different opinions among scientists according to the appropriate scale of VA. ADGER ET AL. (2004), for example argue that the national level is an appropriate scale, because it allows a comparison of countries. He further states that many local conditions, as for example economic well-being of vulnerable groups, are strongly influenced by national policies.

This is only partly true, because e.g. coping capacity approaches may work in one group but not in another, due to cultural or social situations.

From the evaluation of different VA studies, it can be concluded that vulnerability assessment must be place-based in order to adjust to variability in physical parameters and social characteristics and to be useful for decision making. Only on place-based level, public involvement is possible. BORUFF ET AL. (2005) clearly show the regional variability of vulnerability, which is important for local planning and mitigation. In some regions, improvements in social conditions might have greater impacts in reducing vulnerability than physically based measures. For example BORUFF ET AL. (2005) compare the US Atlantic, Pacific, and Gulf coast concluding that at the Gulf Coast social vulnerability plays the dominating role - e.g. age and birth rate are main indicators -, while at the Atlantic and Pacific coast, SLR rise is the dominating indicator.

Another crucial point is that to make use of a scientific based vulnerability assessment, it has to encompass all relevant items for local planning and management. A spatiotemporal differentiated consideration has to incorporate and review different claims for utilization. This requires integrative assessment, including the consideration of a multi-hazard-approach. The predominantly sectoral perspective used in many assessment studies is thus not advisable, because systems rarely face only one stress at the same time. Instead, interdisciplinary quantitative approaches to vulnerability assessment are necessary to understand impacts on social, economic and ecological systems. These multifaceted approaches should account for physical impacts as well as the systems capacity to recover and adapt and help to identify networks and structures to improve coping and adaptive efforts.

Most vulnerability assessment studies consider above all the aspects of geo-physical hazards, erosion and flooding due to storm surges and sea-level rise or damage and loss of monetary economic values (e.g. GORNITZ, 1997; REESE ET AL., 2003). In these studies, the vulnerability of a region is assumed to be closely related to physical properties. They do not consider the people's resilience or coping capacity to reduce vulnerability, sufficiently. Or they assume a given increase for future SLR, and at the same time assume current levels of social vulnerability, perhaps modulated by changes in population density.

Yet, determining vulnerability is more complicated, requiring examination of the interacting physical attributes and the socio-economic characteristics of an area (CUTTER, 2005; KLEIN & NICHOLLS, 1999; SMALL & NICHOLLS, 2003). In a study in the Flood Hazard Research Center, for example, flood researchers developed an approach for estimating the impact of early flood warning lead time on damage. For different levels of inundation depth, an increase in warning time by more than two hours has the potential of reducing damage by more than 10% (PENNING-ROWSELL ET AL. 2003). This reveals that human efforts and coping strategies during the warning lead time of a flood have a clear impact on flood damage.

Based on the assessment of the physical, social, and economic structure of the coastal system (as outlined in chapter 5.1), vulnerability analysis can provide a process-informed framework on which risk management strategies can be established. In the context of integrative risk management, the role of social capacity, prevention and early warning, public perception (as the results of the investigation in the North Sea Region showed), information, and participation are increasingly important.

The outputs of integrated vulnerability assessment should be the identification of special vulnerable groups, the description of vulnerability under different scenarios, and the identification of points for intervention, which would lead to the formulation of adaptation and response actions. Finally, the outputs should be related to stakeholder decision making and policy.

Figure 6-4 summarizes the links between vulnerability assessment and risk management.

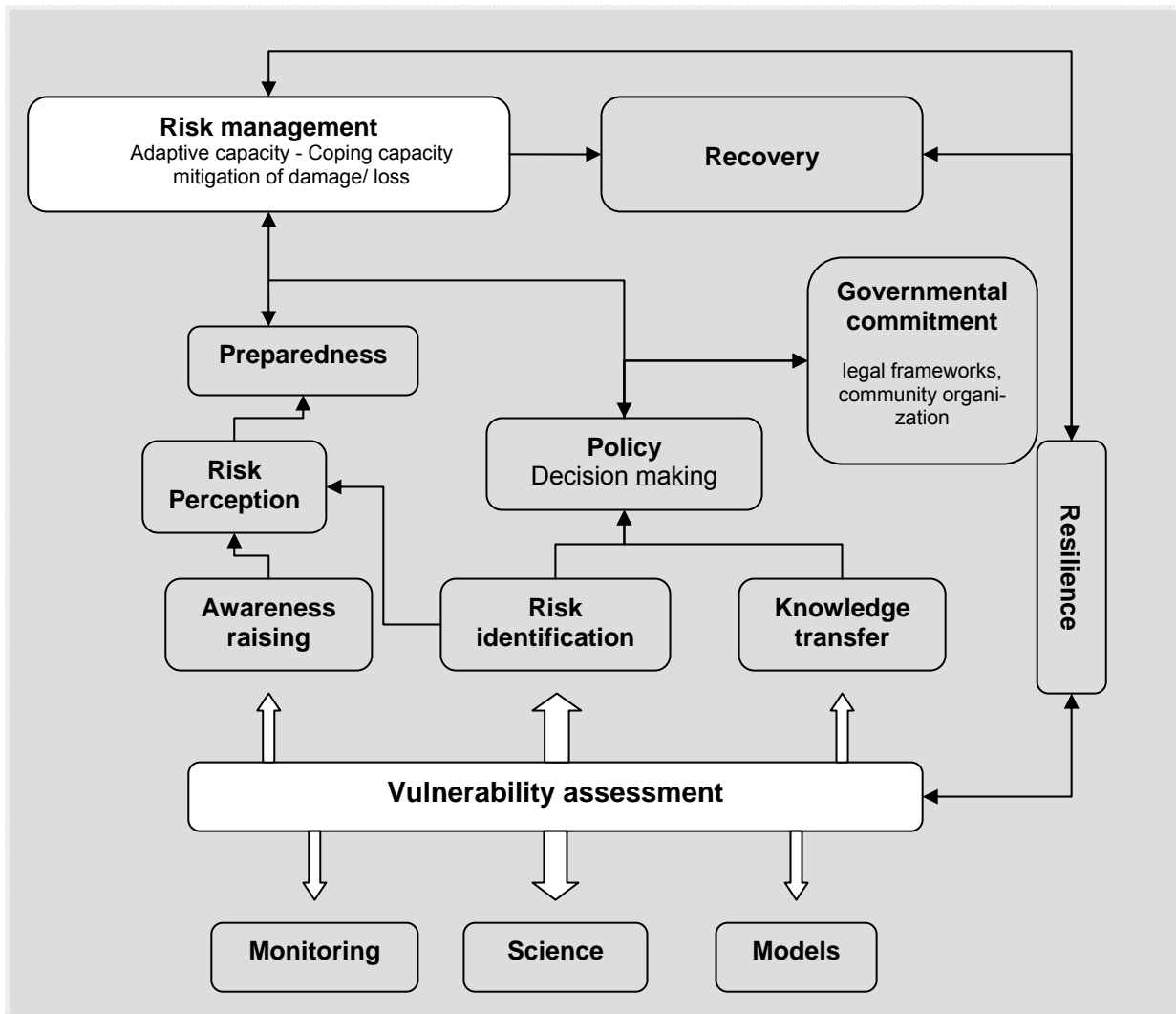


Figure 6-4: From vulnerability assessment to risk management

There are many reasons why vulnerability assessments lack some crucial information to deliver these issues:

- Incomplete knowledge of the relevant processes affected by SLR and their interactions
- Insufficient data
- Difficulty in developing the local and regional scenarios of future change, including climate change
- The lack of appropriate analytical methodologies for some impacts
- Mismatch between scales as with decreasing scale data availability and comparability decreases the precision of this data increases.

6.3 Adaptability of a concept of indicators for risk management

In connection with the application of the concept of vulnerability to coastal risk management the use of vulnerability and resilience indicators has to be considered.

Coastal management is normally conducted following specific guidelines and goals to achieve. These goals are addressing diverse functions of the coastal zone and different stakeholders.

Not all the risks to coastal societies can be eliminated, either because of the lack of money (cost-benefit) and possibilities to implement 100% safety measures because of conflicts of interests between stakeholders, or because of the uncertainty and unpredictability of natural hazards. Therefore the identification of especially vulnerable spots is crucial to find adequate solutions.

However, even when knowing the vulnerable areas, again the question is: "how safe is safe enough?" What is the risk that can be accepted? Once the possible adaptation strategy has been established it is crucial to hold this level of safety against changing conditions, i.e. increasing risks due to global warming and sea-level rise. Thus natural and human developments have to be monitored, to adapt risk management and adaptation strategies to these potential developments.

Politicians and local decision makers need an instrument which helps them easily to understand the complex interactions of coastal functions and to evaluate changes and consequences. Complicated, drawn-out processes to assess actual risks are not convenient to coastal planners and thus will be neglected. Furthermore decisions about coastal management and spatial planning have to be made long before implementation. Thus, despite uncertainties about risks and their possible increase clear and easily understandable parameters and proxies are needed.

A possibility to build a bridge between science and policy is the use of indicatorsystems. Indicators can help to translate the huge amount of data incorporated in risk and vulnerability assessment by selection or aggregation into clear parameters. They indicate the causes of risk and can be used for performance and the control of the adaptation process by controlling changes and directing development towards specific goals.

The information generated by an indicatorsystem supports decision-makers on local and national level to analyze and understand the risk a community is exposed to. The identified vulnerabilities and deficits in capacities & measures indicate areas of intervention for disaster risk reduction. If thresholds are defined indicators allow a monitoring of processes and so can serve as early warning instruments, when chosen with a sufficient sensitivity. At the same time they indicate the success of response strategies.

A regular application of an indicatorsystem will allow to monitor changes over time and assist in decision making. The status of a society can be measured, various societies can be com-

pared, and important issues which need to be addressed in order to promote the development of a given society along certain paths can be identified. For example the development of demography or the development of the GDP allow for an assessment of the temporal evolution of a country.

In addition, specific development targets can be set by promoting policies and measures which will change the magnitude of the indicators in specific directions (increase, decrease). An example is the imposition of limits regarding the emission of toxic gases and CO₂ concentrations in the atmosphere and related policies, like the Kyoto protocol, to reduce or control such emissions.

Indicators applied for risk and vulnerability assessment can deliver fundamentals for risk management, disaster management and sustainable development by facilitating:

- the assessment of hazards and risks,
- policy advice,
- information of politicians and the public,
- the choice of priorities in risk management,
- the clear definition of goals,
- operationalizing management goals,
- Integrating data of different sources and disciplines,
- monitoring developments and changes which change the vulnerability
- early warning
- to monitor the degree of performance of development goals,
- the control of achievement of management and development goals,
- communication and participation, and
- solutions of conflicts.

(modified from MÜLLER & WIGGERING, 2004:124)

As many coastal management issues are accompanied by conflicts, e.g. building houses in flood prone areas, indicators help in decision making by solving conflicts of interests by giving concrete and clear parameters.

Nevertheless indicators can never give detailed information of everything to solve risk management problems. The aggregation and simplification of variables has not only advantages. There are also limitations of indicatorsystems for vulnerability and resilience indicators and their usability in risk management.

- There is no close connection between scientific investigations and administration. Although indicators aim at simplifying complex issues, they fail to speak the language of

administration. The more local in scale the more difficult it is to match with stakeholder views and political issues. Participation of all concerned is ideally but not practically given.

- Tresholding and drawing conclusions from a changing indicator is not clear. If an indicator changes in a negative sense, it is not automatically clear what to do as with regard to coastal risk management. The question is than: How have different indicators to be weighted, which is more important than another? Where are locally relevant tresholds? Who is responsible? What to do, if two indicators develop in different directions? Is it possible to make decisions on the specific administrative and political situation as a result on the changing indicator?
- The selected indicators only approximate or interpret a complex situation we would like to measure. They are not really a measure of the situation itself. Only a test application can validate the indicators for suitability and policy sensitivity.

However the key set of indicators developed in this work can be used as an instrument for decision makers to monitor vulnerability of all sectors that are subject to coastal risks. These key indicators do not have to show the whole spectrum of coastal processes but they show some crucial variables. Any negative changing of these variables should remind risk managers at an early point of time to decide about adaptation strategies to changing risk conditions. According to local conditions indicators should be chosen to specific characteristics:

- Relevance to the specific political targets,
- feasible for the building of thresholds,
- senitivity towards changes,
- measureability,
- availability in a justifiable financial scope,
- availability of data easily to access, and
- actualisation.

Besides showing changes with clear parameters and proxies, indicators fulfil another function in coastal risk management. Beeing more comprehensible for politicians than highly detailed scientific data, they enhance risk perception, risk awareness, risk communication and participation, which are crucial elements in reducing and preparing for disasters and adverse impacts. In this point indicators can help as they give a clear and comprehensible overview of the current situation. Together with other instruments like riskmaps they contribute to a better risk communication and understanding and thus strenghten coping capacity and simplify decision making.

6.4 Converging approaches for risk handling

To promote an integrated approach methodologies have to be shared to facilitate integration. The handling of present disasters and the preventive measures taken are in many respects closely related to those prevention and adaptation measures planned for a long term sea level rise.

Although disaster risk management and adaptation planning to future climate change as adapted in the DRMC and the CCC follow different research approaches with different political relations, they pursue the same goal of reducing coastal risks to protect life, nature, and economic values. Therefore, climate change adaptation measures can benefit from the practical experience in disaster management (SPERLING & SZEKELY, 2005).

In the Hyogo Framework for Action 2005-2015, established on the WCDR, 2005, in paragraph 19, under Key Activities, (i) Environmental and natural resource management it is stated:

(c) Promote the integration of risk reduction associated with current climate variability and future climate change into strategies for the reduction of disaster risk and adaptation to climate change. This would include the clear identification of climate-related disaster risks, the design of specific risk reduction measures and an improved and routine use of climate risk information by planners, engineers and other decision makers.

Furthermore, one of the outcomes of the WCDR is that in Chapter IV Implementation and follow up, under B. States have committed themselves to: *Promote the integration of risk reduction associated with existing climate variability and future climate change into strategies for the reduction of disaster risk and adaptation to climate change.*

Although problems such as an accelerating sea level rise are quite new ones, there are important synergies between policy frameworks and practical methodologies in disaster risk management and adaptation to climate change. This is mainly because impacts associated with climate change exacerbate existing threats and modulate underlying risk factors which influence the vulnerability and the probability of a disaster occurring.

In the DRMC, there is a demand to further develop prevention strategies, because climatic hazards are assumed to be amplified by climate change or shift regionally affecting other regions in different matters than before. „The primary message of climate change for disaster management is that vulnerability reduction is even more urgent than before” (HELMER & HILHORST, 2006:3). Consequently climate change leads to a shift in disaster risk management from response and recover with a short term view to awareness, preparedness and risk reduction with a long term view. The disaster risk management community is increasingly

adopting a more anticipatory and forward-looking approach, bringing it in-line with the longer-term perspective of the climate change community on future vulnerabilities.

On the other hand the CCC is decreasing in scale, shifting from mitigation to adaptation. More, it is increasingly incorporating socio-economic variables and local decision frameworks. As outlined in chapter 5, the social component and the significance of coping capacity are insufficiently regarded in most risk and vulnerability assessment studies in climate impact research.

As disaster risk reduction will be a major aspect of adaptation, the challenges of climate change might best be met by building on current disaster risk reduction to reduce the likelihood of overlapping responsibilities, to provide a better understanding of risk management, and in order to increase the cost efficiency of disaster and climate change risk management and adaptation. Climate change adaptation has to improve the capacity of governments and communities to address existing vulnerabilities to current climate variability and climatic extremes, linking it to the disaster risk management community.

Current risk associated with extreme climate events is a reasonable proxy for risk associated with climate change in the near future. Societies that are unable to cope with current climate hazards will be even less able to cope with the adverse impacts of climate change. An increase in the frequency and severity of extreme climate events is likely to exacerbate their vulnerability. Thus there is a win-win role of disaster risk management as a response to future climate change (HULME ET AL., 1999). "The lack of capacity to manage the risks associated with current climate variability (on a season to season and year to year basis) is the same that will inhibit countries from addressing the future increases in the complexity and uncertainty of risk due to global climate change. In a way, the entire potential of the future already exists like a seed in the present moment" (UNDP, 2004). Therefore the question to ask is: How can disaster risk be reduced in order to reduce the long-term risk of climate change?

The most effective way of addressing the risks posed by climate change and disasters is to lessen the underlying factors causing vulnerability. However both communities failed to reduce vulnerability so far. The unpredictability generated by climate change places more emphasis on the need to identify and support generic adaptive capacity along with hazard-specific response capacity (SCHIPPER & PENNING, 2006:29).

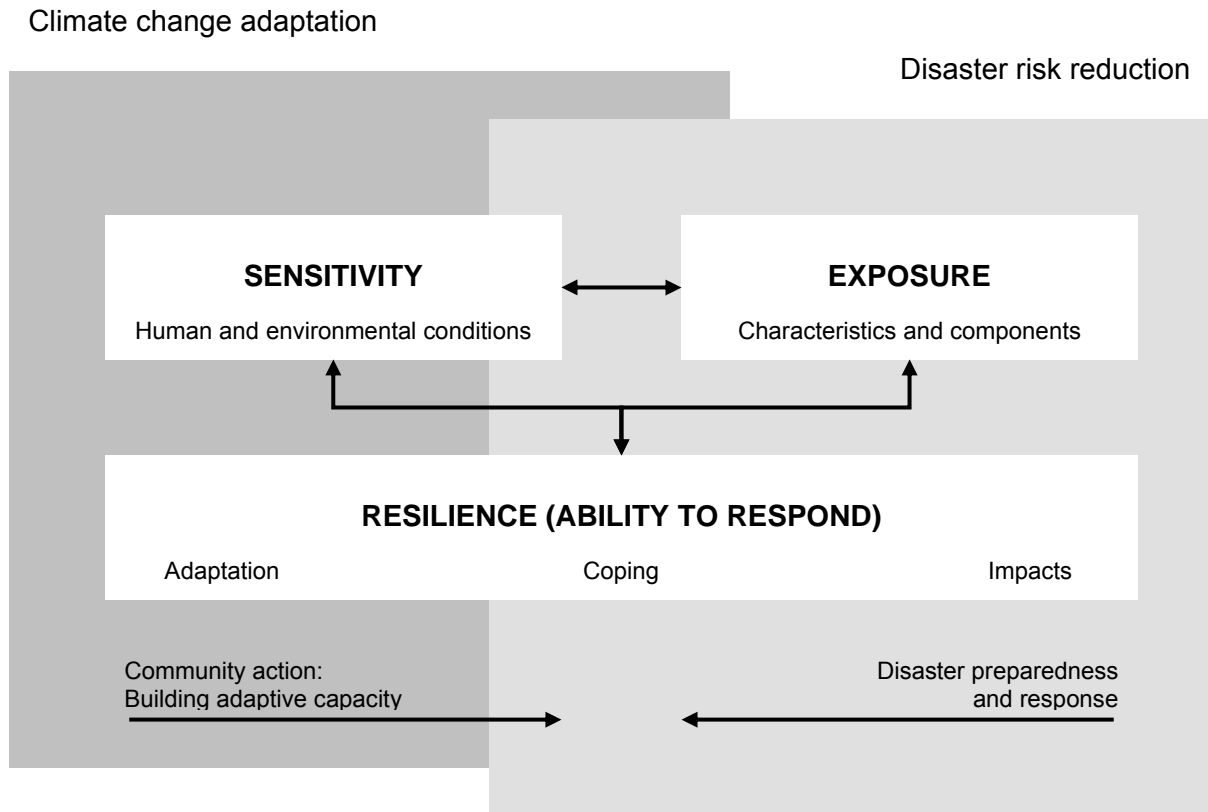


Figure 6-5: Traditional conceptual and operational foci of the climate change adaptation and disaster risk management communities (Source: THOMALLA, 2006:44, adapted from TURNER ET AL., 2003)

Figure 6-5 relates the traditional foci of the climate change adaptation and disaster risk communities to the three components of vulnerability: sensitivity, exposure and resilience. Natural hazards and climate change impacts affect numerous natural, economic, political and social activities and processes. Hence, these challenges need to be addressed in an integrated framework on all political levels and involve all sectors of society.

Although there are some theoretical thoughts and approaches to integrate methodologies from natural disaster reduction and climate change adaptation (UNDP 2004; SPERLING & SZEKELY, 2005; KLEIN & FÜSSEL, 2004; BURTON & AALST, 2004), there are only few practical examples. One example is the CPACC and the MACC project. Led by the Caribbean Disaster and Emergency Response Agency (CDERA) and the MACC team, national disaster coordinators, climate change focal points, and representatives from specialized regional institutions, the University of the West Indies and the insurance industry, identified a program of common actions for adapting to climate change and mitigating hydro-meteorological hazards. Specific recommendations were made to explore synergies between disaster risk management and adaptation to climate change.

To overcome the problem of separate handling of the DRMC and CCC, the UNDP (2002) proposed a framework of *integrated climate risk management* that includes elements of anticipatory risk management, compensatory risk management, and reactive risk management. It must be recognized that future climate hazards can be different to current ones. For example, some low-lying countries (e.g. small island states) might become effectively uninhabitable due to sea-level rise. New hazards can occur. Others occur in one region for the first time. Nonetheless, dramatic qualitative changes in climate are likely to occur in the medium to long-term run. The most immediate concern should be increasing the people's ability to cope with near-term change and current extreme events. Existing engineering and institutional techniques for coastal zone protection should be able to cope with the impacts of climate change.

One way to strengthen societies today and even prepare them for the future is promoting and operationalizing resilience.

6.5 Operationalizing resilience to respond to coastal disasters

In chapter 5.3, the importance of resilience was outlined. The resilience of coastal societies is more closely linked to larger scale processes today than in the past. Economic linkages, globalization of trade, and ecological goods and services tie regions together much more than before (ADGER ET AL., 2005). Resilience does not focus on what is missing in a crisis (needs and vulnerabilities) but on what is already in place (resources and adaptive capacities) (O'BRIEN ET AL., 2006:71). Thus the superior goal of reducing vulnerability could be achieved best by strengthening resilience to make systems able cope with hazards. Theoretically, there is work done concerning the importance of resilience, but there is still no operational tool to actively make use of the concept of resilience.

If resilience is measured and specified in vulnerability assessment, coastal managers could build on this to develop strategies to strengthen resilience, e.g. by training and capacity building programs. Therefore it would be useful to construct a resilience index to complete the vulnerability index to assess the degree to which vulnerable coastal sites are able to withstand hazards. Resilience strategies in risk management increase the recovery rate in case of flooding. Vice versa, risk management increases the resilience of a system by decreasing its vulnerability.

The key factor in the concept of resilience is that it includes much more than just technical adaptation measures. Not all parts of a system have the same vulnerability; especially social units may experience exposure differently and maintain different response options. In an ongoing process, it requires proactive activities to improve coping and adaptive capacity and

the ability to recover. This process includes information, training, awareness raising, monitoring, and many more.

Operationalizing resilience requires a clear definition of the concept. The original idea of resilience, to return to the original state after a disaster, is only partly desirable. Ecological systems, once disturbed or harmed, are more able to bounce back than social systems. Nevertheless, returning to the original state is not desirable because the original state has been subject to a disaster because of its vulnerability. Resilience to disasters thus has to be seen as a dynamic process. A system should recover after a disaster, but this system must be different from that one that was harmed by a disaster to be better capable the next time. This implies that resilience is an ongoing process which needs dynamic tools to function.

The starting point for operationalizing resilience, however, should be the involvement in vulnerability assessment. With the indicators proposed in this work –comprising preparedness, coping capacity, adaptive capacity, and recovery - it can be measured and give quantitative information to which degree it is reducing vulnerability. From the information about the lacking resilience in a specific region, strategies can be developed as how to strengthen resilience in the risk management process.

Focussing on the coastal system, strengthening resilience may be achieved by decreasing the probability of hazard occurrence by protection, reducing potential effects of hazards, and facilitating recovery from the damages when impacts occur.

Promote information dissemination, establish training programs, and participation to improve the perception of risk is one possibility to operationalize resilience.

6.6 Recommendations and outlook

The present study aims at analyzing how coastal vulnerability assessment has to be organized and measured to contribute more effectively to risk management under special consideration of the resilience factor.

The methodological approach is based on review of scientific literature, and on empirical investigations on risk perception and participation in the NSR with help of a trans-national survey.

In the beginning of this thesis, some research questions were formulated.

- What is the hazard potential in coastal zones?
- Which approaches and methods exist to assess vulnerability?
- What results do international vulnerability assessment studies deliver on different scales?
- How can vulnerability be differentiated?
- What role does the resilience factor of coastal communities play?

- Which indicators can measure vulnerability and resilience?
- Can/should risk perception be integrated in risk and vulnerability assessment?
- How can vulnerability assessment contribute to risk management?

It could be asserted, that coastal zones are increasingly subject to multi-stressors (cf. chapter 2). These stressors are twofold; on the one hand, coastal hazards are increasing due to global climate change. On the other hand, socio-economic development results in a population growth in coastal areas, accompanied by an accession of values and resource pressure. These conditions make coastal zones extremely vulnerable. Assessing and reducing this vulnerability is thus a major task.

From an extensive literature review, it could be concluded that there are mainly two communities dealing with coastal vulnerability assessment (cf. chapter 3), namely the climate change community (CCC) and the hazard or disaster risk management community (DRMC), which - although having the same goal - follow different approaches. The main differences between these two communities are temporal and spatial scale. While climate impact assessments mostly follow a top down scenario driven approach, VAs in the DRMC follow a more bottom up approach, seeing the vulnerable community itself instead of global drivers such as climate change as a starting point of investigation.

A range of international VA studies were then analyzed and evaluated and deliver very different results (cf. chapter 4). These results are mainly related to scale and purpose. It could be asserted that most of the studies work with a sectoral perspective expressing vulnerability in form of physical damage categories, land loss, and loss of lives. Two indicator-based assessments (DE LA VEGA ET AL., 2005, BORUFF ET AL., 2005) explicitly included a range of social indicators referring to their importance.

In a vulnerability framework, vulnerability was differentiated in social, economic, and ecological vulnerability, which are the three superior classes describing the coastal environment and its impact categories. Furthermore vulnerability cannot stand alone in risk assessment. The resilience factor plays a crucial role, as it is reducing vulnerability. Resilience and vulnerability are balancing each other 1/1. Resilience incorporates different issues from ecological resilience, i.e. the capacity of a natural system to buffer adverse impacts and the socio-economic resilience comprising issues of humans capability to self-organize and to cope. To assess vulnerability and resilience in order to describe a specific region with a specific factor of risk, it must be quantified. In this work, it is assumed that vulnerability in a broader sense is best measurable with the help of indicators. Therefore a key set of indicators has been worked out (cf. chapter 5). These indicators cover the full range of social, economic, and ecological vulnerability as well as the socio-economic and ecological resilience.

A focus of this work is on risk perception, where a study was carried out in the North Sea Region. As the perception of risk is seen as a crucial factor of resilience, it was investigated if it

can be integrated in vulnerability assessment. The study in the North Sea Region showed that there is a low risk perception and a large information deficit in the North Sea Region. It was recommended to improve this in the framework of risk management to increase the safety towards storm surge risks.

The final question of how VA can contribute to risk management can be answered addressing two issues: Scale and integrated assessment. The problem of scale, i.e. the constraints that large scale assessment do not deliver the detailed data necessary for coastal management and on the other hand local studies do not include climate change scenarios sufficiently and are hindered by large efforts in resources, cannot be solved completely. There is no single best method. Instead, every method has its own advantages and disadvantages. The development of a transferable method is meaningful, but it is always hindered by the need for consideration of very specific local conditions, because there the decisions are made.

Vulnerability assessment must be holistic to get a full picture of the actual vulnerability of the social, economic and ecological system. Sectoral views are not sufficient because they tend to over or underestimate the risk. Furthermore place-based methods that simplify micro-scale assessment methods, e.g. by using remote sensing data or by aggregating damage classes have to be further developed.

The problem of decision making upon uncertain climate change prognosis is here proposed to overcome by converging the approaches of climate change research and disaster risk management.

Based on these outcomes, some recommendations and proposals can be given for further vulnerability assessment and response to coastal hazards.

I. Promotion of a multi hazard approach

As coastal sites are seldom, if ever, subject to only one hazard, it is meaningful to promote a multi-hazard approach when developing strategies for hazard reduction. SLR should not be the only variable, when assessing vulnerability to climate change. Global warming superimposes hydro-meteorological hazards and increases the risk of extreme events such as storm surges and hurricanes. Furthermore, human impacts are a key risk factor, often worse than natural impacts. Thus, when assessing the risk potential socio-economic exposure has to be taken into account.

II. Application of integrated vulnerability assessment – including social, economic and ecological vulnerability as well as socio-economic and ecological resilience

Part of the difficulty of reaching an effective management of risk has been the absence of a holistic theory of risk and vulnerability.

Most vulnerability research so far focused on the assessment of physical risk factors, land loss, and loss of life. Predominantly, monetary damage categories were assessed. Especially social and ecological functions at risk were widely neglected. A wider range of coastal ecosystems and their vulnerability have to be considered, i.e. coral reefs and seagrass, or sub-tidal areas.

There is a demand for more integrated assessment and modeling of socio-economic factors, cultural aspects, health, and many more on the coastal system. Many socio-economic indices exist, but they are not developed with the view of coastal impact and adaptation. More, many variables are in a form which makes regional analysis difficult. However, the abilities of all people in a given place to adapt are rarely homogeneous. Some individuals or social classes will likely be better equipped to cope with specific stresses than others. Even though people can be expected to try to respond to global change, sometimes their possibilities are constrained by inadequate resources (including information) or political-institutional barriers.

Vulnerability should not be evaluated without considering resilience, i.e. the system's capacity to buffer adverse impacts and to cope. Vulnerability should therefore provide a more in-depth evaluation of coping and adaptive capacity and analyze the resilience factor.

The hazard based analysis should be supplemented by the scenario and centralized defense planning by understanding the perception, actual behavior, and attitudes of locals (individuals, households, communities).

III. Preference of place based assessment and facilitation of cross scale linkages

Risk and vulnerability assessment is fairly constraint by a mismatch of scale. There is still no clear guidance, on how to integrate global drivers such as climate change and SLR into local assessment studies. On the other hand, modeling approaches on global scale do not deliver the data required by coastal managers for risk management.

However, vulnerability assessment is missing its main task, if it does not lead to concrete advice for hazard reduction and adaptation strategies. As vulnerability strongly differs on local level, especially due to socio-economic conditions, vulnerability assessments should be "place-based" (according to BORUFF ET AL., 2005), meaning a study area that is small relative to study areas commonly discussed in climate change impact studies (e.g., a village or group of villages instead of a country or group of countries). Yet, the analysis should not exclude processes operating at other spatial scales. Regional interaction across sectors is required to place vulnerability in the context of local and regional development. To gain adequate data

for risk management and sustainable planning, there is a need to bridge the gap between local, regional, and global modeling scales. Therefore methodologies that link scales have to be improved. Major barriers in cross scale linkages include data availability, quality, and compatibility. Data harmonization and the use of new technologies, e.g. remote sensing data to simplify the data assimilation, may be one possible solution. Another one is the reduction of indicators and value categories to a number that is better to handle instead of going up in scale.

IV. Integration of disaster management and climate change adaptation

Disaster management and adaptation to climate change differ in temporal and spatial scale. While disaster management aims at reducing disaster risk to current natural hazards at specific locations, climate change aims at a more long term adaptation to impacts of global changes such as sea level rise. As climate impact research is always afflicted with a degree of uncertainty - a fact that impedes management activities - , it is meaningful to integrate future aspects in the current risk management approaches to promote sustainable development. A system that is able to cope with today's hazards will even be better prepared for future climate change impacts.

V. Integration of the natural hazard issue in risk management and coastal planning

Coastal planning is conducted even without the consideration of risks and hazards. Integrated coastal zone management or other land use planning activities are going on at the coast, trying to balance the variety of functions and actors (tourism, agriculture, fishery, coastal defense, industry, etc.). This planning is closely related to local political frameworks and governmental decisions. Risk management and disaster management with regard to climate change should be integrated in coastal zone management and coastal flood defense planning. For example, many of the natural features that attract tourism to an area are threatened, directly or indirectly, by the impacts of climate change. To promote sustainable tourism, integrating vulnerability assessments could be useful when planning for new developments to promote targeting areas less likely to be affected by the impacts of climate change and sea level rise, and building infrastructure that will protect and/or be protected from these impacts.

VI. Prevention instead of reaction – strengthening resilience and capacity building

Still the majority of activities are dedicated to relief. Adaptation and management has to be individually adopted, but in general there should be a shift from preventive to reactive strategies. Many negative effects could be avoided or managed effectively with proactive measures. This suggests the need to increase capacity to manage the coast in a short, medium and above all long term time-scale. Improvement of local emergency systems, information,

and capacity building should be of significance. This includes the issues of perception and other determinants of adaptive capacity. The development of better tools and guidance for decision-making under conditions of uncertainty should be developed.

At the same time the limits of adaptation (technical, socio-cultural or financial) must be identified and priority setting has to be made.

VII. Integrate local decision makers and stakeholders more intensively

The assessment of vulnerability should not solely be based on scientific knowledge, but also involve policy and stakeholder opinions. Scientists are predestined to develop and test new methodologies based on new cognitions, data quality and technical possibilities. To bridge the gap between scientific outcomes and policy making, which is indeed getting larger because scientists keep on developing new methods not always having end-user capabilities and possibilities of application in mind, participation should be promoted. Decision makers and stakeholders know best what in fact is manageable in a region, what kind of resources, know how, and attitudes are given, and what kind of risk management and adaptation is feasible. To guarantee this, efficient dissemination and communication strategies have to be developed that reach stakeholders by intensifying the communication process between institutes.

The development of new methodologies and indicators for vulnerability assessment is important, because it helps us to further understand dynamic processes and developments and interactions of human-environment relations. However, there are still difficulties to overcome barriers between science and decision making and between policy and practice.

To identify the most appropriate strategy to reduce and manage existing and forthcoming risks, the full context in which impacts of coastal hazards occur has to be considered. It also has to be taken into account that risk management happens within a broader policy process. This is crucial because the costs or the perceived social and economic worth of the resources within the region at risk will determine which, if any, efforts are made.

The key factor to balance policy and management is an exact understanding of present and future risks, and the role of society in causing and adapting to this risk. Policy response to climate change is dependent on a number of factors, such as readiness to accept the reality of climate change, institutions and capacity, as well as willingness to embed climate change in development strategies. These conditions do not yet exist universally. Thus it requires a new approach to climate change risk and a change in institutional structures and relationships.

Adaptation to climate change requires long-term plans and decisions about costly protection measures which have to be made today, although the benefits lie in the far future. What decision makers need to know are exact estimates of climate change impacts, cost, and bene-

fits of taking action as well as relevance of coastal hazards in relation to other environmental and socio-economic changes such as famine or disease.

This information can only partly be given by scientists, because future prognoses are always made with some degree of uncertainty. Therefore, it is supposed to build on current risk and disaster response strategies, since systems that are able to cope with present hazards will even be better prepared for future challenges. It is still not possible to predict with any degree of confidence how climate will develop in the future and which impacts this will have on the frequency and intensity of extreme events at any specific location. Management strategies that may be meaningful today might be senseless in the future due to changing conditions or technology. It is also not clear how societies will develop and how vulnerable they will be at a certain point of time in the future.

Nevertheless, decisions for the future will always be made with some degree of ignorance (HANDMER ET AL., 1999). Adaptation, capacity building, and the development of sustainable livelihoods are long lasting processes which are too late to be started when the consequences of climate change have become inevitable.

7 References

ADGER, WN (1996): Approaches to vulnerability to climate change. Norwich, Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich.

ADGER, WN (1999): Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. World Development **27**(2): 249-269.

ADGER, WN; KELLY, PM (1999): Social vulnerability to climate change and the architecture of entitlements. Mitigation and Adaptation Strategies for Global Change **4**: 253-266.

ADGER, WN; NIGEL, WA; TOMPKINS, L (2005): Successful adaptation to climate change across scales. Global Environmental Change **15**: 77-86.

ADGER, WN; HUGHES, TP; FOLKE, C; CARPENTER, SR; ROCKSTRÖM, J (2005): Social-ecological resilience to coastal disasters. Science **309** (5737): 1036-1039.

ALEXANDER, B (1997): The study of natural disasters 1977-1997: some reflections on a changing field of knowledge. Disasters **21**: 284-304.

AMELUNG, SB (2006): Global (environmental) change and tourism. Issues of scale and distribution. Maastricht.

ARNSTEIN, SR (1969): A ladder of citizen participation. Journal of American Institute of Planners **35**: 216-224.

BAARSE, G (1995): Development of an operational tool for Global Vulnerability Assessment (GVA): Update of the number of people at risk due to sea level rise and increased flooding probability. CZM Centre Publication 3, Ministry of Transport, Public Works and Water Management, The Hague, the Netherlands.

BAKER, EJ; PATTON, DJ (1974): Attitudes towards hurricane hazard on the Gulf Coast. In: WHITE, GF (ed.): Natural Hazards. Local, national, global. New York, 30-36.

BAUMANN, JM; SIMS, JH (1978): Flood insurance: Some determinants of adoption. Economic Geography **54** (3): 189-196.

BEHNEN, T (1998): Der beschleunigte Meeresspiegelstieg und seine sozio-ökonomische Folgen: Eine Untersuchung der Ursachen, methodischen Ansätze und Konsequenzen unter besonderer Berücksichtigung Deutschlands. Dissertation. Hannover.

BELIORE, S; BALGOS, M; MCLEAN, B; GALOFRE, J; BLAYDES, M; TESCH, D (2003): A reference guide on the use of indicators for integrated coastal management. ICAM Dossier. Paris.

BENIOFF, R; GULL, S; KEE, J (1996): Vulnerability and Adaptation Assessment. An international Handbook. Dordrecht.

BERGER, M (2001): Methoden der Schadenspotenzialanalyse in überflutungsgefährdeten Küstenregionen unter besonderer Berücksichtigung eines mesoskaligen Ansatzes. Diplomarbeit am Geographischen Institut der Universität Hannover (unpublished).

BLAIKIE, P; CANNON, T; DAVIS, I; WISNER, B (1994): At Risk Natural Hazards, People's Vulnerability and Disaster. London and New York.

BOHLE, HG; DOWNING, TE (1994): Climate Change and social vulnerability - towards a sociology and geography of food insecurity. Global Environmental Change 4 (1): 37-48.

BORUFF, BJ; EMRICH, C; CUTTER, SL (2005): Erosion Hazard Vulnerability of US Coastal Counties. Journal of Coastal Research 21(5): 932-942.

BRIGNLIO, L (2004): Economic vulnerability and resilience: Concepts and Measurements. Paper presented at the international workshop on "Vulnerability and Resilience of Small States" organised by the Commonwealth secretariat and the University of Malta, University Gozo Centre, Malta.

BROCKHAUS ENZYKLOPÄDIE 1986

BROOKS, N (2003): Vulnerability, risk and adaptation: A conceptual framework. Tyndal Centre Working Paper 38, Norwich.

BROOKS, N; ADGER, WN; KELLY, PM (2005): The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental change 15: 151-163.

BRUCE, JP (1999): Disaster loss mitigation as an adaptation to climate variability and change. Mitigation and Adaptation Strategies for Global Change **4**: 295-306.

BRYANT, E (2005): Natural Hazards. Cambridge.

BURTON, I; KATES, RW; WHITE, GF (1978): The Environment as hazard. New York.

BURTON, I; KATES, RW; WHITE, GF (1993): The Environment as Hazard. New York.

BURTON, I; HUQ, S; LIM, B; PILIFOSOVA, O; SCHIPPER, EL (2002): From Impacts Assessment to Adaptation Priorities: the Shapping of Adaptation Policy. Climate Policy, Amsterdam, Vol.2, pp. 145-159.

BURTON, I; VAN AALST, M (2004): Look before you leap. Washington.

CALLAHAN, J (1994): Proceedings "The Rising Challenge of the Sea". Margarita Island, Venezuela, NOAA.

CANNON, T; TWIGG, J; ROWELL, J (2003): Social Vulnerability, Sustainable Livelihoods and Disasters. Report to DFID, Conflict and Humanitarian Assistance Departement (CHAD) and Sustainable Support Office, Natural Resources Institute, University of Greenwich, kent, UK.

CAPOBIANCO, M; DE VRIEND, H; NICHOLLS, R; STIVE, M (1999): Coastal area impact and vulnerability assessment: the point of view of a morphodynamic modeller. Journal of Coastal Research **15**(3): 701-716.

CARDONA OD (2003): The need for rethinking the concepts of vulnerability and risk from a Holistic Perspective: A necessary review and criticism for effective risk management. In: **BANKOFF, G; FRERKS, G; HILHORST, D**: Mapping Vulnerability: Disasters, Development and People. London.

CARPENTER, S; WALKER, B; ANDERIES, JM; ABEL, N (2001): From Metaphor to Measurement: Resilience of What to What? Ecosystems **4**: 765-781.

CARTER, TR; PARRY, ML; NISHIOKA; HARASAWA, H (1994): Technical Guidelines for Assessing Climate Change Impacts and Adaptations. Report of Working Group II of the Intergovernmental Panel on Climate Change, University College London, UK and Centre for Global

Environmental Research, Tsukuba, Japan.

CENTRE FOR RESEARCH ON THE EPIDEMIOLOGY OF DISASTERS, CRED (2004). Thirty years of natural disasters 1974-2003: The numbers. Brussels.

CLARK, MJ (1998): Flood insurance as a management strategy for UK coastal resilience. Geographical Journal **164** (3): 333-343.

COLIJN, F; HAMANN, M; REESE, S; ROHR, T (2000): Wertermittlung für die potentiell sturmflutgefährdeten Gebiete an den Küsten Schleswig-Holsteins. Teilll. Gutachten im Auftrag des Ministeriums für ländliche Räume, Landwirtschaft, Ernährung und Tourismus des Landes Schleswig-Holstein (unpublished).

CUFF, J (2001): Participation Processes: A tool to assist the wise use of catchments. A guide based on experience. Report of the Wise Use of Floodplains EU Environment Project. (http://www.floodplains.org.uk/pdf/technical_reports/Participatory%20Processes%20Report.pdf - 10.01.2004).

CUTTER, S (1996): Vulnerability to environmental hazards. Progress in Human Geography **20**: 529-539.

DE BRUIJN, KM (2005): Resilience and flood risk management. A systems approach applied to lowland rivers. Delft Hydraulics Selected Sries 6/2005. Delft.

DE LA VEGA-LEINERT, AC; NICHOLLS, RJ; TOL, RSJ (2000): Proceedings of the SURVAS Expert Workshop on European Vulnerability and Adaptation to Accelerated Sea-Level Rise. Hamburg, Germany, 19-21 June 2000, Flood Hazard Research Centre, Middlesex University, Enfield, UK.

DE LA VEGA-LEINERT, AC; KLEIN, RJT AND THE DINAS-COAST CONSORTIUM (2005): Final Report of the DINAS-COAST Project. Potsdam Institute for Climate Impact Research, Potsdam.

DEUTSCH, K (2002): Risikowahrnehmung und Risikokommunikation. (<http://www.umis.de/umweltpsych/deutsch.htm> - 10. 02. 2002).

DILLMAN, D (1978): Mail and telephone surveys. The total design method. New York.

DELFT HYDRAULICS (1991): Impact of sea level rise on society. A case study from the Netherlands. Delft.

DIERßEN, K; HOFFMANN-MÜLLER, R (2004): Naturschutzziele, Naturschutzplanung und Indikatoren für den Zustand der Natur aus der ökologischen Flächenstichprobe. In: **WIGGERING, H; MÜLLER, F** (eds.): Umweltziele und Indikatoren. Wissenschaftliche Anforderungen an ihre Festplanung und Fallbeispiele. Berlin.

DOUGLAS, M; WILDAVSKY, A (1982): Risk and culture. An essay on the selection of technological and environmental dangers. Berkeley.

DOVERS, SR; HANDMER, JW (1995): Ignorance, the precautionary principle and sustainability. Ambio **24**: 92-97.

DOWNING, TE; FRANKLIN, S (2004): Resilience and Vulnerability. SEI Poverty and Vulnerability Programme/GECAFS Briefing Paper, Stockholm Environment Institute, Stockholm.

DOWNING, TE; BUTTERFIELD, R; COHEN, S; HUQ, S; MOSS, R; RAHMAN, A; SOKONA, Y; STEPHEN, L (2001): Vulnerability Indices: Climate Change Impacts and Adaptation. UNEP Policy Series, UNEO, Nairobi.

EBENHÖH, W; STERR, H; SIMMERING, F (1997): Potenzielle Gefährdung und Vulnerabilität der deutschen Nord- und Ostküste bei fortschreitendem Klimawandel. Case study in Anlehnung an die Common Methodology der IPCC Coastal Zone Management Group. Oldenburg.

EL-RAEY, D; EL-HATTAB, M (1999): Adaptation to the impacts of sea level rise in Egypt. Mitigation and Adaptation Strategies for Global Change **4**: 343-361.

EUROPEAN ENVIRONMENT AGENCY, EEA (2002): Lincolnshire Coastal Defense Consultation Document. Bristol.

EUROPEAN ENVIRONMENTAL AGENCY, EEA (2004): Impacts of Europe's changing climate. An indicator-based assessment. Copenhagen, EEA.

EUROPEAN ENVIRONMENTAL AGENCY, EEA (2005): Multilingual Environmental Glossary. <<http://glossary.eea.eu.int/EEAGlossary>>

EUROSION (2004): Living with coastal erosion in Europe: Sediment and Space for Sustainability. Results from the EUROSION study (www.euroSION.org).

FISCHHOFF, B; SLOVIC, P; LICHTENSTEIN, S; READ, S; COMBS, B (1978). How safe is safe enough? A psychometric study of attitudes toward technological risks and benefits. Policy Science **9**: 127-152.

FLEISCHHAUER, M (2004): Klimawandel, Naturgefahren und Raumplanung. Ziel- und Indikatorenkonzept zur Operationalisierung räumlicher Risiken. Dortmund.

FOLKE, C; BERKES, F; COLDING, J (1998): Ecological practices and social mechanisms for building resilience and sustainability. In: **BERKES, F; FOLKE, C** (eds.): Linking social and ecological systems. London, pp: 414 - 436.

FOLKE, C; CARPENTER, S; ELMQVIST, T; GUNDERSON, L; HOLLING, CS; WALKER, B; BENGTTSSON, J; BERKES, F; COLDING, J; DANELL, K; FALKENMARK, M; GORDON, L; KASPERSON, R; KAUTSKY, N; KINZIG, A; LEVIN, S; MÄLER, KG; MOBERG, F; OHLSSON, L; OLSSON, P; OSTROM, E; REID, W; ROCKSTRÖM, J; SAVENIJE, H; SVEDIN, U (2002): Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. Scientific Background Paper on Resilience for the process of The World Summit on Sustainable Development on behalf of The Environmental Advisory Council to the Swedish Government, Stockholm.

FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS, FAO (2004): Sharing our resources – Participation. (<http://www.fao.org/Participation>).

FÜRST, D; SCHOLLES, F; SINNING, H (2001): Gesellschaftswissenschaftliche Grundlagen. Planungsmethoden. Partizipative Planung. (<http://www.laum.uni-hannover.de>).

GOMMES, R; DU GUERNY, J; NACHTERGAELE, F; BRINKMANN, R (1998): Potential impacts of sea-level rise on populations and agriculture. Rome.

GORNITZ, V (1991): Development of a global coastal hazards data base: Annual technical report. Oak Ridge, Tennessee.

GORNITZ, V; DANIELS, RC; WHITE, T; BIRDWELL, KR (1994): The Development of a Coastal Risk Assessment Database: Vulnerability to Sea-Level rise in the U.S. Southeast. Journal of

Coastal Research, Special Issue **12**: 327-338.

GORNITZ, V; BEATY, TW; DANIELS, RC (1997): A Coastal Hazards Database for the U.S. West Coast. Oak Ridge, Tennessee.

GOUGH, C; CASTELLS, N; FUNTOWICZ, S (1998): Integrated Assessment: An Emerging Methodology for Complex Issues. Environmental Modelling and Assessment **3(1/2)**: 19-29

GUNDERSON, L; HOLLING CS (2001): Panarchy: understanding transformations in human and natural systems. Washington DC.

HABEKOST, T (1999): Nutzungsmöglichkeiten des Internets als Instrument der Partizipation privater Personen und Gruppen an kommunalen Planungsprozessen. Diplomarbeit am Geographische Institut der Universität Hannover.

HAMANN, M; KLUG, H (1998): Wertermittlung für die potentiell sturmflutgefährdeten Gebiete an den Küsten Schleswig-Holsteins. Gutachten im Auftrag des Ministeriums für ländliche Räume, Landwirtschaft, Ernährung und Tourismus des Landes Schleswig-Holstein. Unveröffentlichter Endbericht.

HAMILTON, JM; TOL, RJS (2004): The Impact of Climate Change on Tourism and Recreation. In: **SCHLESINGER, M** (ed.): Human-Induced Climate Change – An Interdisciplinary Assessment. Cambridge.

HANDMER, JW; DOVERS, S; DOWING, T (1999): Societal Vulnerability to Climate Change and Variability. Mitigation and Adaptation Strategies for Global Change **4**: 267-281.

HARTJE, V; MEYER, I; MEYERHOFF, J (2002): Kosten einer möglichen Klimaänderung auf Sylt. In: **DASCHKEIT, A; SCHOTTES, P** (eds.): Klimafolgen für Mensch und Küste. Berlin, Heidelberg, New York.

HELMER, M & HILHORST, D (2006): Natural disasters and climate change. Disasters: **30** (1):1-4.

HEWITT, K (1983): Interpretations of Calamity from the Viewpoint of Human Ecology. Boston.

HIDAJAT, R (2001): Risikowahrnehmung und Katastrophenvorsorge am Merapi in Indonesien.

Deutsches Komitee für Katastrophenvorsorge (ed.). Bonn.

HINKEL, J (2005): DIVA: an interactive method for building modular integrated models. Advances in Geosciences **4**: 45-50.

HOLLENSTEIN, K (1997): Analyse, Bewertung und Management von Naturrisiken. Zürich.

HOLLING, CS (1973): Resilience and stability of ecological systems. Annu Rev Ecol Syst **4**: 1-23.

HOLLING, CS (1986): The resilience of terrestrial ecosystems; local surprise and global change. In: **CLARK, WC; MUNN, RE** (eds.): Sustainable development of the biosphere. Cambridge.

HOLLING, CS (1995): What barriers? What bridges? In: **GUNDERSON, LH; HOLLING, CS; LIGHT, SS**: Barriers and Bridges to the Renewal of Ecosystems and Institutions. USA, pp 3-34.

HOOZEMANS, FMJ; MARCHAND, M; PENNEKAMP, HA (1993): Sea level rise - A Global Vulnerability Assessment: Vulnerability Assessment for Population, coastal Wetlands and Rice Production on a Global Scale. Second revised edition. Delft Hydraulics and Rijkswaterstaat, Delft and The Hague, the Netherlands.

HOOZEMANS, FMJ; HULSBERGEN, CH (1995): Sea-level rise: a world wide assessment of risk and protection costs. In: EISMA, D. (ed.), Climate Change: Impact on Coastal Habitation. Lewis Publishers, London, pp 137-163.

HULME, M; BARROW, EM; ARNELL, NW; HARRISON, PA; JOHNS, TC; DOWNING, TE (1999): Relative impacts of human-induced climate change and natural climate variability. Nature **397**: 688-691

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, IPCC (2001): Third Assessment Report. Cambridge.

INTERNATIONAL FEDERATION OF RED CROSS AND RED CRESENT SOCIETIES, IFRC (1999): Vulnerability and Capacity Assessment: an International Federation Guide. Geneva.

INTERNATIONAL FEDERATION OF RED CROSS AND RED CRESENT SOCIETIES, IFRC (2003): Disaster preparedness, Climate Change and RC/RC National Societies: 5 Pilots. The Hague, Red Crescent Centre on Climate Change and Disaster Preparedness.

INTERNATIONAL STRATEGY OF DISASTER REDUCTION, ISDR (2002): Natural Disasters and Sustainable Development: Understanding the Links between Development, Environment and Natural Disasters. Geneva.

INTERNATIONAL STRATEGY FOR DISASTER REDUCTION, ISDR (2004): Living with risk. Geneva.

INTERNATIONAL STRATEGY OF DISASTER REDUCTION, ISDR (2005): World Conference on Disaster Reduction. Kobe.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, IPCC, COASTAL ZONE MANAGEMENT SUBGROUP, CZMS (1992): A common methodology for assessing vulnerability to sea-level rise –second revision. In: Global Climate Change and Rising Challenge of the Sea, Report of the Coastal zone Management Subgroup, Response Strategies Working Group of the IPCC, Ministry of Transport, Public Works and Water Management, The Hague, The Netherlands, Appendix C, 27pp.

JORISSEN, R; LITHJENS-VAN LOON, JU; LORENZO, AM (2001): Flooding risk in coastal areas; an inventory of risks, safety levels and probabilistic techniques in five countries along the North Sea coast. Road and Hydraulic Engineering. Den Haag.

JUNGERMANN, H; SLOVIC, P (1997): Die Psychologie der Kognition und Evaluation von Risiko. In: **BECHMANN, G** (ed.): Risiko und Gesellschaft. Grundlagen und Ergebnisse interdisziplinärer Risikoforschung. Opladen: 167-207.

KAISER, G; REESE, S; STERR, H; MARKAU, HJ (2004): COMRISK-Common strategies to reduce the risk of storm floods in coastal lowlands. Subproject 3: Public perception of coastal flood defense and participation in coastal flood defense planning. Final Report, Kiel (unpublished).

KAPLAN, S; GARRICK BJ (1997): Die quantitative Bestimmung von Risiko. In: **BECHMANN, G** (ed.): Risiko und Gesellschaft, Opladen, 91-124.

KARGER, C (1996): Wahrnehmung und Bewertung von „Umweltrisiken“. Was können wir aus

der Forschung zu Naturkatastrophen lernen? Arbeiten zur Risiko-Kommunikation: 57. Jülich.

KATES, RW (1997): Climate Change 1995 - impacts, adaptations and mitigation. Environment **39** (9): 29-33.

KAY, RC; HAY, JE (1993): A decision support approach to coastal vulnerability and resilience assessment: a tool for integrated coastal zone management. In: **MCLEAN, RF; MIMURA, N** (eds.): Vulnerability Assessment to Sea-Level Rise and Coastal Zone Management, , Proceedings of the IPCC/WCC'93 Eastern Hemisphere Workshop, Tsukuba, Japan, 3-6 August 1993, Department of Environment, Sport and Territories, Canberra, Australia, pp. 213-225.

KLAUS, J; SCHMIDTKE, RF (1990): Bewertungsgutachten für Deichbauvorhaben an der Festlandsküste – Modellgebiet Wesermarsch. Bundesministerium für Ernährung, Landwirtschaft und Forsten (Hrsg.). Kurzfassung des Untersuchungsberichtes. Bonn.

KLEIN, RJT, NICHOLLS, R (1998): Coastal Zones. In: **FEENSTRA, JF; BURTON, I; SMITH, JB; TOL, RSJ** (Eds.): Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies. Geneva, pp. 7.1-7.35

KLEIN, RJT; SMIT, MJ; GOOSEN, H; HULSBERGEN, CH (1998): Resilience and Vulnerability: Coastal Dynamics or Dutch Dikes. The Geographical Journal **164** (3): 259-268.

KLEIN, RJT; NICHOLLS, RJ; THOMALLA, F (2003): Resilience to natural hazards: How useful is this concept? Environmental Hazards **5**: 35-45.

KLEIN, RJT; NICHOLLS, RJ (1999): Assessment of coastal vulnerability to climate change. Ambio **28** (2): 32-37.

KLEIN, RJT; NICHOLLS, RJ; MIMURA, N (1999): Coastal Adaptation to climate change: Can the IPCC Technical Guidelines be applied. Mitigation and Adaptation Strategies for Global Change **4**: 239-252.

KLEIN, RJT; MACIVER, DC (1999): Adaptation to climate variability and change: Methodological issues. Mitigation and Adaptation Strategies for Global Change **4**: 189-198.

KLEIN, RJT; NICHOLLS, RJ; THOMALLA, F (2002): The Resilience of coastal megacities to weather-related hazards. A review. The future of disaster risk: Building safer cities, Pro Ven-

tion Consortium, Washington.

KLEIN, RJT; FÜSSEL, HM (2002): Assessing Vulnerability and adaptation to climate change: An evolution to conceptual thinking. UNDP Expert Group meeting, Havana.

KLEIN, RJT (2003): Coastal Vulnerability, Resilience and Adaptation to Climate Change: An Interdisciplinary Perspective. Dissertation, CAU, Kiel.

KLEIN, RJT (2004): Approaches, Methods and Tools for Climate Change Impact, Vulnerability and Adaptation Assessment. Buenos Aires.

KYSTDIREKTORATET (2004): Comrisk – Subproject SP / . Risk assessment for the Wadden Sea. Draft Report. Lemvig.

LEATHERMAN, S; YOHE, G (1996): Appendix H: Coastal Resource Impacts and Methods of Adaptation Assessment. In: Benioff, R et al. (Eds.): Vulnerability and Adaptation Assessments. An international Handbook: 1-39. Dordrecht.

MARKAU, HJ (2003): Risikobetrachtung von Naturgefahren. Berichte Forschungs- und Technologiezentrum Westküste der Universität Kiel, **31**, Büsum.

MARKS, G; VON WINTERFELDT, D (1984): Not in my backyard: Influence of motivational concerns on judgments about risky technologies. Journal of Applied Psychology **69**: 408-415.

McFADDEN, L; VAFEIDIS, A; NICHOLLS, RJ (2003): A Coastal Database for Global Impact and Vulnerability Analysis. 5th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: Coastal Sediments '03, Clearwater Beach, Florida, USA, 18-23 May 2003.

MERTSCH, S (2003): Risikomanagement als Konzept zur Risikominderung am Beispiel überflutungsgefährdeter Räume Schleswig-Holstein. Unveröffentlichte Diplomarbeit an der Rheinisch-Westfälischen Universität Bonn, Bonn.

MEYER, V (2004): Methoden der Sturmflut-Schadenspotenzialanalysen an der Deutschen Nordseeküste. Fachbereich Geowissenschaften. Hannover, Universität Hannover.

MINISTRY OF TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT, MINVENW (2001):

Flooding risk in coastal areas. Risks, safety levels and probabilistic techniques in five countries along the North Sea coast. Delft.

MOLINE, NT (1974): Perception research and local planning: Floods on the Rock river, Illinois. In: **WHITE, GF** (ed.): Natural Hazards. Local, national, global. New York, 52-59.

MOSS, RH; BRENKERT, AL; MALONE, EL (2001): Vulnerability to climate change. A quantitative approach. Pacific Northwest national laboratory. Report prepared for the US Department of energy. Available online: <http://www.globalchange.umd.edu/cgi-bin/Details.pl?sref=PNNL-13765>.

MÜLLER, F; WIGGERING, H (2004): Umweltindikatoren als Maßstäbe zur Bewertung von Umweltzuständen und –entwicklungen. In: **WIGGERING, H; MÜLLER, F** (eds.): Umweltziele und Indikatoren. Wissenschaftliche Anforderungen an ihre Festlegung und Fallbeispiele. Berlin.

MUNICH RE (1998): World Map of Natural Hazards. München.

MUNICH RE (2005): Topics Geo – Annual review: Natural catastrophes 2005. München.

MUNICH RE (2006): Topics Geo – Annual review: Natural catastrophes 2005. München.

NICHOLLS, RJ (1995): Synthesis of vulnerability analysis studies. World Coast 93, The Netherlands.

NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION, NOAA (2003): Science of Tsunami Hazards: 21(1).

NICHOLLS, RJ; LEATHERMAN, SP (1995): Impacts of Sea-level Rise on Developing Countries. Journal of Coastal Research, Special Issue 14.

NICHOLLS, RJ (1998): Coastal vulnerability assessment for sea-level rise: Evaluation and Selection of methodologies for implementation. Technical Report in the CPACC Projekt.

NICHOLLS, RJ; MIMURA, N (1998): Regional issues raised by sea-level rise and their policy implications. Climate Research 11: 5-18.

NICHOLLS, RJ; BRANSON, J (1998): Enhancing Coastal Resilience: Planning for an Uncertain

Future. Geographical Journal **164**: 255-343.

NICHOLLS, RJ; HOOZEMANS, FMJ; MARCHAND, M (1999): Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. Global Environmental Change **9**: 69-87.

NICHOLLS, RJ; DE LA VEGA-LEINERT, AC (1999): Guidelines for Synthesis and Aggregation of National Results. Second order Draft of the SURVAS Methodology Workshop.

NICHOLLS, RJ; SMALL, C (2002): Improves Estimates of Coastal Population and exposure to Hazard Release. EOS **83** (28): 301 and 305.

NICHOLLS, RJ (2003): Case study on sea-level rise. OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers. Paris.

NICHOLLS, RJ; LOWE, JA (2004): Benefits of mitigation of climate change for coastal areas. Global Environmental Change **14**: 229-244.

O'BRIEN, G; O'KEEFE, P; ROSE, J; WISNER, B (2006): Climate change and disaster management. In Disasters: **30** (1): 64-80.

O'KEEFE, P; WESTGATE, K; WISNER, B (1976): Taking the naturalness out of natural disasters. Nature **2606**: 56-567.

ÖSTERREICHISCHE GESELLSCHAFT FÜR UMWELT UND TECHNIK, ÖGUT (2004): Partizipation & Umweltmediation in Europa. (<http://www.partizipation.at>)

OKRENT, D (1980): Comment on societal risk. Science **208** (4442): 372-375.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, OECD (1993): OECD Core set of indicators for environmental performance reviews. Paris.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, OECD (2003): OECD Environmental indicators. Development, measurement and use. Paris.

PARRY, M; CARTER, T (1998): Climate impact and adaptation assessment. London.

PEDUZZI, P (2000): Insight on common/key indicators for Global Vulnerability Mapping. Geneva.

PEDUZZI, P (2004a): Global evaluation of human risk and vulnerability to natural hazards. Enviroinfo 2004.

PEDUZZI, P (2004b): Is climate change increasing the frequency of hazardous events? The Environment Times. UNEP GRID-Arendal.

PEERBOLTE, EB; DE RONDE, JG; DE VREES, LPM; MAN, M; BAARESE, G (1991): Impact of Sea Level Rise on Society: A Case Study for the Netherlands. Delft and The Hague, Delft Hydraulics and Rijkswaterstaat.

PENNING-ROUSELL, E; JOHNSON, C; TUNSTALL, S; MORRIS, J; CHATTERTON, J; COKER, A; GREEN, C (2003): The benefits of flood and coastal defense: techniques and data for 2003. Flood Hazard Research Centre, Middlesex University.

PETAK, WJ; ATKINSSON, AA (1982): Natural Hazard Risk Assessment and Public Policy. Anticipating the unexpected. New York.

PIMM, SL (1984): The complexity and stability of ecosystems. Nature **307**: 321-326.

PLAPP, T (2003): Ausgewählte Ergebnisse der Befragung zur Wahrnehmung von Risiken aus extremen Naturereignissen. In: Plapp, T et al. (eds.). Ergebnisse aus dem Interfakultativen Graduiertenkolleg Naturkatastrophen. Zusammenstellung ausgewählter Veröffentlichungen und Forschungsberichte 1998 bis 2002: 53-66.

PLAPP, T (2001): Perception and Evaluation of Natural Risks. Interim report on first results of a survey in six districts in Germany. Risk Research and Insurance Management Working Paper No. 1, Karlsruhe.

PLATE, EJ; MERZ, B (2001): Naturkatastrophen. Ursachen, Auswirkungen, Vorsorge. Stuttgart.

RAHMSTORF, S; SCHELLNHUBER, HJ (2006): Der Klimawandel. München.

REESE, S (2003): Die Vulnerabilität des schleswig-holsteinischen Küstenraumes durch

Sturmfluten - Fallstudien von der Nord- und Ostseeküste, Berichte Forschungs- und Technologiezentrum Westküste der Universität Kiel, **31**, Büsum.

REESE, S; MARKAU, HJ; STERR, H (2003): MERK - Mikroskalige Evaluation der Risiken in sturmflutgefährdeten Küstenniederungen. Büsum.

RENN, O (1989): Risikowahrnehmung – Psychologische Determinanten bei der intuitiven Erfassung und Bewertung von technischen Risiken. In: **HOSEMANN, G** (ed.): Risiko in der Industriegesellschaft. Erlangen, pp. 167-192.

RENN, O; ZWICK, MM (1997): Risiko- und Technikakzeptanz. Berlin.

RIBE KOMMUNE (2005): Stormflodskort for Ribe Kommune.
www.ribekommune.dk/page522.asp.

RIBOT, JC (1996): Introduction. In: Ribot, JC; Magalhães, AR; Panagides, SS (eds): Climate variability, climate change and social vulnerability in the semi-arid tropics, Cambridge.

ROHRMANN, B (1995): Technological risks: Perception, evaluation, communication. In: **MECHLERS, RE; STEWART, MG** (eds.): Integrated risk assessment. Current practice and new directions, Rotterdam, pp. 7-12.

SCHIPPER, L; PENNING, L (2006): Disaster risk, climate change and international development: scope for, and challenges to, integration. In: Disasters **30** (1): 19-38.

SCHMUCK, H (2003): Leben mit Zyklonen. Geographische Rundschau **55** (11): 34-39.

SHI, H; SINGH, A (2003): Status and inter-connections of selected environmental issues in the global coastal zones. Ambio **32**: 145-152.

SLABY, M; URBAN, D (2002): Risikoakzeptanz als individuelle Entscheidung. Zur Integration der Risikoanalyse in die nutzentheoretische Entscheidungs- und Einstellungsforschung. Schriftenreihe des Instituts für Sozialwissenschaften der Universität Stuttgart (1). Stuttgart.

SLAFSZTEIN, CF (2003): Vulnerability and response measures to natural hazards and sea level rise impacts: Long-term coastal zone management, Ne of the Sate of para, Brazil. Zentrum für Marine Tropenökologie **17**, Bremen.

SLOVIC, P (1987): Perception of risk. Science **236**: 280-285.

SLOVIC, P; FISCHHOFF, B; LICHTENSTEIN, S (1985): Facts and fears: understanding perceived risk. In: **SCHWING, RC; ALBERS, WA** (eds.): Societal risk assessment: how safe is safe enough? New York, pp. 181-216.

SMALL, C; COHEN, JE (1999): Continental Physiography, Climate and the Global Distribution of Human Population. In: **XU, G; CHEN, Y** (eds.): Towards Digital Earth. Proceedings of the International Symposium on Digital Earth, Beijing, China. pp. 965-971.

SMALL, C; NICHOLLS, RJ (2003): A global analysis of human settlement in coastal zones. Journal of Coastal Research **19** (3): 584-599.

SMITH, JB; TIRPAK, D (1989): The potential effects of global climate change on the United States. US Environment Protection Agency. Washington DC.

SMITH, K; WARD, R (1998): Floods. Physical Processes and Human Impacts. Chichester.

SMITH, K (2005): Environmental Hazards. Assessing risk and reducing disaster. London.

SPERLING, F; SZEKELY, F (2005): Disaster Risk Management in a Changing Climate. Discussion paper prepared for the World Conference on Disaster Reduction on behalf of the Vulnerability and Adaptation Resource Group (VARG). Reprint with Addendum on Conference Outcomes. Washington, D.C.

STARR, C (1969): Social benefits vs. technological risk: What is our society willing to pay for safety? Science **165**: 1232-1238 .

STEFFEN, W; SANDERSON, A; TYPSON, PD; JÄGER, J; MATSON, PA; MOORE III, B; OLDFIELD, F; RICHARDSON, K; SCHELLNHUBER, HJ; TURNER II, BL; WASSON RJ (2004): Global Change and the Earth System. A Planet under Pressure. The IGBP Series, Berlin, Heidelberg, New York.

STEPHEN, L; DOWNING, T (2001): Getting the scale right: A comparison of analytical methods for vulnerability assessment and household-level targeting. Disasters **25** (2): 113-135.

STERR, H; SIMMERING, F (1997): Wissenschaftliches Sekretariat Klimaänderung und Küste – AFFORD. Endbericht. o.V. Oldenburg.

STERR, H; KLEIN, RJT; REESE, S (2000): Climate Change and the Coastal Zone. An overview of the state-of-the-art on regional and local vulnerability assessment, FEEM.

STERR, H (2001): Coastal Zones at risk. In: **LOZAN, JL; GRAßL, H, HUPFER, P** (eds.): Climate of the 21st century: Changes and Risks. Hamburg.

SUSMAN, P; O' KEEFE, P; WISNER, B (1983): Global disasters: a radical interpretation. In: **HEWITT, K** (ed.): Interpretations of Calamity from the Viewpoint of Human Ecology. Boston. 263-283.

TAEGER, U (2004): Umweltpolitische Anforderungen and Umweltindikatoren. In: **WIGGERING, H; MÜLLER, F** (eds.): Umweltziele und Indikatoren. Wissenschaftliche Anforderungen an ihre Festlegung und Fallbeispiele. Berlin.

THE AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE 2006.

THE H. JOHN HEINZ III CENTRE (2000): The hidden costs of coastal hazards. DC: H. John Heinz III Centre of Science, Economics and the Environment, Washington.

THE H. JOHN HEINZ III CENTRE (20002): Human Links to Coastal Disasters. DC: H. John Heinz III Centre of Science, Economics and the Environment, Washington.

THIELER, ER; HAMMER-KLOSE, ES (1999): National Assessment of Coastal Vulnerability to Sea Level Rise: Preliminary Results for the US Atlantic Coast. US Geological Survey, Woods Hole, MA.

THIELER, ER; HAMMER-KLOSE, ES (2000A): National Assessment of Coastal Vulnerability to Sea Level Rise: Preliminary Results for the US Pacific Coast. US Geological Survey, Woods Hole, MA.

THIELER, ER; HAMMER-KLOSE, ES (2000B): National Assessment of Coastal Vulnerability to Sea Level Rise: Preliminary Results for the US Gulf of Mexico Coast. US Geological Survey, Woods Hole, MA.

THOMALLA, F; DOWNING, T; SPANGER-SIEGFRIED, E; HAN, G; ROCKSTRÖM, J (2006): Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. In: Disasters: **30**(1): 39-48.

TIMMERMAN, P (1981): Vulnerability, resilience and the collapse of society. Environmental Monograph **1**. Institute of Environmental Studies, Toronto.

TITUS, JG; ET AL. (1991): Greenhouse effect and sea level rise: potential loss of land and the cost of holding back the sea. Coastal Management **19**: 171-204.

TOBIN, GA; MONTZ, BE (1997): Natural Hazards. Explanation and Integration. New York.

THOMALLA, F; DOWNING, T; SPANGER-SIEGFRIED, E; HAN, G; ROCKSTRÖM, J (2006): Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. In: Disasters: **30** (1): 39-48.

THOMALLA, F; SCHMUCK, H (2004): We all knew that a cyclone was coming. Disaster preparedness and the cyclone of 1999 in Orissa, India. Potsdam Institute for Climate Impact Research, Potsdam.

TONN, B (2003): An equity first, risk-based framework for managing global climate change. Global Environmental Change **13**: 295-306.

TOOGOOD, M; CUFF, J (2000): 2000 Techniques for Talking. Bedfordshire.

TURNER, BL; KASPERSON, RE; MATSON, PA; MCCARTHY, JJ; CORRELL, RW; CHRISTENSEN, L; ECKLEY, N; KASPERSON, JX; LUERS, A; E, MARTELLOG, ML; POLSKY, C; PULSIPHER, A; SCHILLER, A (2003): A framework for vulnerability analysis in sustainability science. PNAS **100** (14): 8074-8079.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, UNFCCC (2004): Application of methods and tools for assessing impacts and vulnerability, and developing adaptation responses. Buenos Aires.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, UNFCCC (2004): What is dangerous climate change? Buenos Aires.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, UNFCCC (2005): Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change. Final draft report. UNFCCC Secretariat. Buenos Aires.

UN/DESA (2001): World population prospects – the 2000 revision. Population Division, Department of Economic and Social Affairs, New York.

UNITED NATIONS (2000): Millennium Declaration Document No.A/RES/55/2.UN, New York.

UN/ISDR (2003): World Summit on Sustainable Development Follow-Up Actions to the Outcome of the Plan of Implementation in Relation to Disaster Reduction. UN/ISDR, Geneva.

UNITED NATIONS DEVELOPMENT PROGRAMME, UNDP (2002): A climate risk management approach to disaster reduction and adaptation to climate change. UNDP Expert Group Meeting on Integrating Disaster Reduction with Adaptation to Climate Change. Havana.

UNITED NATIONS DEVELOPMENT PROGRAMME, UNDP (2002): World Population Prospects – The 2000 Revision. Department of Economic and Social Affairs, United Nations Secretariat, New York.

UNITED NATIONS DEVELOPMENT PROGRAMME, UNDP (2004): Reducing Disaster Risk. A Challenge for Development. New York.

UNITED NATIONS ENVIRONMENTAL PROGRAMME, UNEP (2003): How will global warming affect my world? A simplified guide to the IPCC's Climate Change 2001: Impacts, Adaptation and Vulnerability. Geneva.

VINER, D; AGNEW, M (1999): Climate Change and its Impacts on Tourism. Climatic Research Unit, UEA. Report commissioned for WWF UK, WWF.

VILLAGRAN DE LEON, JC (2006): Vulnerability. A conceptual and methodological review. SOURCE. UNU-EHS: Bonn.

WATES, N (2000): The Community Planning Handbook. London.

WATTS, MJ; BOHLE HG (1993): The space of vulnerability: the causal structure of hunger and famine. Progress in Human Geography 17: 43-67.

WEICHSELGARTEN, J (2001): Naturgefahren als soziale Konstruktion. Rheinische Friedrich Wilhelms Unisversität Bonn, Bonn.

WIGLEY, TML (1995): Global mean temperature and sea level consequences of greenhouse gas concentration stabilization. Geophysical Research Letters **22** (1): 45-48.

WILLOWS, RI; CONNELL, RK (2003): Climate Adaptation: Risk, Uncertainty and Decision-Making. UKCIP Technical Report. UKCIP, Oxford.

WILCHES-CHAUX, G (1989): Desatres, Ecologismo y Formacion Profesional. SENA, Colombia.

WISNER, B; BLAIKIE, P; CANNON, T; DAVIS, I (2004): At risk. Second Edition. Natural hazards, people's vulnerability and disasters. London.

WISSENSCHAFTLICHER BEIRAT DER BUNDESREGIERUNG, WBGU – GLOBALE UMWELTVERÄNDERUNGEN (1999): Welt im Wandel: Strategien zur Bewältigung globaler Umweltrisiken. Vollständiger Jahresbericht, Berlin.

YAMADA, K; NUNN, PD; MIMURA, N; MACHIDA, S; YAMAMOTO, K (1995): Methodology for the assessment of vulnerability of South Pacific Island countries to sea-level rise and climate change. Journal of Global Environment Engineering **1**:101-125.

ZEIDLER, RB (1992): Assessment of the vulnerability of Poland's coastal areas to sea-level rise. Application of the IPCC Common Methodology. Institute of Hydro-Engineering IBW-PAN. Gdansk. Poland.

ZIERVOGEL, G; DOWNING, T; PATWARDHAN, A (2004): Linking Global and Local Scenarios under Climate Change, SEI Poverty and Vulnerability Programme Adaptation Research Workshop Briefing Paper, Stockholm Environment Institute, Stockholm, Sweden.

[1] <http://lead.virtualcentre.org/en/dec/toolbox/Refer/EnvIndi.htm>

[2] www.resilienceallianz.org

8 Glossary

Acceptance

The affirmative or tolerable attitude of a person or group to normative principles or regulations. Concerning the material field it is the positive attitude to the development and distribution of new technologies or products. The attitude results in a corresponding behaviour. A lack of acceptance can lead to a change of official standards or influence social-political decisions (BROCKHAUS ENZYKLOPÄDIE, 1986).

Adaptation

Adjustment in natural or human systems in response to actual or expected impacts of climate change aimed at moderating harm or exploiting beneficial opportunities (KLEIN, 2002).

Adaptive capacity

The ability to plan, prepare for, facilitate and implement adaptation measures. Factors that determine adaptive capacity of human systems include economic wealth, technology, information and skills, infrastructure, institutions and equity (IPCC, 2001).

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 (ISDR, 2004).

Coastal vulnerability

The susceptibility of the natural system and of coastal societies (persons, groups or communities) towards one or multiple coastal hazards. Vulnerability is a condition resulting from a system's ecological, social and economic factors and is a function of its resilience, namely its natural and social coping capacity and adaptive capacity to adverse impacts.

Coping capacity

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 (ISDR, 2004).

Damage analysis

Evaluation of the damage of elements at risk in a specific area, depending on the characteristics of a specific impact (modified, REESE, 2003).

Damage potential analysis

The quantitative and/or qualitative evaluation of the values of risk elements which are potentially at risk of a specific impact in a specific area. The damage potential analysis gives information about the total damage occurring in a worst case (modified, REESE, 2003).

Disaster

External danger, the loss of development potential and the helplessness of the affected population; 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 risk management

The systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (modified, UNDP, 2004).

Early warning

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 (ISDR, 2004).

Exposure

Elements at risk, an inventory of those people or artefacts that are exposed to a hazard. (UNDP, 2004).

Hazard

A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period and area (EEA, 2005).

Hazard Analysis

The hazard analysis is the methodical, comprehensible and formal procedure to evaluate the threat of specific events, conditions, processes or actions in a specific area. It is displayed as the combination of hazard (intensity) and frequency (probability) of a specific threat (KAISER ET AL., 2004).

Mitigation

Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards (ISDR, 2004).

Natural hazard

A natural process or phenomena occurring in the biosphere that may constitute a damaging event. Natural hazards can be of hydro-meteorological, geological or biological origin and can occur on global, regional or local scale (ISDR, 2004).

Natural disasters

A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources (ISDR, 2004).

Preparedness

Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (ISDR, 2004).

Recovery

Decisions and actions taken after a disaster with a view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risk (ISDR, 2004).

Relief

The provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected. It can be of an immediate, short-term or protracted duration (ISDR, 2004).

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 (UNDP, 2004; ISDR, 2004).

Resistance

The ability to stop (or resist) change (NICHOLLS ET AL., 1998).

Risk

The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UNDP, 2004).

Risk assessment/analysis:

A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend (ISDR, 2004).

Risk management:

Risk management comprises all activities that enable a region or coastal community to cope with coastal risks, including singular extreme events as

well as long term changes due to climate change. Risk management is the process of using administrative decisions and operational skills to implement policies, strategies and coping capacities to enable a system to function at present and in the future despite disturbances. This comprises all forms of activities, structural and non-structural to avoid or to limit adverse effects of hazards and to enhance sustainable development.

Risk Acceptance:

Risk acceptance is the personal or team willingness to tolerate the subjective, accepted risk of a condition or process (HOLLENSTEIN, 1997).

Risk perception

Risk perception is the subjective appraisal, based on intuitive judgement, personal experience, and acquired information that people make about the characteristics and severity of a risk.

Risk Evaluation:

Risk evaluation is the individual or collective judgement of risk under the aspect of receiving information and the influence of personal, social and cultural parameters. The decision process is classified into two phases. During the perception phase risks are identified, analysed and verbalised. The judgement (evaluation) phase is characterised by the creation and valuation of alternatives and the decision of practices. The result of the risk evaluation is a numerical or qualitative risk level of the (not) accepted risk (KAISER ET AL., 2004).

Susceptibility:

The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct or indirect (IPCC, 2001).

Social vulnerability:

The ability of social groups to respond to, in the sense of cope with, recover from and adapt to any external stress placed on their livelihoods and well-being (ADGER & KELLY, 1999).

Vulnerability:

The degree 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, adaptive capacity and the degree of exposure of the system to climatic hazards (IPCC, 2001).

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

ANNEX

A Questionnaire on the survey on risk perception

Questionnaire:

“PERCEPTION AND PARTICIPATION IN COASTAL FLOOD DEFENSE“

Preamble

The survey is carried out for the coastal defense division in the Schleswig-Holstein State Ministry of the interior by the Institute for Geography of the German University of Kiel.

Both the inquiry and the evaluation are anonymous. The households were selected randomly.

Please return the questionnaires in the supplied, stamped envelope.

As there are no personal data about the interviewees available, we would like to know where about you live in the flood prone area. Whether you live directly behind the sea wall or five kilometres from the coastline makes a difference in your perception. We have to consider this in our evaluation.

Please mark with a cross where approximately you live in the area!



Questionnaire Part I – Risk Perception

Please fill in the questionnaire and mark the chosen answers with only **one cross** per question, where it is required.

R 1) Have you ever experienced a storm flood?

yes no

R 2) Have you ever experienced a coastal flooding (defense breaching)?

yes no

R 3) Do you know the year when a storm flood disaster occurred in xxx in the past?

yes (in the year _____) no

R 4) How high do you estimate the probability of a coastal flooding in xxx?

assessment: (<high) + + + - - - (low >)

R 5) Could your dwelling be hit by the floodwater in case of a coastal flooding?

yes no

R 6a) Have you taken personal measures to be generally prepared for a storm flood?

yes no

R 6b) If you have answered *yes* in the previous question (**R 6a**), what kind of measures did you take?

Please write here:

R 7a) In your opinion, is there sufficient protection against storm floods in xxx (e.g. disaster relief measures, public warning)?

yes no

R 7b) If you have answered *no* in the previous question (**R 7a**), how, in your opinion, could the safety in case of a storm flood be improved?

R 8a) Do you know what to do in case of a coastal flooding?

yes no

R 8b) If you have answered *yes* in the previous question (**R 8a**), what exactly can you do to protect yourself in case of a coastal flooding?

R 9) How well have you been informed about the basic risks of a storm flood by the responsible authorities?

assessment:	(<high)	++	<input type="checkbox"/>	+	<input type="checkbox"/>	-	<input type="checkbox"/>	--	<input type="checkbox"/>	(low >)
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R 10a) Do you know how to get precautionary information about your own protection in case of a storm flood?

yes no

R 10b) If you have answered yes in the previous question (**R 10a**), where do you get the information from?

Please tick at the most three possibilities:

authorities neighbours/ friends internet

prevention / fire brigade press radio / TV

other sources _____

R 11) Do you feel personally endangered by a sea-level rise, induced by the global climate change?

assessment:	(<high)	++	<input type="checkbox"/>	+	<input type="checkbox"/>	-	<input type="checkbox"/>	--	<input type="checkbox"/>	(low >)
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R 12) How high do you estimate the influence of a sea-level rise on the danger of a storm flood in xxx?

assessment:	(<high)	++	<input type="checkbox"/>	+	<input type="checkbox"/>	-	<input type="checkbox"/>	--	<input type="checkbox"/>	(low >)
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Questionnaire Part II - Participation
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P 1) Have you ever taken part in a participation procedure concerning coastal protection (round table, workshop, mediation, referendum, sensitivity analysis or other)?

yes no

P 2) If you have answered yes in the previous question (**P 1**), what kind of participation procedure was it?

subject of the participation procedure	kind of participation procedure

P 3) If you have answered *no* in the previous question (**P 1**), why did you not participate? (*please choose only one possibility*)

I have not enough time I am not interested no participation procedure has taken place

I don't expect a successful result I am not affected

other reasons _____

P 4) Are you interested in giving your opinion to the planning process of coastal protection matters?

assessment:	(<high)	++ <input type="checkbox"/>	+ <input type="checkbox"/>	- <input type="checkbox"/>	-- <input type="checkbox"/>	(low >)
-------------	---------	-----------------------------	----------------------------	----------------------------	-----------------------------	---------

P 5) Are you interested in being actively involved in the planning process of coastal protection matters?

assessment: (<high) + + + - - - (low >)

P 6) If you want to represent your opinion in coastal protection planning what would you like to do?

Please choose only one possibility:

work regularly as a volunteer

**sacrifice a work-day
for a volunteer work**

go to an information evening

make a phone call

P 7) From your view, what are important reasons to engage yourself in coastal protection?

P 8) Do you know a possibility to represent your opinion, if you do not agree with the decisions of the coastal protection authorities?

yes **no**

P 9) What could you do, if you do not agree with the coastal protection plans?

General data

D 1) How long have you lived in xxx?

years

D 2) Please tick your age:

below 30 years

30 - 60

over 60 years

D 3) Please tick :

female male

Personal comments:

Thank you for your support!

Even if you did not fill in the entire questionnaire, please send it back. It is even then useful for us!

B Results from vulnerability assessment studies

Table B-0-1: Vulnerability studies using the Common Methodology (Source: NICHOLLS ,1995)

COUNTRY	STUDY TYPE	REMARKS
Antigua	Country study	excludes Barbuda Island
Argentina	Country study	
Australia	Local study area	Geographe Bay and the Cocos Islands
Bangladesh	Country study	
Belize	Country study	preliminary results
Benin	Country study	
Brazil	Country study	largely qualitative study
China	Country study	preliminary estimates, plus case studies
Cuba	Country study	largely qualitative study
Egypt	Country study	emphasis on the Nile Delta
England / Wales	Local study area	East Anglia and South Coast
France	Local study area	Rochefort sur Mer
Germany	Country study	preliminary results
Ghana	Country study	qualitative study
Guyana	Country study	
India	Local study area	Orissa and West Bengal
Japan	Country study	emphasis on Tokyo Bay area
Kiribati	Country study	Betio Island
Malaysia	Country study	largely qualitative study
Maldives	Country study	qualitative study
Marshall Islands	Country study	Majuro Atoll
Mexico	Local study area	Rio Lagartos, Yucatán
Moorea Island	Country study	qualitative study
Netherlands	Country study	
Nicaragua	Country study	preliminary study
Nigeria	Country study	
Peru	Country study	qualitative study
Poland	Country study	
Senegal	Country study	
Seychelles	Country study	qualitative study
St Kitts-Nevis	Country study	
Tonga	Country study	Tongatapu Island
Turkmenistan	Country study	qualitative study (Caspian Sea)
USA	Country study	land loss and protection costs
Uruguay	Country study	
Venezuela	Country study	
Vietnam	Local study area	Red River delta (preliminary results)
Global Vulnerability Analysis (GVA)	Global study (4 factors)	Population at Risk Wetlands at Loss Rice at Change Protection Costs

Table B-0-2: Impacts of ASLR in the Netherlands, Germany, Poland (NICHOLLS & MIMURA, 1998)

Country	ASLR scenario (m)	People Affected		People at Risk		Capital Value at Loss		Dry Land at Loss		Wetland at Loss	Adaptation/ Protection Costs	
		people (1000s)	% Total	people (1000s)	% Total	Million US\$	%GNP	km ²	% Total	km ²	Million US\$	%GNP
Netherlands	1.0	10,000	67	3,600	24	186,000	69	2,165	6.7	642	12,300	5.5
Germany	1.0	3,200	3.9	309	0.3	7,500	0.05	13,900	3.9	2,000	23,500	2.2
Poland	0.1	n.a.	n.a.	25 (18)	0.1 (0.05)	1,800	2	n.a.	n.a.	n.a.	700+4	2.1+0.01
Poland	0.3	n.a.	n.a.	58 (41)	0.1 (0.1)	4,700	5	845	0.25	n.a.	1,800+8	5.4+0.02
Poland	1.0	235	0.6	196 (146)	0.5 (0.4)	22,000	24	1,700	0.5	n.a.	4,800+400	14.5+1.2