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Assessment of Social Vulnerability to River Floods in Germany

by Alexander Fekete

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Alexander Fekete

About the author

Alexander Fekete is Desk Officer at the Federal Office of Civil Protection and Disaster Assistance in Bonn, Germany. He leads the project KritisKAT which develops concepts for criticality assessments of infrastructures. His work involves mainly scientific research but also consulting and building partnerships between science, public authorities, NGOs, and the economy.

Mr. Fekete was resident scholar and PhD candidate at the United Nations University Institute for Environment and Human Security (UNU-EHS) from 2005 to 2009. During this time, he earned his doctorate at the University of Bonn, Germany. Within the Disaster Information System for Large-Scale Flood Events Using Earth Observation (DISFLOOD) project he assessed social vulnerability related to river floods and developed climate change adaptation indicators in the KLIMA-PAKT project. As a consultant, he provided expertise about vulnerability and risk analyses, early warning systems and risk management structures for public authorities and NGOs in Armenia.

Previously to UNU-EHS, Mr. Fekete analysed natural and anthropogenic factors triggering landslides and earthquakes in Iran for his master thesis in Geography at the University of Würzburg, Germany.

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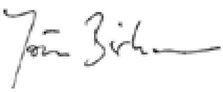
Foreword

The increasing evidence of anthropogenic climate change, the respective modification and particularly intensification of extreme events – such as floods, droughts and sea level rise – as well as the increase in human exposure to these hazards and their vulnerability shows that the enhancement of strategies on how to reduce disaster risk and promote adaptation to extreme events is key for human security. While in the past most concepts for reducing risk to natural hazards were focusing on the hazard itself, its frequency and magnitude, we need now to shift the focus. It is important to understand that disasters deriving from hazards of natural origin are only partially determined by the physical event itself. Growing economic losses, high numbers of casualties and the disruption of livelihoods in various places of the world, at an even higher rate than the increase of magnitude and frequency of extreme events, underline that the vulnerability of societies exposed is the key determinant of disaster risk. Vulnerability however, is highly context specific and highly differentiated (wealth, gender, age, ethnicity, etc.).

Dr Alexander Fekete examines in his dissertation how social vulnerability to river floods in Germany can be characterized and measured at sub-national scale. His systematic review of existing approaches, as well as his own approach of a Social Susceptibility Index for measuring social vulnerability in Germany shows that the concept of vulnerability can be usefully applied to the context of an industrialized country. The dissertation of Dr Fekete focuses particularly on the question how the abstract concept of social vulnerability can be operationalized in the context of flood risk in Germany and how respective indicators might help to identify different patterns of vulnerability at sub-national scale. Although the topic of flood risk is not new, the dissertation goes far beyond the state of the art. Dr Fekete does an excellent work in terms of combining theoretical and conceptual issues with practical problems on the one hand and practical application questions on the other. Particularly the data gathering and the evaluation of the quality of different indicators and aggregation methodologies, using among other methods a factor analysis, gives an in-depth overview of the challenges existing when aiming to develop indicators and indices for social vulnerability in Germany.

Overall, the dissertation illustrates the merits and the feasibility of conducting a semi-quantitative vulnerability assessment to floods in Germany at sub-national scale. Dr Fekete´s analysis of key determinants of vulnerability, such as exposure, susceptibility and coping and adaptive capacities of a system at risk shows a comprehensive approach and underlines that aspects that have often been neglected by traditional hazard or risk analyses so far, can be taken into consideration. The dissertation is therefore an important reading for all the researchers and practitioners who aim to better understand disaster risk to floods and who are struggling with the task to translate the abstract concept of vulnerability into measurable criteria and indicators.



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Abstract

The assessment of social vulnerability unveils hidden weaknesses and strengths of human society towards a certain stressor or hazard. In this study, vulnerability is analysed in terms of its relation to the hazard posed by extreme river floods. The study starts with an assessment of the varying impacts that river floods typically produce in Germany. The serious cases of flooding of the rivers Danube in 2002, the river Elbe in 2002 and 2006, and the river Rhine in 1993 and 1995 affected large areas of Germany. The review of the published research reveals that few studies have tackled hidden issues of flood risk such as social vulnerability in this regard.

At the county level, this study develops a pilot approach on how to identify and compare social vulnerability along river channels in Germany. The concept enables later cross-validation with data and studies from other sources and other spatial levels. The theoretical foundation of this vulnerability assessment is the baseline for the methodological development of vulnerability indicators which capture the exposure, susceptibility, and capacities of social groups concerning river floods.

One important cornerstone of this study is a Social Susceptibility Index (SSI) map based on population characteristics of the counties of Germany. This map is based on a composite index of three main indicators for social susceptibility in Germany – fragility, socio-economic conditions, and regional conditions. These indicators have been identified by a factor analysis of selected demographic variables obtained from the Federal Statistical Office. Therefore, the indicators can be updated annually based on a reliable data source.

The influence of the susceptibility patterns on disaster outcome is shown by an independent second data set of a real case event. It comprises a survey of flood-affected households in three federal states. By using logistic regression, it is demonstrated that the theoretically presumed indications of susceptibility are correct and that the indicators are valid. It is shown that indeed certain social groups such as the elderly, the financially weak, or urban residents are susceptible groups. Additionally, the Social and Infrastructure Flood Vulnerability Index (SIFVI) map combines both social and infrastructure vulnerability, as well as flood exposure scenarios, and demonstrates the integration of hazard and vulnerability information. The SIFVI map is thus the first comprehensive map of its kind for Germany that identifies vulnerable counties and delivers validation. As part of the DISFLOOD project, this study is furthermore an example of how theoretically and methodologically a multi-disciplinary research project can be carried out.

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1. Introduction

The consciousness of the Western world was especially galvanized by hurricane Katrina in 2005. It was vividly revealed that this disaster was man-made, despite its natural origin. The former Secretary-General of the United Nations, Kofi Annan stated: “Disasters are a problem that we can and must reduce.” (UN/ISDR 2002: vii). A report by UN/ISDR (2002: 392) also stressed the need to “develop indicators for disaster risk reduction measures.” The research mandate for monitoring disaster risk was elaborated by scientists and policymakers in the Hyogo Framework for Action (UN/ISDR 2005b). The framework not only formulates the overall value of disaster risk reduction but explicitly mentions national and local risk assessments and maps as well as indicators and vulnerability as major foci (UN/ISDR 2005a: 46). Floods are one area where indicators of social vulnerability are needed to prepare strategies and countermeasures to disaster risk (Bogardi 2004: 361). Research on vulnerability is acknowledged as an important field within recent natural hazards science (Dikau and Weichselgartner 2005; Felgentreff and Glade 2008) and disaster risk management (FIG 2006). This study is part of four PhDs within the DISFLOOD project on the topic of integrated hazard and vulnerability assessment of river floods in Germany (see Chapter 6).

Could a disaster such as Katrina happen in Germany? This seems at first glance to be a question of whether a hurricane such as Katrina could happen in Germany. However, extreme events of this magnitude are only one half of what makes a disaster. The other half is how the disaster is exacerbated by the fabric of German society. The vulnerability of society is the focus of this study. The scope is worst-case scenarios, when extreme weather events hit people who are unaware, unprepared, and lack resources and skills for mitigation of and recovery from the hazard event. The 1962 flood in Hamburg caused by a storm surge hit many new residents living behind the dykes who had no awareness of the hazard (Geipel 1992: 221). They were caught by surprise by rapidly rising water levels after waves overtopped and breached a dyke during the night: 347 people drowned. In recent times several river floods have left an imprint on social awareness. Some of them, labelled ‘century floods’, have caused major damage, for example, the floods of the river Rhine in 1993 and 1995, the transboundary flood of the river Oder in 1997, floods along the river Danube in 1999 and 2002, and the floods along the river Elbe in 2002 and 2006. At first glance it might be surprising to compare Katrina 2005, Hamburg 1962, and the recent river floods, but it is not the type of hazard that prompts comparison but the underlying social patterns that determine whether an extreme event turns into a disaster or not. What about the demographic profile of the residents, how did social vulnerability lead to some people suffering differently to others? Are there patterns of society detectable that would influence the impact of a future extreme flood event? By which categories and indicators can these patterns be detected and measured? Which regions would suffer most when hit by a river flood, not only because of the hazard magnitude but also because of the social characteristics of the people living there? Are these regional patterns observable at a sub-national level, such as county level? These are the core questions and motivation behind this study.

1.1 Objective of this study

Currently, there exists no satisfying assessment of social vulnerability to river floods that is capable of comparing larger regions within Germany. Social vulnerability characterizes the predisposition of society to be afflicted by hazards such as river flooding. It approaches fields that go beyond traditional hazard and risk assessments that mainly focus on economic damage and structural defence measures. Social vulnerability is often a neglected aspect of these types of assessments. An overview of the extent and patterns of social vulnerability to river floods in Germany is clearly missing.

One of the main research questions of this study is to identify those social characteristics which render people vulnerable to flooding hazards in Germany, and consider whether these characteristics are identifiable as regional patterns at county level. Based on the vulnerability assessment, it is possible to allocate resources to counteract potential weaknesses. It is especially challenging to identify what social problems exist and which of these make people vulnerable in regard to floods. It is especially interesting to show what kind of parameters describe these problems best, how these parameters can be measured at regional level, and how they can be linked with hazard parameters for an integrated vulnerability assessment.

1.2 Procedure of analysis

The second chapter presents background information on the research area, Germany. Potential impacts of river floods and common disaster mitigation approaches are briefly outlined. Then existing literature is reviewed in regard to evidence about social vulnerability to flooding in Germany. The background information about the hazard and social vulnerability settings guides the selection of suitable variables for the vulnerability indices.

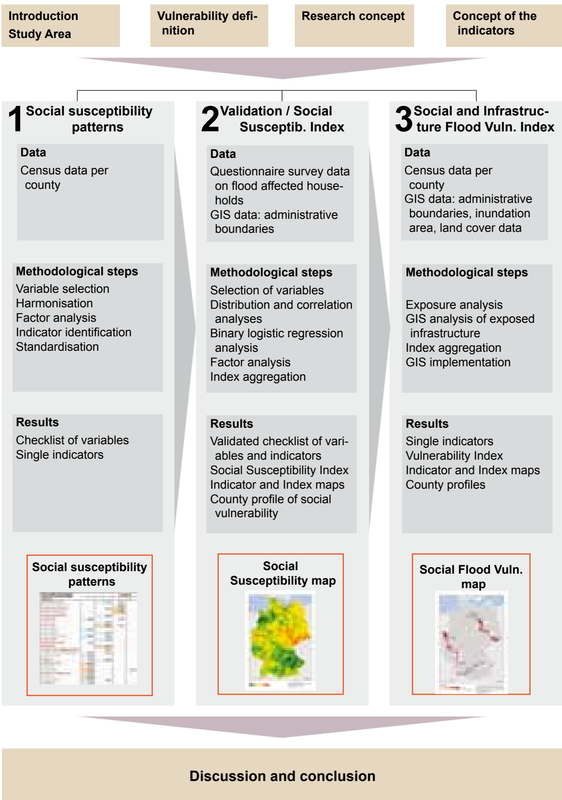
The third chapter describes the conceptual frame for the social vulnerability and the SIFVI (see Figure 1). Terminology is clarified, and a working definition is given. The conceptual framework frames the objectives of vulnerability assessment and illustrates the procedure of analysis. This analytical structure allows the reader to understand the logical concept and the construction of the indices.

In the fourth chapter, the vulnerability assessment is carried out. As the main target, a SSI for German counties is developed (see Figure 1). This is done by selecting and aggregating demographic statistical data. Single variables are grouped by factor analysis to identify social profiles. These profiles are validated by analysis of an independent second data set for a real flood event. The data source is a household questionnaire survey of flood-affected persons. The resulting social profiles at household level are compared with the county profiles, and a validated index is derived. A composite SSI is the main result of aggregating these single indicators. Additionally, the SSI is demonstrated to be integrable with hazard information. The hazard information is derived from inundation maps of rivers. The result is an SIFVI that combines the SSI with an exposure analysis carried out for two major waterways in Germany. This step shows the potential of the susceptibility index for integration with other relevant flood vulnerability information. The vulnerability maps should be comprehensible and useful for both science and decision-making.

The fifth chapter is a synthesis that discusses the results concerning validity and limitations. Technical implications as well as findings on social vulnerability in Germany to flooding are discussed. The theoretical assumptions and possible opportunities for further development are verified.

In the sixth chapter, the results of this study are analysed to determine whether they can be transferred to and interlinked with several fields of application. Consequences and interlinkages of this study are discussed in combination with other hazard scenarios and the dynamic development of society. Finally, recommendations for the application of vulnerability assessments are provided for decision makers.

Figure 1: Flow chart of the research procedure



Source: Author

2. Hazard and vulnerability context

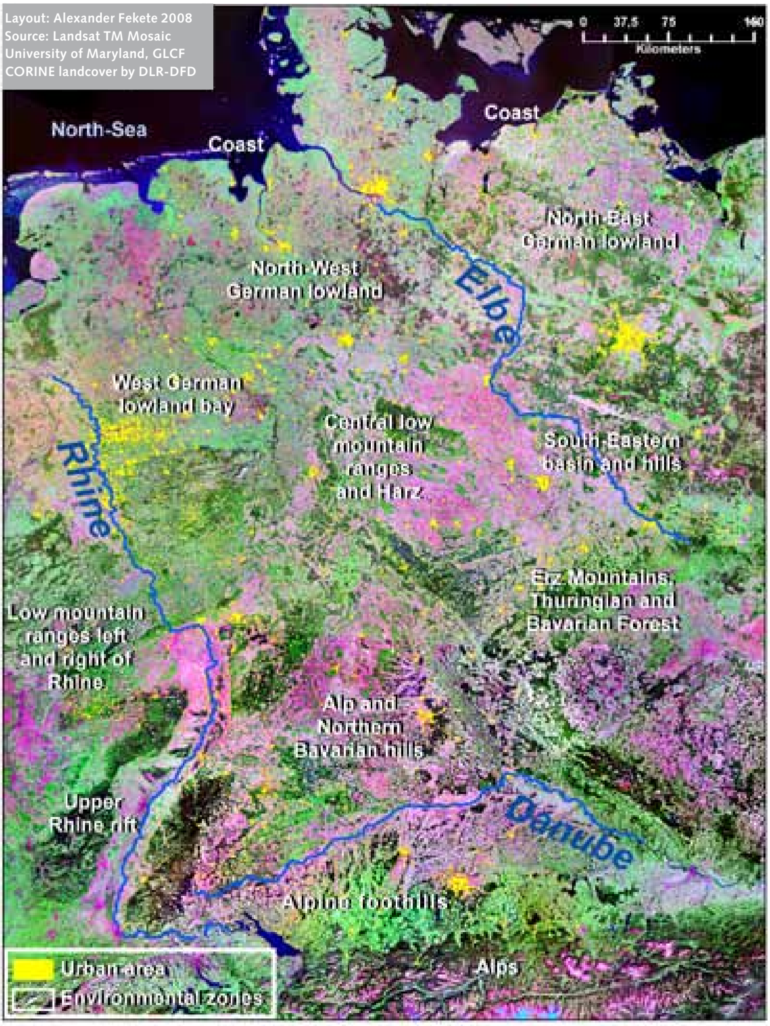
The set-up of this study is determined by the specifics of the hazard and by German society. One element is information about the specific hazard, its characteristics, impacts, and mitigation strategies. The other element is an investigation of the fabric of society and how it frames potential weaknesses and peculiarities towards a potential disaster impact. The Pressure and Release (PAR) model (Wisner et al. 2004: 51) is used to elicit such latent deficiencies in society. However, like the access model of the same authors (Wisner et al. 2004: 89) or the livelihood approach (DFID 2000), it provides less guidance about the hazard background. Since information about both the hazard and the social fabric are important for the context of this study, this chapter starts with a review of hazard peculiarities.

2.1 Flood impact in Germany

Three major waterways, Elbe, Danube, and Rhine, are the centre of interest of this study (see Figure 2). Although the river regimes of these long waterways change downstream due to topography, watershed, and precipitation characteristics (Marcinek 1997: 470; Smith and Ward 1998), they have certain aspects in common. The floods are characterized by a slow increase of the water level and propagation of the flood wave. The lateral diffusion and groundwater level rise is greater in low lying areas of the northern parts of Germany; for example, the North-East German lowland, the North-West German lowland, or the West German lowland bay (see Figure 2). The Upper Rhine rift is a special case of geologic graben, which is also characterized by low topography. The southern parts close to the Alps and Erz mountains are more directly dependent on discharge feed in the spring months caused by snow melt. Even downstream along the Elbe or Rhine, snow melt in combination with frozen ice has caused severe damage in the past. For example, a flood carrying sheets of ice destroyed 161 houses, caused 21 casualties, and left 1800 people homeless in the Rhine area in 1784 (Bröhl 1996: 45). In recent times, floods with ice have been rare and less severe. Still, some experts warn not to underestimate the hazard (Jochen Steiner, head of the fire and ambulance service in Bonn, Steiner 2007). Tributary rivers such as the Mosel increase the flood wave enormously, which happened in the 1993 flood along the Rhine.

The hazard is aggravated by secondary effects arising from land use and infrastructure. Soil-sealing is a major problem within densely populated areas of Germany (see Figure 2). Imperviousness increases surface run-off (UBA 2006: 28; BBR 2005: 333) and a goal of the government is to reduce the amount of newly sealed areas (BBR 2002: 7). Dykes are a controversial issue since they can create faster flow conditions and because of the risk of a dyke breach. In the latter case a disaster can happen to an unprepared population behind the dyke, the so-called "levee effect" (White 1945; Deutsche Rück 1999: 2). It is believed that climate change may alter the flood hazard according to topographical regions in Germany (Spekat et al. 2007; Zebisch et al. 2005; Schmidtke 2004). In particular, it is believed that seasonal patterns, snow melt, and glacier feed may change. There is still a great amount of uncertainty in the predictions and some studies raise doubts about the occurrence of more extreme events (Mudelsee et al. 2003).

Figure 2: Map of Germany displaying the main environmental zones



Source: Author. Data Sources: Environmental zones of Germany, modified from Zebisch et al. 2005: 169, Landsat images by GLCF, University of Maryland 2005, CORINE landcover 2000 by DLR, administrative boundaries by BKG 2007

River valleys are attractive locations for settlement, economic activities, and traffic connections. This has been the case for at least 7000 years, as demonstrated by erosion deposits and traces of early trade patterns for flint stones (Jäger 1994: 33). The distance to rivers or smaller water courses has been a major settlement distribution factor during this time (Schier 1990). Today, the population density along rivers in Germany is 8 per cent, which is double the average settlement density in Germany (DKKV 2003: 35). Hence, approximately two million people are exposed to floods just along the German part of the river Rhine (IKSR 2001: 8).

In recent years, so-called ‘century floods’ have left an imprint on German society, as has been reported by the mass media (Thorwarth 2001: 426). Especially disturbing to the public is why these ‘century floods’ occurred with the same river twice within a few years, and not every 100 years as expected (see Table 1). The statistical value of a given water discharge of a recurrence interval level of 100 years is difficult to conceive for laymen. Within 10,000 years such a discharge is on average expected to happen 100 times, but this gives no indication of exactly when each event is going to happen (Smith and Ward 1998: 17; Kron 2006). This value is even more difficult since it is subject to change after each new flood event (BfG, oral com. 2006; Merz and Emmermann 2006).

Table 1: River floods in Germany: recurrence rates and economic damage

River and Year	Discharge – Q statistical equivalent on years of recurrence	Economic damage in Germany m = million	People affected
1954 Danube	No data	50 m US$	0 casualties
1993 Rhine	100	600 m US$	5 casualties
1995 Rhine	100	320 m US$	5 casualties
1997 Oder		360 m US$	0 casualties
1999 Several rivers in Bavaria, Baden-Württemberg	>100 (300)	350 m US$	5 casualties
2002 Elbe	150-200	11.6 billion US$	21 casualties, 110 injured, 337.000 directly affected, 35.000 evacuated in the city of Dresden
2002 Danube	100	100 m US$	0 casualties
2006 Elbe	Discharge at the Elbe was 13 cm higher than in 2002 in the town of Hitzacker and was the highest in Boizenburg and Doemitz since records began 110 years ago	No data	1,000 evacuated along the Czech border

Sources: DKKV 2003: 21,22, Darthmouth Flood Observatory, accessed 24 July 2008, Deutsche Rück 1999, Deutsche Rück 2002, Freistaat Sachsen 2002, NATHAN by MunichRe, accessed 15 May 2008, UBA 2006

Table 2: The disaster risk index of UNEP-GRID for natural hazards in Germany

	Disasters per year [nb/year]	Causalities [killed/year]	Physical exposure [nb/year]	Relative vulnerability [killed/mio. exp.]
Droughts	x	x	x	x
Earthquakes	0.05	0.0	357.730	0.1
Floods	0.38	1.0	3.976.284	0.3
Tropical Cyclones	x	x	x	x

Source: UNEP-GRID 2003

The impacts of river floods in Germany are characterized by economic damage, and less by mortality (UNEP-GRID 2003; UNDP 2004: 31, 41; Table 1 and Table 2). Germany however, ranks second only to Italy in the occurrence of severe river flood disasters within Europe from 1950 to 2005 (Barredo 2007: 141). Flooding (both coastal and riverine) has been identified as the "most important potential disaster in Germany", even compared to technical risks (Lass et al. 1998: 23). The flood disaster along the Elbe 2002 caused the death of 21 people (DKKV 2003: 29). Serious health impacts were not reported except for single cases. The damage recorded so far was mainly the destruction of houses and infrastructure, economic loss, contamination by fuel tanks (Deutsche Rück 1999: 27; UBA 2006: 26) and chemical industry (WBGU 2000: 140; von Tümpling et al. 2006). Damage to personal belongings, work-interruptions, trade-interruptions, costs for evacuation and technical protection measures are additional effects of river floods (Merz 2006: 189). Information about non-structural harm caused by flooding is more difficult to obtain. Such harm includes the so-called 'indirect' and 'intangible' damage aspects (Smith and Ward 1998: 35), such as disruption of daily life, stress and trauma, and prolonged recovery processes (White 1945; Tapsell et al. 2002).

2.2 Flood mitigation in Germany

> "It is very easy for me to calculate the positions of the sun, moon, and any planet, but I cannot calculate the positions of water particles as they move through the earth."
>
> Galileo

Germany has a long tradition of water engineering. Dams and dykes were first considered to be technical feats and were not perceived as threats. The 'conquest of nature' (Blackbourn 2006) by river training mainly produced economic benefits for trade, turning rivers in Germany into highly important European waterways. As a side-effect of river training and drainage of wetlands, the swamps were dried out and related diseases were reduced (Pohl 2002: 33). After the 18th century however, the failure of dams and negative side-effects of river training changed public and expert opinion about placing too much trust in technical protection only (Blackbourn 2006; Plate et al. 2001: 14). However, this paradigm shift transformed structural water engineering and traditional flood risk management only slowly (Merz and Emmermann 2006; Kuhlicke and Steinführer 2007). Events such as the Rhine floods of 1993 and 1995, and the Elbe flood in 2002 prompted citizens' initiatives and consideration of non-structural flood defence measures (DKKV 2003).

Flood mitigation in Germany is characterized by traditions in the administration and governmental system. The spatial planning tradition for instance not only governs the management of space by regulating land use and determining administrative boundaries (Blackbourn 2006), it also reflects the mindset of controlling nature and the hierarchical structure of spatial units. In combination with the historical background of the federal system, this provides a confusing array of multiple levels of responsibility for disaster risk management (DRM) (von Kirchbach et al. 2002: 215). The responsibility is distributed among multiple levels for different tasks (Lass et al. 1998: 31), encompassing states, counties, municipalities, villages, and citizens themselves.

Volunteerism and responsibility of the citizens are important features of German flood mitigation. This can be traced back to centuries of dyke construction and maintenance in the coastal areas but also along rivers. Dyke reeves (German: Deichgraf; Storm 1888) were elected by the people and even today dyke maintenance and patrols are organized by the citizens themselves. Volunteering for emergency help and sand bag defences is widespread among rescue organizations and local residents in cases of floods (information after interviews with relief organizations at the Elbe flood 2006). This also has negative consequences since it leads to a varying degree of professionalism in some organizations (Lass et al. 1998: 31). Responsibility for preparation and information about flood hazards lies with the citizens themselves (Bundesgesetzblatt 2005). This, on the other hand is not always perceived as such by the people themselves (Steinführer and Kuhlicke 2007: 119). People say that they do not believe a single person can sufficiently protect himself (Wöst 1992: 63).

Currently there is ample activity in the preparation of flood-related disaster information. Recent incentives of DRM include the development of hazard maps (Baden-Württemberg 2005; MUNLV 2003) as commissioned by the European Union (EC 2007). Other incentives are guidelines for flood preparedness of the population (UBA 2006), buildings (BBR 2004), spatial planning (BBR 2002), or critical infrastructure (BMI 2006; BBK 2009). Transboundary cooperation for integrated flood risk management (IKSE 2003; IKSR 2001) and the improvement of early warning systems (EWS) are also fields of action (von Kirchbach et al. 2002). While more and more flood risk maps are available on the internet, they rarely include information other than flooded areas on a topographical map. The insurance industry has developed its own system that contains four risk zones including the location of buildings (ZÜRS; Müller 2002). However, it is not accessible to the public or for science. Increasingly, information about the vulnerability of the population is requested (UN/ECE 2003; Plate 2001: 159; Lass et al. 1998).

2.3 Flood vulnerability assessments

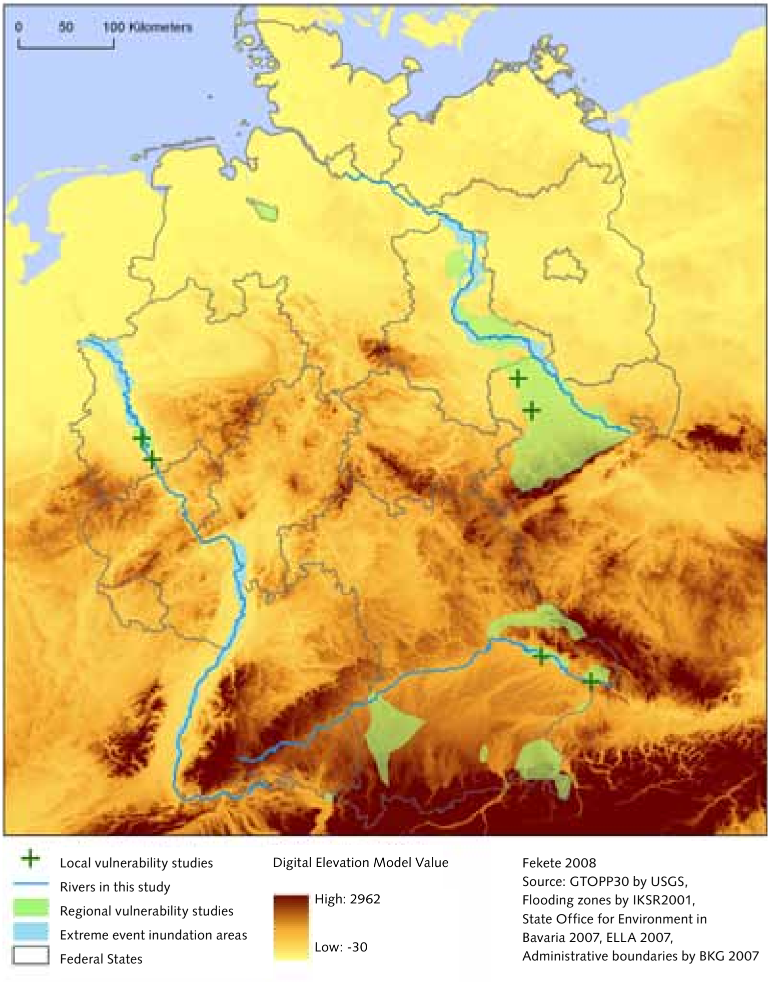
"Germany lacks complete and generally accessible data on disasters and disaster management" (Lass et al. 1998: 41). Lack of data, expert analysis, and integration with planning has been observed, among other problems (Dombrowsky and Brauner 1998: 13). Ten years later, there is still a lack of accessible information or maps including aspects of social vulnerability. Information systems with a Decision Support System (DSS) character typically focus on implementing EWSs or hazard measurements (cf. overview on 42 flood projects on http://www.eu-medin.org/, accessed 26 May 2008). When demographic information is included it is often limited to one or two variables and regarded as an appendix. The same can be said about most classical flood risk assessments, where risk is mainly regarded as a hazard probability or economic loss probability. The loss function often reduces human harm to measurable monetary units, for example buildings or economic values. The insurance industry measures vulnerability mainly by monetary values. For example, the 'natural hazard risk index for megacities' measures vulnerability by building values, building regulations, flood protection, and population density among other criteria (Munich Re 2004: 41). Reduction of social aspects into economic values or mortality is also common for global or national risk or development assessments. The Centre for Research on the Epidemiology of Disasters (CRED) database (www.cred.be/), the Human Development Index (http://hdr.undp.org), and various global and national risk indices (cf. discussion in Birkmann 2007) share this limitation, mostly due to lack of data.

Vulnerability is a component of DRM and research that has been neglected. This is not only due to lack of data but also because of a lack of research. Even at local level only a very few studies have been carried out on non-structural aspects of flooding impact, including social vulnerability. Studies on risk perception concerning floods (Plapp 2004) focus on specific aspects of risk behaviour and include demographic and social structures only partially. Such local studies are, however, very important to identify empirical information about social vulnerability patterns (e.g. Pfeil 2000). Nevertheless, they are naturally very specific to context and locality and are very limited in extrapolating the characteristics of the flood-affected people to wider regions or even to the whole area of Germany. In recent years an increase in studies can be observed which have researched social patterns of diverging preparedness and recovery from flooding events. The Elbe flood in 2002 particularly stimulated such research (Steinführer and Kuhlicke 2007; Thieken et al. 2007).

For a comparison of whole regions within Germany, however, still no satisfying social vulnerability maps exist. A recent study captured social risk criteria, but the information depth was limited to total population and population density (Meyer et al. 2007: 40). Another comparable study carried out a multi-hazard assessment with a multitude of variables on social vulnerability, but only for one federal state (Kropp et al. 2006). Recent approaches regarding coastal flooding have headed in a similar direction (Sterr et al. 2007). In the current state of the art it can be observed that social vulnerability detection measured by quantification and mapping of regions in Germany, is certainly a recent addition to the agenda. The focus has shifted from hazard and structural risk assessments to the inclusion of human risk dimensions. In this perspective, the aim of vulnerability assessments is to enrich risk assessments on important aspects of human characteristics of flood vulnerability.

The map (see Figure 3) shows the limited regional cover of the local studies on social vulnerability aspects in relation to floods (see Table 3). Still, insufficient local

Figure 3: Map of the existing local and regional vulnerability studies



Source: Author

information is available to allow for a comparison of regions along the Rhine with the Elbe or Danube. This research gap will be filled by this study at county level.

2.4 Who are the vulnerable to flooding?

> "We are not an endangered species ourselves yet, but this is not for lack of trying."
> Douglas Noel Adams

The lives of people are not determined by a single factor such as poverty only. Human profiles are composed of several characteristics and conditions. With a limited set of characteristics, certain 'typical' social groups can be identified. Of course, such a typology is inadequate for explaining the complexity of human character, but it is helpful for identifying patterns of vulnerable groups. Studies on social milieus or class describe disadvantaged people. For example, the social or political milieu of 'the precarious group' is characterized by low social status, downward social mobility, a low to middle level of education, the highest ratio of unemployment, blue-collar working class, predominantly male sex, and lives in Eastern Germany and in rural areas (Neugebauer 2007: 82). Eight per cent of the population belong to this milieu, according to this study. This group is closely related to social welfare and unemployment, especially long-term unemployment. Social milieus and class are constantly shifting. At the end of the 1980s, the German poor were elderly women, in the 2000s the poor are young children and young mothers (Strohmeier and Kersting 2003). Children of single mothers are especially affected by poverty, as are children of immigrants and recipients of social welfare (UNICEF 2008). The education opportunities of children are linked to family structure and social class, but less so in eastern Germany (Baumert et al. 2003). All typified groups presented here are disadvantaged in terms of general social standards. They struggle mostly for economic equality but also for status recognition.

However, are these groups 'vulnerable' to natural disasters, or more precisely to river floods? This is a very difficult question to answer for at least three reasons: first, there are still too few studies on this issue in Germany to establish clear criteria on what makes a person vulnerable to natural hazards. Second, those who are most socially disadvantaged cannot be the same as those who are exposed to, or the most severely affected by floods. The affluent, one may argue, have more to lose and can afford to live in more exposed fashion in attractive river-side locations. Third, who is vulnerable is very much dependent on interpretation and definition. If vulnerability is a function of economic loss, then start-up entrepreneurs who bear a high financial risk would be the most vulnerable group, not the poor.

Few studies have established a relationship between flood impact and social groups in Germany (see Table 3 and Figure 3). The studies are typically of a very local focus and the findings cannot easily be generalized. In Beuel, a city quarter in Bonn, new and inexperienced residents were more affected by the floods of the Rhine in 1993 and 1995 than the old population (Pfeil 2000). The new residents were not yet integrated and were not familiar with flood protection and emergency behaviour. Conversely, in Eilenburg and surrounding towns during the flood of 2006 of the river Elbe, the elderly and long-term residents were especially badly hit. They believed the flood would not rise above previous flood levels. They were sceptical about preparedness measures and evacuation, whereas young working people were more mobile, flexible, and better informed (Kuhlicke, pers. com. 2006; Steinführer and Kuhlicke 2007: 64). The study of Eilenburg seems to support the view that old age and tenure played a key role in disaster preparedness (Steinführer and Kuhlicke 2007: 114). The following table reviews typical characteristics of social vulnerability as found in studies in Germany (see Table 3).

The social vulnerability characteristics have to be regarded in the context of international vulnerability studies. Lists and reviews of social vulnerability parameters are provided by several authors (Morrow 1999: 10; Tapsell et al. 2002: 1520; Cutter et al. 2003: 246 ; Schneiderbauer and Ehrlich 2006: 88; Simpson and Katirai 2006: 14; Masozera et al. 2007: 301) summarize social vulnerability characteristics found in other countries for comparison. This comparison is valid, since characteristics such as old age generally correlate with higher degrees of mortality due to floods. Eight of nine persons killed within buildings by a flash flood in southern France in 1999 were of retirement age (IKSR 2002: 14). A study in the United Kingdom (Tapsell et al. 2002: 1522) states that ages of 75+ have been shown in epidemiological research to display a sharp increase in health problems. Experiments reveal thresholds up to which people of average age and constitution could withstand loss of stability or manoeuvrability due to water height and velocity (RESCDAM 2000: 44). The findings conclude that people with reduced physical strength are less able to withstand a flood. This would typically include the elderly, disabled, or persons with additional loads, such as women caring for children.

Regarding income deficiencies, the financially deprived are less likely to be insured, and therefore have more difficulties in recovery (Tapsell et al. 2002), but there are also special groups severely affected by floods which are often forgotten in standard vulnerability assessments. One of these is the transient or homeless who typically is not recorded in standard statistics (Wisner 1998; Masozera et al. 2007). Campers are often highly exposed as camp sites are often situated in flood plains. In 1983 in Savoy, 23 campers died when camping in a flood plain (IKSR 2002: 15). In Southern France in 1999, 10 of 24 persons during a flash flood were killed inside their cars (IKSR 2002: 14). Evacuation assistance needs are identified as a major indicator of social vulnerability (Chakraborty et al. 2005). Certain variables have been analysed for the construction of an index of social vulnerability for evacuation assistance. The variables include the population up to five years of age and population over 85 years (Chakraborty et al. 2005: 26). Similar observations on evacuation needs of special needs groups such as children, the disabled, or persons in need of special medical care have been made for Germany and neighbouring countries (IKSR 2002: 16).

Table 3: Review of vulnerability characteristics of humans to flooding in Germany

Demographic characteristics	Characteristics of higher vulnerability	Characteristics of higher capacities
Old people	Suffering physical/health consequences Received less support (Steinführer and Kuhlicke 2007: 113, 114) Less capable of performing emergency measures effectively (Thieken et al. 2007: 1031) Forced to seek shelter in emergency accommodations (Birkmann et al. 2008: 134-6)	Holding insurance (Steinführer and Kuhlicke 2007: 113)
Very young people	Need more time to evacuate (Birkmann et al. 2008: 134-8)	Suffering less physical/health consequences Suffering lower general impact on household (Steinführer and Kuhlicke 2007: 113)
Gender		*Female gender:* Higher risk perception and preparedness for action (Martens and Ramm 2007, for city of Bremen)
Income	*Lower income*: Lesser degree of insurance (special case of east Germany) (Steinführer and Kuhlicke 2007: 113)	*Higher Income:* Insurance more common (Steinführer and Kuhlicke 2007: 114; Birkmann et al. 2008: 134-7) Capable of performing emergency measures effectively (Thieken et al. 2007: 1031)
Education	*Lower education*: Received less support (Steinführer and Kuhlicke 2007: 114)	Higher education: Capable of performing emergency measures effectively (Thieken et al. 2007: 1031)
Home owners	Properties are more affected Suffering general high impact on household (Steinführer and Kuhlicke 2007: 113)	Applying precautionary measures (Steinführer and Kuhlicke 2007: 113; Thieken et al. 2007: 1034; Reusswig and Grothmann 2004: 99 for the City of Cologne)
People without local networks	Experiencing lack of information (Steinführer and Kuhlicke 2007: 113)	
Household size	*One person households*: A majority considers itself dependent on others in case of an evacuation (Birkmann et al. 2008: 134-6) They spend the least amount of money for flood protection (Kreibich et al. 2005a: 122)	Younger families seem to invest in insurance and retrofitting Household size correlated with taking effective emergency measures (Thieken et al. 2007: 1031, 1034) 3-5 person households are more ready to take action and take more responsibility (Martens and Ramm 2007, for the City of Bremen)

Source: Author

3. Research concept

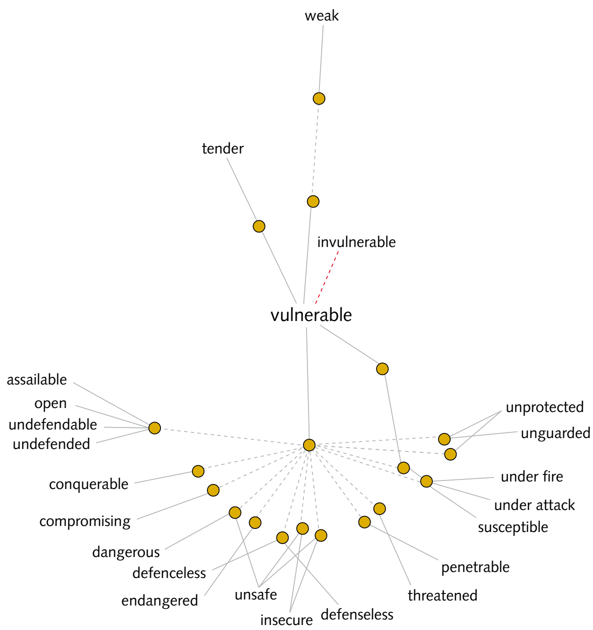
> "Problem formulation is more difficult than problem solution."
> Murray Gell-Mann

Within the field of vulnerability assessments it is important to state how the terminology is used (see Chapter 3.1) and which concept is applied. In this case the concept is a vulnerability framework established by UNU-EHS (see Chapter 3.2). Based on this framework, the goal, procedure, and the components of measurement are identified for the development of the vulnerability indicators.

3.1 Vulnerability terminology

Researchers dealing with the term 'vulnerability' encounter a variety of definitions. While this is often stated as a major problem that hinders applicability (Cannon 2006: 41; Füssel 2007: 155), uncertainty in definitions is a common problem in science (Feynman 2007). For example, terms such as 'risk', 'disaster', 'uncertainty', 'sustainability' or even 'system', 'probability' or 'flood' are defined in multiple ways (Rothman et al. 2008; Quarantelli 1998). By etymology, the term 'vulnerability' stems from Latin 'vulnus', the wound and 'vulnerabilis' – being wounded.

Figure 4: Diagram of the relations of the term 'vulnerability' to similar expressions



Source: www.visualthesaurus.com, accessed 21 May 2008

The confusion around the different interpretations of vulnerability arises from the differing meanings and normative attributions assigned to it. Adding new definitions to the already long list is not the aim of this study. However, in the research community it is essential to provide a working definition to enable an understanding of the research stance. Prior to this, it is necessary to highlight some important points of discussion in vulnerability terminology.

3.1.1 Important points of discussion in vulnerability terminology

In terms of etymology, vulnerability is a negative expression, but there is a trend to attach a positive side to it. The chart of the term vulnerability illustrates its relation to similar expressions and denotes its closeness to negative attributions in common language (see Figure 4). The attachment of a positive side of the coin is driven by relief organizations and some disciplinary schools (Anderson and Woodrow 1998: 11; Twigg 2004: 19; Wisner et al. 2004: 112). They stress the importance of not viewing humans only as victims; in addition, their capacities should also be emphasized (Wisner et al. 2004). In this respect it is instructive to understand the disciplinary discourse of different schools of vulnerability that have been extensively reviewed (Hewitt 1983; Cutter 1996; Weichselgartner 2001; White et al. 2001; Brooks 2003; Few 2003; Adger 2006; Birkmann 2006). Against the backdrop of different disciplines and fields of application – from food security to climate change, the variety of definitions (Cutter 1996; Weichselgartner 2001; Thywissen 2006) can be understood. The range of definitions is given by normative views of disciplines but also by the fundamental difference in science philosophy between reductionist and holistic views.

Reductionist versus holistic viewpoints are two ends of a spectrum of vulnerability definitions. The first analyses vulnerability in terms of a single dimension of real existing objects, for example the porosity of a wall. The holistic view synthesizes a wide range of facets of vulnerability. Often, heterogeneous facets are included in this basket and thus comprise an analytical construct. An example of a holistic approach is the research not only of one human individual, but of a social system. There are many transitions in between the two extreme ends of a spectrum of strictly reductionist and holistic views. This division of definitions is helpful for understanding the diverging mindsets and analytical structures behind vulnerability assessments.

Vulnerability is often regarded as being connected to a specific context. This context can be the type of external stressor, for example natural hazards or civil conflict. Also important is the spatial and temporal context, as is stressed in place-based approaches (Cutter 1996; Research and Assessment Systems for Sustainability Programme 2001: 4; Steinführer and Kuhlicke 2007: 115). The vulnerability to a certain hazard in the spatial and temporal context further demands clarification of who or what is vulnerable. But there are also standpoints of a general vulnerability that more or less prevail as a general condition (Wisner et al. 2004; Bohle 2007: 808) or are even hazard-independent (Schneiderbauer 2007: 27). The term 'overall-vulnerability' (Kleinosky et al. 2007) signifies different vulnerabilities that can be individually researched and then aggregated. There is a range of spheres for which vulnerability can be assessed.

There are considerable overlaps of vulnerability with terms such as 'damage potential' or 'loss'. The lack of concise separation of these terms hampers common understanding. A new term should not be introduced when it can be substituted by one that already exists. One example is the common definition of vulnerability as loss or damage potential. This conveys economic assessments which reduce vulnerability to a one-dimensional view of monetary damage. For reductionist vulnerability assessments this provides a very precise definition, but it is less useful for holistic vulnerability assessments. Damage can be thought to be subdivided into direct and indirect, tangible and intangible damage (Smith and Ward 1998: 35). Still, this bears a resemblance to measurable units such as money or body counts and to economic measurements such as damage functions. Normative views of anthropologists and social scientists stress human capabilities that hardly seem congruent with this perspective (Wisner et al. 2004; Bohle 2007). The composition of the vulnerability definition is dependent on who or what is the object of interest. When humans are the centre of interest, non-structural aspects such as social networks and human behaviour have to be included in risk assessments.

3.1.2 Working definitions

Disaster is "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." (UN/ISDR definition, http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm, accessed 18 April 2009).

Risk is the state prior to a disaster. Risk is perceived here as encompassing aspects of the hazard and the vulnerability of the human-environmental system towards extreme river floods. Risk = f(vulnerability, hazard). It comprises the probability of frequency and magnitude of the hazard as well as the inherent weaknesses and strengths of humans. This is therefore an integrated and constructed notion of risk, combining technical and social risk conceptions.

The *hazard* is, in the case of river floods, a natural event that is perceived as a threat and not as a resource by humans. It can be thought of as a natural process that exceeds a certain threshold of a 'negotiated balance' between the human and the environmental system. When a certain criticality level is exceeded, the resource, for example the river, becomes a threat. When this threat transgresses certain spatial and temporal boundaries of human safety spheres, the hazard is realized as an impact. The hazard is revealed in the state of exposure, when the natural event actually hits the vulnerable elements.

Vulnerability captures the conditions of a phenomenon of observation that characterize its disadvantages in the face of natural hazards (i.e. to a given stressor). Vulnerability encompasses exposure, susceptibility, and capacities of the unit of research, and is related to a specific hazard or stress context.

Vulnerability is integrated with hazard components in the risk formula; risk = f (vulnerability, hazard). Vulnerability changes in time and space and aims to identify and explain why the object of research is at risk and how risk can be mitigated. Vulnerability is both state and degree: everyone is vulnerable in the state of exposure to a hazard and is vulnerable to a certain degree. Vulnerability is a constructed analysis concept since the content and research scope is selected after arbitrary decisions of the researcher or target group.

One critical problem in understanding the term 'vulnerability' lies with the point in time observed – before, during, or after a disaster. People are always vulnerable, regardless of the time phase. Still, it might be useful to distinguish between *potential vulnerability* and *revealed vulnerability*. *Potential vulnerability* describes the pre-disaster conditions of the components exposure, susceptibility, and capacities. This is the type of vulnerability typically addressed by vulnerability indicators that aim at prediction of potential disasters. *Revealed vulnerability* shows itself in a post-disaster situation as an impact measure of unequally distributed loss and hardships amongst social groups, for instance.

Vulnerability can be subdivided into analytical *components*:

Exposure is the measure of susceptible elements within a region threatened by a hazard. The *exposure potential* is the predisposition of a region due to the portfolio of its physical assets.

Susceptibility describes the characteristics that render persons or groups of people generally weak or negatively constituted against stresses and threats.

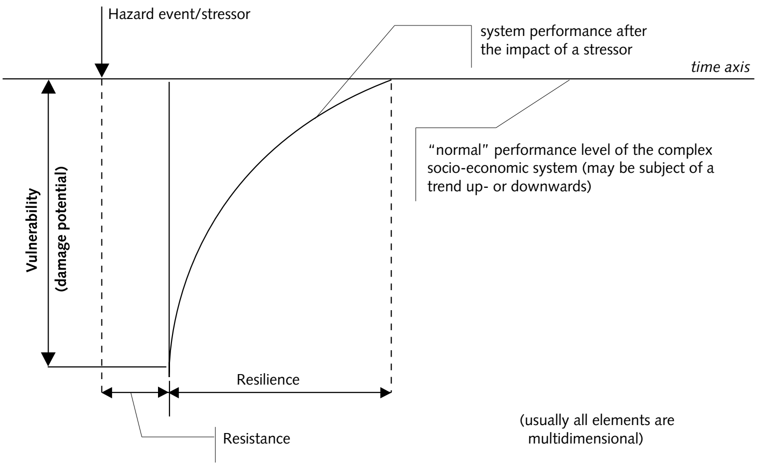
Capacities are positive characteristics that comprise all phases of the disaster cycle, from preparedness, response, or coping during the disaster, and recovery and adaptation after the disaster.

Social vulnerability is the predisposition of society and individuals towards a stressor or hazard to be harmed (cf. definition by Wisner et al. 2004: 11). It is the potential to be wounded or to continue to be wounded. Social vulnerability is bound to human beings; all constituting factors are solely relevant in their function to humans (cf. Wisner et al. 2004). Social vulnerability is understood as a specific focus on the social features of a social-environmental system that create vulnerability, in this case to river floods.

Society is regarded as a social system. The social system consists of elements, humans, who interact with other humans and the environment. Within system boundaries, elements and internal processes take place that are qualitatively different to the system environment outside the spatial and cognitive boundaries of this system. A social system can be, for example, a county. This is therefore a place-based vulnerability view (Cutter 1996). The environment is, on the one side, nature as transformed by human action. On the other side there is a system environment which is an artificial distinction between the internal and external realms of the social system level of interest; counties in this case. The human system as an object of interest is vulnerable due to its own properties and stressors from nature, but also due to stressors from the human system itself.

In order to put vulnerability in the context of the hazard, several models or conceptual frameworks exist, and have already been extensively reviewed (e.g. Birkmann 2006; Villagránde León 2006). Bogardi (2006, as cited in Villagrán de León 2006: 51) provides a concept which visualizes how the hazard impacts on vulnerability and how the system performs after the impact (see Figure 5).

Figure 5: Visualization of the concept of vulnerability



Source: Bogardi 2006, as cited in Villagrán de León 2006: 51

This concept also displays a precise distinction between the resistance and resilience and the system performance after the impact of a stressor on a time line. For this study it is interesting to see the capacities of a system divided into a phase where the system still can resist (resistance) and a phase where the recovery from the impact (resilience) takes place. This concept is one example from a more engineering point of view on how to embed vulnerability into a system perspective and how to link it to the resilience debate. This study specifically targets social vulnerability, and for the sake of simplicity and stringency does not embark on the larger debates of coupled human-environmental systems, resilience, or adaptation. Nevertheless, it is important to highlight that vulnerability assessment is an important precursor of risk, adaptation, and resilience studies. Without knowledge about inherent system weaknesses and strengths, the development of risk management or adaptation strategies will be rather haphazard.

3.2 Conceptual frame of the vulnerability indicators

Since at least the 1960s, social indicators and indices have been used for monitoring social processes (Simpson and Katirai 2006). The attraction of indices lies in the summation of complex information into intuitively conceivable numbers. In the context of this study, indices would allow for spatial and temporal comparison of vulnerability between different communities. General problems known for indicators and indices include subjectivity, bias, weighting, aggregation, normalization, and selection of indicators and data sources. The purpose of building indicators is to derive general approximations over a number of research units and to be able to make comparisons between these units. The aim is to organize information in order to derive knowledge about spatial distribution patterns, thus attempting to 'measure' social vulnerability in this case. Indicators are numerical values that represent real world phenomena in a highly reduced form. An indicator can itself be either a single variable or a composite number of different variables. However, it seems generally accepted that there is a progression from information to data to indicators to indices (Birkmann 2006: 59; Simpson and Katirai 2006: 2).

Other terms such as 'attribute', 'metric', 'parameter', 'value' or 'variable' are used to explain the components of indicators as pieces of quantified data that contain an order, ranking, or more generally, direction. An indicator is thus the opposite of unorganized and non-valuing information. It is often a statistical measurement value which in its variations signifies a change of magnitude, but is usually not an accurate measurement of a phenomenon that is easily observed in the real world (Simpson and Katirai 2006).

Various sources provide an introductory overview of characteristics of vulnerability indicators (Birkmann 2006; Villagrán de León 2006). The design of indicators is dependent on their expected use, inherent properties of the phenomenon of research, methodologies and, the availability of data (Villagrán de León 2006: 26). The selection process is key to ensuring the quality of indicators (Briguglio 2003; Hahn et al. 2003; Villagrán de León 2006) and receives special attention in this study.

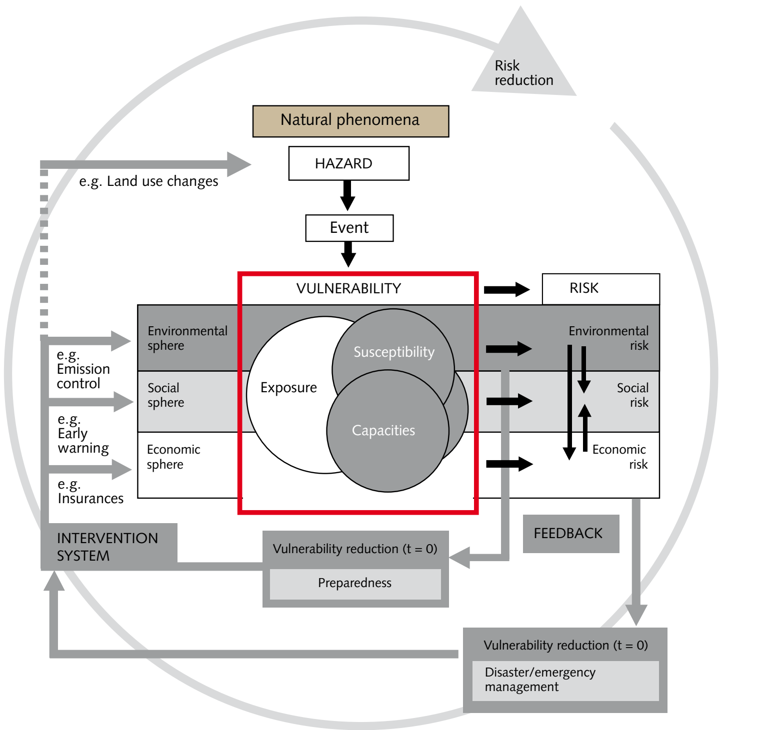
Why measure vulnerability? Answers to this discussion were provided in the UNU-EHS/Munich Re Foundation Summer Academy on water-related social vulnerability at Schloss Hohenkammer in 2006:

- To define, where the greatest need is (Erich Plate)
- Assess socially distributed vulnerability (Anthony Oliver-Smith)
- Alert the public, improve the intervention tools (Melanie Gall)
- To represent social responsibility (Ursula Oswald Spring)
- Show that there is more than a 'natural' cause to natural disasters (Ben Wisner)
- Anticipate undesirable states (Ricardo Guimaraes)
- To look at the social roots of vulnerability (Dirk Reinhard).

The measurement of vulnerability demands a model which delivers the structure, context, and objectives of the analysis. The BBC framework, named after the authors Bogardi, Birkmann, and Cardona (see Birkmann 2006: 34, see Figure 6), explicitly links vulnerability to the three spheres of sustainability: society, economy, and environment. One could argue that institutions or politics also play a role, but they already exist in these three spheres. This framework, as developed at UNU-EHS, is based on theoretical considerations, how social, economic, and environmental dimensions of human security can be integrated with existing hazard and risk concepts. This framework thus displays recent research considerations and the paradigm shift from hazard-orientated research towards an integrative risk reduction perspective (Bogardi and Birkmann 2004).

In the BBC framework, vulnerability is put into a succession chain starting from a natural phenomenon that evolves to a hazard event and hits an exposed, susceptible population that could be equipped with coping capacities. Through a combination of vulnerability and hazard, risk is created. This risk is dynamic, and there are two entry points for risk mitigation provided by the framework: during the pending risk and after the hazard event has started to affect the people. The BBC framework is therefore especially useful to show the interconnections of hazard, vulnerability, risk, and DRM.

Figure 6: BBC framework with red highlighting of the main focus of this study



Source: Modified from Bogardi/Birkmann 2004 and Cardona 1999/2001, as cited in Birkmann 2006, red box highlighting by the author

The BBC framework puts the main analytical components of vulnerability into focus for an assessment. These three components – exposure, susceptibility, and coping capacity – provide the main entry and structuring points for the development of vulnerability indicators in this study. The main focus of this study is on the assessment of the social component of susceptibility and social vulnerability. Indicators are linked to distinct objectives and context (Birkmann 2005: 3). Both objectives and context are provided by the BBC framework.

For the purpose of this study, the assessment of the vulnerability of the social sphere is of principal interest. The social sphere is nested within the environmental sphere and is also deeply interlinked with the economic sphere (see red box in Figure 6). However, the aim of this study is to analyse how a focus on the social aspects rather than on economic and environmental aspects contributes to knowledge of the overall vulnerability of the population. As outlined in the previous chapters, economic and environmental aspects are different foci of research. The social vulnerability assessment focuses on aspects of potential weaknesses and also capacities of the human population. The BBC model displays risk as the outcome of a chain of hazard and vulnerability. This implies that vulnerability cannot be understood without taking into account the specifics of the hazard context.

This means that indicators for social vulnerability have to be selected to be relevant to a hazard context. For example, GDP cannot be taken as a general measure without a direct link to river flood related vulnerability. On the other hand, the BBC model shows the distinction of regarding hazard analysis as a different field from vulnerability analysis. The outcome of both hazard and vulnerability results in specific spheres of risk being created. For the purpose of this study, it is interesting to identify how the social components of susceptibility, together with exposure, construct a certain vulnerability for the population per county. In this case, the 'social vulnerability' component will be assessed by combining a SSI, including capacities to reduce this susceptibility, with exposure information. Within this study, the contribution of the social parameters is the centre of interest, yet, naturally, the term 'social' is fuzzy, since certainly the economy and also the environment as many argue, are socially constructed, or at least are heavily influenced by society. This study focuses only on the social vulnerability aspects, since it is set in a larger project context where the other project partners will provide in-depth information about environmental vulnerability, economic damage, and hazard estimations (project DISFLOOD, see Chapter 6.1).

The steps in creating the SSI following the BBC framework are:

- The identification and definition of the goal of this study: the detection of spatial patterns of vulnerability for the whole area of Germany at county-level. Identification of the role of social vulnerability in the construction of risk.

- Scoping: The domain of research is the population per county. The target audience is scientists and decision makers dealing with disaster risk.

- Temporal and spatial spans: annual data at county-level to enable a snap-shot of the current vulnerability conditions. This serves as a starting point for monitoring and risk reduction.
- The context setting of hazard and different spheres in which vulnerability exists. The display of interlinkages between the spheres. The hazard – vulnerability – risk chain.
- Identification and selection of the set of indicators regarding exposure, susceptibility, and capacities (see Chapter 4).
- Aggregation and validation of a SSI (see Chapter 4).
- Integration of susceptibility with exposure into a vulnerability index (see in Chapter 4).
- Synthesis of how the results reflect on the concept (see Chapters 4 and 5).

Table 4: Indicator development as based on the BBC framework

Goal	Disaster risk reduction
Target group	Scientists and decision makers dealing with disaster risk
Focus	Social sphere of vulnerability
Components of analysis	Exposure, susceptibility, and capacities
Elements	The population per county
Context	Hazard: river floods
Research area and scale	German counties
Point in time	Before the next flood event

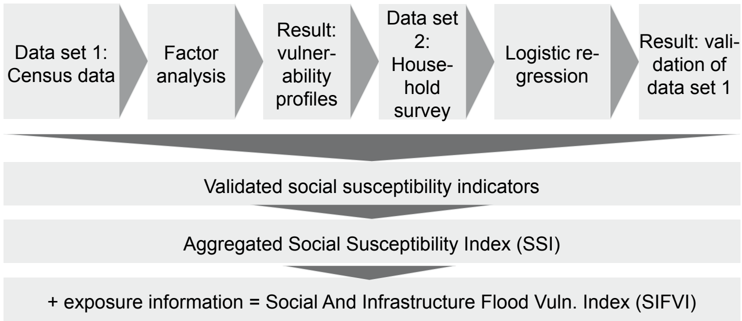
Source: Author

The indicators are measures of the components (exposure, susceptibility, capacities) of social vulnerability. The index is the aggregated form.

4. Vulnerability assessment

Chapter 4 applies the theoretical concept of vulnerability (see Chapter 3) on the basis of the findings about the study area of Germany (see Chapter 2). The technical aim of the vulnerability assessment is the creation of a SSI. This index is based on susceptibility profiles of the population per county. These profiles are obtained by factor analysis of census data. An independent second data set is used for the validation of these susceptibility profiles. The results are susceptibility indicators that are aggregated to an index. By adding exposure information, a SIFVI is created according to the BBC framework in chapter 3.2 (see Figure 7).

Figure 7: Steps and phases of the vulnerability assessment



Source: Author

4.1 Objective

The objective behind the social vulnerability assessment in the context of river flooding is to identify and to profile potential social vulnerability in Germany. The input parameters for this index are selected after a literature review and theoretical considerations as outlined in the previous chapters. The selection criteria and thresholds are explicitly developed in the river flood context, for example considering elderly people above a certain age as vulnerable due to increased fragility. The created index can be principally applied to all potential flooding areas in Germany, to some extent even for coastal areas. Developing vulnerability indices at sub-national level is a common approach that is increasingly applied in other countries, such as the United States of America (Clark et al. 1998; Cutter et al. 2000; Wu et al. 2002; Chakraborty et al. 2005; Olfert et al. 2006; Rygel et al. 2006; Kleinosky et al. 2007; Yarnal 2007) the United Kingdom (Tapsell et al. 2002), Spain (Weichselgartner 2002), Latin America (Hahn et al. 2003; Cardona 2005), Australia (Dwyer et al. 2004), the Philippines (Acosta-Michlik 2005) or generally for regions worldwide (Nakamura et al. 2001). In Germany there have been only a few attempts that either capture only one federal state (Kropp et al. 2006) or reduce social vulnerability to very few variables (Meyer et al. 2007). There is still no satisfying profile of social vulnerability or a sub-national index map for the whole territory of Germany. This gap will be filled by the Social Susceptibility and Social Vulnerability Indices for river flooding.

The application area of this assessment is the whole territory of Germany, with the aim of discerning sub-national regions. Counties were chosen as units for the sub-national level of analysis for several reasons: a) counties are relatively homogeneous in size in comparison to municipalities and postal code areas, b) disaster management as well as many other political processes are organized and supervised at the county level, c) the objective to provide an overview of regional patterns with regard to large-scale flood events can be provided best at county level, d) a sufficient number of variables is available from federal statistical data, e) counties correspond to the designated European administrative unit NUTS3. This enables the approach to be transferred to other European countries, f) as administrative units, counties are readily understood by decision makers, and g) Government and reinsurance companies implement commissions to assess damage caused by floods at county level (Deutsche Rück 1999: 18). Furthermore, the county level was found to be a suitable interface for combining this study's vulnerability assessment with the other project partners of the DISFLOOD project (see Chapter 6.1). It also enables multi-scale verification with local studies carried out at the partner institutions and at UNU-EHS (Fekete et al. 2009).

4.2 Social susceptibility per county

Susceptibility describes the general weakness of, in this case, the human population per county towards stresses such as natural hazards. Susceptibility is one of the major components of social vulnerability. Although several characteristics of susceptibility are valid for several natural hazards, for the purpose of this study, the specific susceptibility towards river floods is analysed. The advantage of this approach lies in its applicability for all regions in Germany. At the same time, there are not only weaknesses, but also specific capacities to reduce the susceptibility, which are also captured.

4.2.1 Data

The data used are standard census data of the Federal Statistical Office in Germany. The Federal Statistical Office releases demographic statistics of all counties annually. This enables an annual updating of the index and continuous monitoring for longitudinal studies. The data on variables such as age comes in classes of age groups, per gender, unemployment sub-classes, etc. The used data set, released in the middle of 2007, covers 439 counties and contains 33 categories with around 1100 variable classes from the end of 2004 (Destatis 2006a). The Federal Office for Building and Regional Planning (BBR) releases the same data set in a convenient end-user format (BBR 2007). This data set released in mid-2007 contains 800 'indicators' of 23 categories of data from the end of 2004. At finer resolution some data is available for municipalities, but only for a significantly reduced number of categories (only 12). For example, data on medical care or education is not available at municipal level (Destatis 2006b). Single categories have data gaps and therefore could not be used. The range of available data and the level of resolution are subject to data protection laws. Therefore, income and ethnicity are available only at county level although the data is collected at a finer resolution. The data and sampling can be regarded as very reliable, since federal institutions have long experience of conducting the sampling and use a standardized methodology. The number of counties and especially municipalities has changed over the years and hence, some manual data checking is unavoidable. Especially in the interplay with Geographical Information System (GIS) data on administrative boundaries, the comparison of the number of counties and the harmonization of ID numbers need careful manual revision. The administrative boundaries are provided by the Federal Agency for Cartography and Geodesy (BKG 2007) as GIS files. The 439 counties encompass all rural counties and city counties in Germany.

The terminology used for discerning the different steps of creating the indicators and the final index progresses from data, variables and sub-variables, to single indicators, and finally to a composite index. The artificial term 'sub-variable' means sub-classes or sub-categories of variables and is used to avoid confusion.

Table 5: Analytical categories and assumptions on the explanation of the variables

Main categories of variables	Assumptions of social vulnerability
FRAGILITY	
Age	Susceptibility: Physical fragility and dependency of very young and very old people Capacities: More experience and knowledge of elderly people
DEPENDENCY	
Special needs groups	Susceptibility: Handicapped people and persons in need of medical care are highly dependent on the help and assistance of other people
Gender	Susceptibility: Women in general and especially single mothers have lower income resources Capacities: Females have family and take over responsibility
KNOWLEDGE	
Education	Susceptibility: Linked to income groups Capacities: Could show level of knowledge or access to news
Ethnical background (Foreigners)	Susceptibility: Language problems for understanding flood warnings, less included in flood preparedness institutions Capacities: Own networks, neighbourhood help
INCOME RESOURCES	
	Low income Susceptibility: Precarious income situation Capacities: Less financial resources for private protection measures or insurance
Income (/Job qualification)	High income Susceptibility: More values to lose, less neighbourhood help Capacities: More financial resources for private protection measures or insurance

Source: Author

Before running statistical analyses, the variable selection has to follow certain selection criteria and goals of measurement (Nardo et al. 2005; see Chapter 3.2). Table 5 summarizes the chosen variables and arguments for susceptibility and capacities. Arguments for and against the selected indicators are taken from literature sources as included in table 3, from considerations in table 7, and the review of social vulnerability findings in chapter 2.4. The objective of the following explorative factor analysis is to find whether the single variables can be grouped into certain social profiles. The main topics of interest that are to be analysed on potential linkages are age, gender, ethnic background, education, and income.

In addition to the social group variables, measurable physical contexts, such as infrastructure variables, are included in the factor analysis (see Table 6). The purpose is to show the relationships of certain social profiles to certain infrastructure or regions. It is also investigated whether the social groups have any relation to the economic potential or demographic development of a region.

Table 6: Second set of variable groups containing context variables

Measurable context	Social vulnerability context
Medical supply	Major capacity to reduce mortality and health problems
Urban – rural context	Capacities like disaster management institutions higher in urban areas More surface sealing in urban areas = hazard aggravation More social focal points in urban areas (see also Fekete 2009a).
Building or apartment type	Bigger apartments or single family homes are more related to higher income and home-ownership which means more financial resources and awareness towards private preparedness measures like insurance or retrofitting
Potential of the region/county	Economic prosperity of a region as a capacity in terms of financial resources for flood protection measures Future development of demographic composition like ageing of the population as a susceptibility factor

Source: Author

The selected variables show the vulnerability of a county, as a profile of typified demographic profiles, settlement patterns, and infrastructure information. It is not intended to capture profiles of single individuals or buildings at this level. Therefore, variables such as the number of unemployed people per county suggest general characteristics of the county (see Table 7). While many unemployed individuals might not suffer from financial difficulties, this is nevertheless a reasonable assumption for the group of unemployed people in each county.

The overview table on the variables used for the factor analysis (see Table 7) arranges each variable according to the categories of susceptibility and capacities. The sub-categories of fragility, dependency, knowledge, and income resources guide the analytical scrutiny of gathering arguments for and against the indication of susceptibility by these variables. These arguments are based on the analysis of evidence of social susceptibility from other studies (see Chapter 2.4), the literature review and interpretations of the author. Hence, this is only a preliminary list of assumptions for an exploratory study.

Table 7: Variable matrix with presumed direction of each sub-variable for or against susceptibility

Sub-variables	Physical fragility towards mortality or severe health impact	Dependency on medical assistance, children to supply for, on welfare and supply	Experience, knowledge, awareness, language skills	Financial resources for private preparedness measures like insurance or retrofitting
Age variables				
- Residents below age 6	s	(s)	s	s
- Residents from age 6 to 18	(c)	s	s	(s)
o Residents from age 18 to 25	c			(s)
+ Residents from age 25 to 30	c			
+ Residents from age 30 to 50	c	(s)		(c)
o Residents from age 50 to 65			(c)	(s)
- Residents age 65 and older	s	s	c	(s)
- Dependency ratio age 0-15		s	s	(s)
- Dependency ratio age 65+	s	s	c	(s)
Dependency variables				
- Persons in need of care	s	s		
- Handicapped unemployed ratio	s	s		s
- Female sex		s		(s)
+ Male sex		c		
Education and knowledge variables				
- Graduates without Hauptschule degree			s	s
(-) Graduates with Hauptschule degree			(s)	(s)
o Gymnasium pupils				
+ Graduates with high school graduation				c
+ University students			(c)	c
- Foreigners			s	
Income resources variables				
+ Income per hh				c
- Unemployment				s
- Females unemployment		s		s
- Foreigners unemployment			s	s
- Young people unemployment		s		s
o Elderly unemployment			c	s
- Long term unemployment		(s)		s
+ Female employed		(s)		c
+ Foreign employed			(s)	c
o Low qualification employed				
+ High qualification employed				c
- Foreign females		s	(s)	
- Social welfare recipients				s
- Female social welfare recipients		s		s
- Foreign social welfare recipients			s	s
- Rent subsidies				s
- Youth social welfare recipients				s
Resulting predominating direction of susceptibility: increase: -, reduction: +, neutral: o	s = higher susceptibility than average c = predominant capacities hh = household			

Sub-variables	Physical fragility towards mortality or severe health impact	Dependency on medical assistance, children to supply for, on welfare and supply	Experience, knowledge, awareness, language skills	Financial resources for private preparedness measures like insurance or retrofitting
Medical care variables				
+ Doctors		c		c
- Residents per doctor		s		(s)
+ Hospital beds		c		c
Urban – rural type variables				
- Built area per undeveloped area				
c Open space				
- Population per settlement area				
+ Rural population			(c)	
o Urban centre closeness				c
+ Building land prices				
- Commuters in				
Building type / living conditions variables				
c New apartments				c
+ One and two family homes			(c)	c
- Multi family homes (variable was corrupt)				s
- Small apartments				s
+ Big apartments				c
- Persons per room		s		s
- Persons per apartment		s		
+ Living space pp				c
- Persons per hh		(c, s)		(s, c)
+ Single hh		c		(s)
- New residents			s	
Potential of the region / county variables				
- Municipality debts per resident				s
- Tourist overnight stays		(c)	s	s
- Key funds allocation				s
+ Fixed investments				c
+ GDP per labour force				c
+ Regional population potential (=contact potential)			c	c
o Residents per workplace				c
o Value added by primary sector				
o Voter participation (federal parliament elections)			(c)	
- Elementary schools per resident		s		
- Day-care centre		s		
- Rehabilitation centres per Resident		s		
- Medical care centres	(s)	c		
- Population projection age 0-20	s			
+ Population projection age 20-60	c			c
- Population projection age 60+	s			
Resulting predominating direction of susceptibility: increase: -, reduction: +, neutral: o		s = higher susceptibility than average c = predominant capacities hh = household		

Source: Author

The reasoning follows established argumentations of the federal offices concerning the general demographic indication potential of the variables (detailed documentation in INKAR 2006). However, in this study, these argumentations are only considered in the context of deficiencies and advantages of the demographic indications towards river floods. This implies that, for example, the variable *new residents* is a negative measure of increased susceptibility, although in the usual context of demography this variable indicates a positive measure of increased attractiveness of a region. The negative indication is given because of an assumed average deficiency in local knowledge about river floods and lack of involvement in community preparedness. When the indication is found weak, it is put into brackets. The extreme left column shows the resulting overall positive or negative indication of each variable regarding susceptibility (resulting predominating direction of susceptibility: increase: -, reduction: +, neutral: o). The variable *tourist overnight stays* is difficult to interpret; on the one hand it shows the positive economic attractiveness of a region, on the other hand this economy is dependent on the tourists. At the same time, this indicator shows that a high number of tourists are located in a potential disaster area. In the event of a disaster, tourists typically have less local knowledge, but at the same time possess a greater flexibility to abandon the place of stay.

The number of sub-variables differs; for example, there are eight sub-variables of age groups but only one for income. The reason is that there are fewer sub-variables of income available. For social weaknesses a relatively large number of variables were chosen; for example, *unemployment*, *rent subsidy* and *welfare recipients*, although it is quite likely that they were highly correlated from the beginning. However these variables were included on purpose, since the aim was to find as many linkages of these indicators describing social difficulties to the other variables, such as age or education, as possible. In many cases the opposites of the ends of a spectrum are chosen in order to enable a linkage of positive and negative indications. For example, the variable *doctors per total population* measures the same pattern as residents per doctors. However, the indication of a higher numbers of doctors is a positive indicator and is related to other groups of socio-economic strengths, while the higher number of *residents per doctors* is linked to socio-economic weakness groups.

Standardization: Within the harmonization step, ratios are built for certain variables such as the absolute number of unemployed people per total population. The variables are all interval scaled and no categorical or nominal variables are included. The term standardization (=normalization) is used for transforming these harmonized values into equal intervals from zero to one. Population characteristics such as unemployment or age sub-variables are harmonized as ratio per total settlement area of the county and not per total area of the county in order to obtain the best possible precision from the data. There are contrary procedures depending on whether harmonization and standardization steps are conducted before (Bühl and Zöfel 2002: 465; Schneiderbauer 2007: 54) or after the Principal Component Analysis (PCA) and/or factor analysis (Nardo et al. 2005). In a trial phase, all three versions, raw data, harmonized, and additionally standardized data to equal ranges (zero to one) were computed. The resulting factors differed. Some variables switched from the first to the second factor but the overall picture did not change substantially.

The data is harmonized first to enable comparability of the counties which do not have a uniform spatial coverage of settlement area. For example, the total number of unemployed people is set in relation to total population per county. With this step of harmonization, a rural county is not automatically lower in the unemployment profile compared to a large city county. Since the harmonization step builds variables with a certain content of argumentation, this step is performed before the factor analysis. The data set INKAR 2006 (BBR 2007) is selected since it already contains most variables of interest of the federal statistics and already has a standardized harmonization applied. The documentation of INKAR 2006 provides an overview of each variable and its harmonization (BBR 2007). Only the variables male gender, voter participation, municipality debts and unemployed disabled people are added from the data set of Statistik Regional (Destatis 2006a) and are harmonized according to the data set by dividing per total population per county.

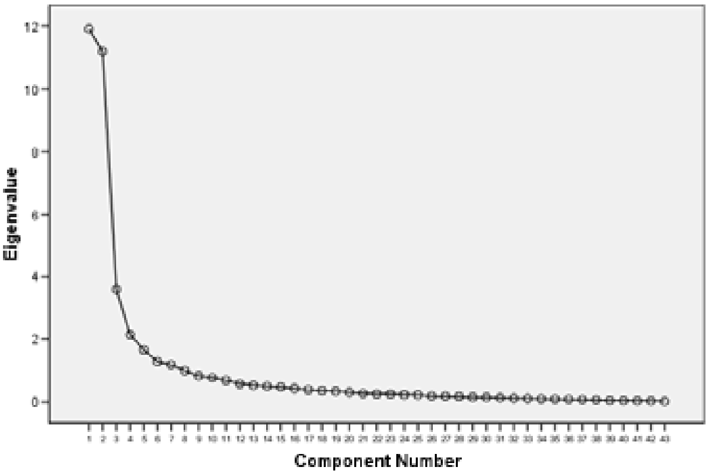
One form of standardization is already built into the procedure of factor analysis (SPSS 14.0). This is one argument against performing an additional standardization step prior to the factor analysis. The standardization step which puts the variables into equal ranges is performed after the factor analysis to enable an equal range summation of the variables for the creation of the indicators. The minimum-maximum technique scales all variables to a common base and to an identical range (Cardona 2005: 157). Standardization (normalization) can be conducted by building percentages or by using z-scores (Simpson and Katirai 2006: 3). Equal ranges from zero to one are selected as a conservative approach, since no reasons for highlighting extreme values (as in z-scores) were found.

4.2.2 Statistical analysis

The scope of this factor analysis is to extract profiles of social groups regarding certain characteristics such as income, gender, or age that can be linked to a certain extent to measurable variables such as building type, urban or rural context, and medical care. The objective of using factor analysis as a method is variable reduction in order to derive a set of variables that summarize social susceptibility characteristics. Additionally, underlying structures of interdependencies between variables can be extracted to build a social susceptibility profile.

Methodology: Factor analysis is a multivariate analysis technique used to identify information packaging by considering the interdependencies between all variables (Bernard 2006: 495). The factor analysis is carried out in SPSS version 14.0 with a PCA for data reduction and identification of variable groupings. The methodology of the factor analysis follows standard procedure (e.g. Nardo et al. 2005). First, the PCA is intended to find a linear combination of variables that accounts for as much variation in the original variables as possible. A Varimax rotation with Kaiser Normalization is applied to the component matrix in order to facilitate the interpretation (Schneiderbauer 2007: 55) by rotating the axes of the components so they are perpendicular to each other. This step places the respective components as far apart from each other as possible. The extracted communalities are all above 0.5, which indicates that the extracted components represent the variables well. For the interpretation, only eigenvalues greater than one are considered and absolute loading values below 0.30 are suppressed (Nardo et al. 2005: 40, 43; Bühner 2006: 200, 211; Bernard 2006: 677). The eigenvalue is the standardized variance associated with a particular factor. The scree plot serves as another criterion to limit the number of factors. The factors on the steep slope up to the ‘scree elbow’ in the curve are especially able to explain most of the data (see Figure 8).

Figure 8: Scree plot of the factor analysis showing the eigenvalues (y-axis) explained by the resulting factors (x-axis)



Source: Author

The factor analysis follows the principle of variance maximization, whereby factors are sought that explain most of the variance of all items (Bühner 2006: 182). The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) of 0.905 indicates that the variable selection is suitable for factor analysis. The KMO explains the proportion of variance in the variables that might be caused by underlying factors. KMO-values above 0.60 indicate an acceptable level, and from 0.80 a good level of compatibility of the variables with the test (as cited in Bühner 2006: 207). A value below 0.05 of the Bartlett’s test of sphericity rejects that the variables are unrelated and therefore unsuitable for structure detection.

Pre-processing procedure: First, a full-model approach is carried out containing all variables and a consequent stepwise exclusion, as this is an exploratory approach. Starting with single variables and exploring the stability of the pattern after adding other variables is found to be problematic in this context. That is because it is not one factor that is the main concern, but at least eight categories, namely age, income, education, ethnic background, gender, urban or rural context, individual house or apartment style and medical care supply. Selecting one category to start with implies a priori judgement and selection bias.

After the factor analysis is carried out, a final set of variables with a stable pattern is established, and explanation patterns of the correlations are analysed (see Table 9 further below). The factor analysis is repeated, this time stepwise in the other direction, starting with only age variables, adding all fragility variables, then the dependency variables, then experience and knowledge variables, then financial variables, and finally exposure variables. Up to the third category, experience and knowledge, the patterns develop slowly, are stable, and the KMO increases to over 0.70. The same patterns as in the stepwise exclusion procedure are found, which supports the validity of these resulting components.

Certain sub-variables, such as unemployed females, female social welfare recipients, etc. are removed after trial runs as they distort the factors. The reason is that these sub-variables are mainly correlated to the female gender variable. Finding this correlation is not the target; rather it is finding correlations of female gender to other social groups. For the same reason unemployed foreigners and other sub-variables of unemployment are excluded. However, the major variables, such as females or foreigners, are still included.

From an initial 69 variables, 41 are used in the factor analysis, while 28 are excluded for various reasons. Excluded variables that are stepwise excluded because they are sub-variables of a latent main variable are:

- Female unemployment
- Female social welfare recipients
- Female university students
- Foreigner unemployment
- Foreign vocational trainees
- Foreign pupils
- Foreign high school students
- Foreign social welfare recipients
- Foreign university students
- Unemployed young people
- Unemployed elderly
- Long-term unemployment
- Young social welfare recipients.

Excluded variables that are redundant or that can be explained by similar variables:

- Dependency ratio of the 0-15 year old
- Dependency ratio of age 65 and older.

Excluded variables that are the contrary to a second variable:

- Commuting out
- Moved away.

The anti-image correlation matrix (= the individual KMO statistics) reveals that some variables, such as the age sub-variables, are all highly correlated. No variables have to be excluded from the criterion of the measure of sampling adequacy (MSA), since the values on the diagonal of the anti-image matrix are all above 0.6, which is regarded as sufficient to show that each variable fits the factor (Backhaus et al. 2006: 310). However, those variables with off-diagonal correlation values of 0.5 and more are consequently excluded.

- Residents from age 6-18
- Residents from age 18-25 (have no direct assumption of susceptibility and can therefore easily be excluded)
- Residents from age 50-65 (have no direct assumption of susceptibility and can therefore easily be excluded)
- Male gender (the opposite of female gender)
- Multi-family homes (the opposite of one and two-family homes)
- Single households (contained in persons per household)
- Doctors (the opposite of residents per doctor)
- Built area per undeveloped area (highly related to population per settlement area)
- Big apartments (the opposite of small apartments)
- Population projection age 20-60.

After the first exclusion of values higher than 0.5 the anti image matrix still reveals three variables with values higher than 0.5. However, they are not excluded since they contain important information about social susceptibility. Two of the variables belong to age groups; residents aged 65 and older and population projection of age 0-20. In particular, the elderly group but also the projection of the very young provide key information on social susceptibility and cannot be discarded. The third variable, commuters, is correlated to a value-loading of 0.5 with new residents. Both variables indicate different aspects of susceptibility (see Table 7) and therefore should not be excluded. Commuters are potentially vulnerable due to interruption of traffic lines, while new residents are vulnerable due to lack of local experience, for example.

4.2.3 Results

The cumulative rotation sums of squared loadings of the first three factors together explain 59.0 per cent, and the seven factors explain 76.6 per cent of the cumulative variance (see Table 8).

Table 8: Variance explained by the components after the Principal Component Analysis and the rotation

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	10.700	26.096	26.096
2	9.057	22.091	48.187
3	4.448	10.848	59.035
4	2.228	5.434	64.469
5	1.938	4.727	69.196
6	1.880	4.586	73.782
7	1.147	2.798	76.580
41	…	…	…
Extraction Method: Principal Component Analysis.			

Source: Author

The value loadings are compared per component in the rotated component matrix. Positive values comprise one group of variables in the components while the negative loadings represent another group. The two groups differ either in one or more distinct variables that logically belong to ends of a spectrum, for example high income versus high unemployment. Therefore, the two groups within a component represent two sides of the coin of susceptibility. The groups can be interpreted and named according to dominant variables within that group with a high value loading. Nevertheless, all variables in each factor are considered in the interpretation.

Table 9: Rotated component matrix of the factor analysis showing the computed value loadings

Input variables with presumed direction towards susceptibility: - more vulnerable, + more capacities	Component						
	1	2	3	4	5	6	7
- Residents below age 6		0.773	-0.423				
+ Residents from age 30 to 50			-0.850				
- Residents age 65 and older		-0.318	0.882				
- Persons in need of care			0.586			0.377	
- Handicapped unemployed		0.629					
- Female gender	0.632		0.545				
+ Income per hh		0.767			-0.343		
- Unemployment		-0.830	0.330				
+ Female employed	0.821						
+ Foreign employed		0.705					
+ High qualification employed	0.737	-0.307				-0.329	
- Foreign females		0.828					
- Social welfare recipients	0.433				0.655		
- Rent subsidies		-0.811					
- Graduates without basic education		-0.415			0.380		0.540
+ Graduates with high school graduation	0.740	-0.337					-0.454
+ University students	0.719						
- Foreigners	0.597	0.618					
- Residents per doctor	-0.829						
+ Hospital beds	0.707					0.348	
+ Rural population	-0.724			0.303			
- Population per settlement area	0.833					-0.358	
+ Open space	-0.735				-0.383		
+ Building land prices	0.634	0.484					
- Commuters in	0.734						
+ New apartments		0.350	-0.681				
+ One and two family homes	-0.819						
- Small apartments	0.824			0.378			
+ Living space pp	-0.351	0.583				0.444	
- Persons per hh	-0.756		-0.376				
- New residents	0.697	0.340	-0.369				
- Municipality debts per resident					0.567		
- Tourist overnight stays				0.904			
+ GDP per labour force		0.637					0.396
- Key funds allocation		-0.800					
+ Fixed investments	-0.375	-0.613			-0.359		
- Day-care centre		-0.866					
- Rehabilitation centres per Resident				0.840			
- Elementary Schools per Resident	-0.649						
- Medical care centres			0.451			0.618	
- Population projection age 60+		-0.736	0.580				
Interpretation:							
Positive value loadings	Urban	Young, income,	Old, fragile	Tourism	Welfare, debts	Care centres	Low education
Negative value loadings	Rural	foreigners Financial deficiencies	Mid-age, home owners				
Percent variance explained	26.1%	22.1%	10.9%	5.4%	4.7%	4.6%	2.8%
Factor name	**Regional conditions**	**Socio-economic conditions**	**Fragility**				
Abbreviations: hh = household, pp = per person. Varimax rotation, PCA, N = 439							

Source: Author

4.2.4 Discussion

The factor analysis of an input of 41 variables uncovers seven latent factors that describe relationships between all variables to 76.6 per cent of the cumulative variance (see Table 9). From these seven factors (or components), only the first three factors contain more than two loading values that are marked per column (see Table 9). The values marked are those per variable which load highest within the seven factors matrix. The value loadings are usually displayed as sorted after the highest value loadings in each component. No sorting is applied here in order to avoid the impression of a logical hierarchy, which should not be interpreted from this explorative approach. Value loadings below 0.3 are suppressed and not visible, since they do not represent a strong explanation of the variance. The absolute value loadings with a precision of three positions after the decimal point might be misleading. Factor analysis contains much uncertainty and subjectivity in the selection process. Therefore, one position after the decimal point is sufficient for the precision of interpretation. This is recommendable, since only minor modifications of the input selection or standardization process lead to shifting positions within the matrix of the highest loading values per variable. Considering only one position after the decimal point reveals that for example, the variable *foreigners* is as much in component 1 as it is in component 2, with a value of 0.6. Foreigners are related to the **regional conditions** as much as to the **socio-economic conditions** factor. The resulting matrix can therefore never be considered as definite. It is only an exploratory suggestion of groupings and patterns. In several intermediate steps the same patterns of variable groupings could be observed. They were relatively stable and support the interpretation of this rotated matrix.

The **first factor** is named **regional conditions** because the variables can logically be related to either more urban or rural environments. For positive value loadings, *population density per settlement area* is the highest loading value, followed by *small apartments, employed females*, and *high school graduates.* This urban environment is also associated with *hospital beds* as a sign of density of medical care. Following the arguments outlined in Table 7, no univocal picture of increased susceptibility can be framed. The variables with positive argumentation for the predominant coping capacities of urban environments prevail, but with six positive versus five negative variables this is not a clear profile. Especially when considering that the variable *foreigners* can also be associated with component one, adding one more negatively assumed variable.

The profile of the positive value loadings in component one describes urban environments. It is composed of variables that are positively associated with high levels of education, medical care supply, and employment opportunities. It is also characterized by variables that would usually describe the attraction of urban space, such as *new residents* and *commuters*. However, the latter two variables have negative assumptions concerning the vulnerability of humans towards river floods. New residents could, on average, be assumed to have less experience of local floods, less local knowledge of preparedness against floods, and maybe fewer networks with neighbours. Commuters are dependent on daily access to their work place and may be affected by job interruption. *Population density per settlement* *area* includes not only attractiveness of job opportunities but also social problems of social segregation and social focal points (see Chapter 2.4). Moreover, of course, more population density means more exposure of human beings, and more needs in terms of evacuation and emergency shelters. *Female gender* is ambiguous, since females are generally more responsible for taking care of children and infirm people. They are therefore bound to rescue other people than just themselves, and are often financially dependent on their partners or the government. On the other hand, females are more risk averse (see Table 3, Chapter 2.4) and more responsibility for other people can also mean more awareness and preparedness. It must be reiterated that there is no intention to stereotype people in this context; the scope is solely on finding general profiles for whole regions, such as counties. *Building land prices* is also on the one hand very positive, since it indicates high financial resources, for example for retrofitting or other measures. On the other hand, river front properties are often expensive, which attracts the affluent but also increases their exposure.

The profile of the negative value loadings in component one also allows no association with negative profiling of susceptibility. Following table 7, indeed the positive arguments prevail for the six variables that are associated with more rural environments. *Rural population* has less population density and settlement area that is exposed, more *open space* indicates less surface sealing and less surface run-off. The high number of *one and two-family homes* suggests more home owners who typically are more interested in preserving their property compared, for example, to tenants. This implies that awareness as well as more financial resources for private preparedness, such as insurance or mobile defence measures, is probably higher for this settlement type than for low-income groups who reside as tenants in multi-family homes. However, living in the countryside has some disadvantages from the perspective of a vulnerability assessment as well. More *residents per doctor* and longer distances to hospital increase susceptibility. The number of *persons per household* is critical in analysis; on the one hand more family members are available to help each other. On the other hand, larger families often have to share income sources and have more dependent people such as children and elderly to evacuate and provide for. *Elementary schools* provide education, but a region can become vulnerable when this central infrastructure is exposed.

The **second factor, socio-economic conditions**, explains a little less percentage variance (22%) than the first factor (26%). Like the first factor, **regional conditions**, it bundles a high number of variables which partly explains why these two factors share high percentages of total variance. However, contrary to the **regional conditions** factor, the factor **socio-economic conditions** paints a clearer picture of positive and negative directions of measurement.

The negative loadings are related to variables with predominantly negative assumptions on susceptibility. The variables *unemployment, rent subsidies,* and the high figure for *key funds allocation* for this type of region all imply financial deficiencies. These financial deficiencies of a county could lead to less investment in technical and non-technical preparedness measures towards floods. While unemployment may not render an individual automatically poor, it is a reliable general indicator of the average income situation in a county. Unemployment is highly associated with the long-term unemployed and the female and foreign unemployed. These are special needs groups that are more dependent on other family members and the government. One might argue that the poor have less to lose, but one could also contend that the low-income groups suffer more from minor income cuts and losses. Low-income groups are also associated with low education and social focal points. As with all variables, precise local studies are necessary to verify such assumptions. The only variable thought to represent a positive argument, fixed investments, could be related to the high figure for *key funds allocation* and therefore is misleading for the interpretation. The high number of *day care centres* and the *population projection age 60+* of a disproportionate increase of the number of elderly people in these regions all indicate that elderly people are associated with regions of less income. Elderly people are not only more fragile in terms of health but are also more dependent on medical care and availability of finance.

The positive loadings of factor two represent the opposite; it is dominated by young people (*residents below age six*) and *high income. Foreigners* are also a strong group, which is probably an artefact of the three variables of foreigners in this component. The grouping of the positive loadings can be interpreted as dependent people of up to six years of age who reside in good living conditions, for example having a large *floor space per person* and high *GDP per labour force*. The *disabled unemployed people* are also dependent. This variable is a surrogate for disabled people in general, since this data is not available from the federal statistics data sets. The association of foreigners with high income variables was found in a steady pattern throughout several trial steps in the factor analyses. This indicates that foreigners should not automatically be stereotyped as poor, at least not from this factor analysis. The highest loading value in this grouping is *foreign females,* who are attributed with a potential lack of language skills, and dependency in terms of caring for children concerning flood hazard (see Table 7). The variable *foreign employed* typically hints at low wage jobs in general (BBR 2007) which makes this group especially interesting for further investigation. Low-income jobs can, for example, indicate susceptibility to even minor cuts in income.

The **third factor, fragility,** denotes age as a discriminator of the physically fit against physically more fragile age groups, such as the elderly. Only four variables carry value loadings high enough to separate them into the third component. This **fragility** factor explains about 10.9 per cent of the variance, which is only half of the variance explained by the first two factors, but still the double the variance of the residual four factors in the rotated component matrix. The positive value loadings clearly designate *residents age 65 and older* as related to *persons in need of* (medical) *care and nursing assistance.* Obviously, this group is also associated with areas of a projected relative population increase of the elderly above 60 years of age. There is also a high relation to female gender, which might be explained by the higher number of females who reach old age, especially in western Germany. The negative value loadings of the fragility factor indicate people of middle age, *residents from age 30 to 50*. They are related to *new apartments,* which could indicate their financial resources and typical time phase for being able to afford a home. In previous trial runs of the factor analysis, this group was also related to male gender and sometimes to persons per household. Generally this group represents the opposite of physical fragility, which is an important discriminator of survival and evacuation needs in case of an extreme river flood.

Factors four to seven load high on only one or two values and are all attributed with negative explanations in terms of the presumptions of higher susceptibility as denoted in table 9. This is at least partly due to an overall over-representation of negatively attributed variables in the selection of this factor analysis. It must be emphasized however, that this pattern remains stable in other configurations of the same data sets even when the ratio of positively and negatively labelled variables (see Table 7) is equal. This was tested in several trial configurations with variable sets containing between five and over 60 variables. The main purpose of this factor analysis is to elicit potential weaknesses. Therefore, it is justifiable to have factors four to seven included in the factor analysis with only negatively attributed variables. These factors pinpoint additional factors that explain much variance and singular characteristics of susceptibility. The inclusion of more variables that compensate for the negative susceptibility indication is hampered by an increase of partial correlation values above 0.6 in the anti-image matrix.

Factor four contains *tourist overnight stays* as related highly with *rehabilitation centres.* Both variables bear a negative susceptibility indication, since regions with this characteristic are dependent on income from tourism. When tourists stay away due to floods, or in flood damage recovery phases, these regions are economically affected. Additionally, the evacuation of a high number of tourists might be a difficult task in the event of an unexpected sudden onset flood. Likewise, rehabilitation centres increase the exposure potential of people dependent on assistance, medical care, and evacuation help. Factor five bundles *social welfare recipients* with *municipality debts*. This indicates the financial problems of residents and the government of a county. Factor six contains only one variable, *medical care centres.* These centres are mainly nursing homes which house a large number of infirm and fragile people. Factor seven is equal to the variable of graduates without 'Hauptschule' qualification. 'Hauptschule' is a distinct German type of school like a secondary modern school. The absence of this education level indicates low-income resources and low job opportunities (BBR 2007). This variable is also highly related to the income deficiencies group in factor two.

The factors allow for profiling of the German counties regarding general susceptibility to stresses and natural hazards, but most precisely to river floods. These profiles are patterns of social demographic groups that can be identified per county. Therefore, this is an excellent tool to compare all counties in Germany since it allows consideration of arguments for and against increased social susceptibility to floods. While the argument categories are amendable and extendable, this profile is a starting point for tagging areas of special concern regarding flood vulnerability as determined by the social composition of the population.

4.3 Flood impact assessment

For the purpose of testing the social susceptibility profiles in a real flood event, a second data set is selected. The research question is whether a real extreme flood event reveals some of the potential social susceptibility that is expected from the literature review and the susceptibility factors developed. Due to the lack of data on extreme event evidence in Germany, validation is difficult. Therefore, the author is very grateful to the partner of the DISFLOOD project, GFZ, who provided a data set developed from a household survey conducted after the extreme floods of 2002 in Germany. While the scope of this survey is mainly on flood damage characteristics of buildings and properties (Kreibich et al. 2005a), it also deals with flood preparedness and recovery (Thieken et al. 2007). Additionally, the survey captures demographic categories which are of special interest for validating the social susceptibility profiles.

4.3.1 Data

The data set of a telephone survey involving 1697 households affected by the floods in 2002 is provided by GFZ and Deutsche Rückversicherung. The survey is entitled "Flooding in 2002: Damage to private households" (GFZ Potsdam and Deutsche Rückversicherung AG 2003). The survey covered three major regions, the River Elbe and the lower Mulde River; the Erzgebirge (Ore Mountains) and the River Mulde in Saxony; and the Bavarian Danube catchment area (see Figure 3, Thieken et al. 2007: 1020). In each region about the same number of interviews was conducted. For the sample design, the authors provide the following detailed description:

"On the basis of information from the affected communities and districts, lists of affected streets in the investigated areas were compiled. A random sample was generated on the condition that each street should be represented in the data set at least once and that each building should be included only once. Thus, only one household was selected in multiple-occupancy houses, so that the sample is representative for buildings. In total, 11,146 households (with telephone numbers) were selected. Computer-aided telephone interviews were undertaken using the VOXCO software package by the SOKO-Institute, Bielefeld, Germany, between 8 April 2003 and 10 June 2003. In each case, the person in the household who had the best knowledge about the flood event was questioned. Tenants were only asked about their household and the content damage. To complete the interview, the building owner was questioned about the building and damage to it. In total, 1697 interviews were carried out; on average, an interview lasted 30 minutes." (Thieken et al. 2007: 1021)

In order to find evidence of whether the presumed social susceptibility concept and profiles play a role in the outcome of a disaster, a testing category has to be identified. The questionnaire data provide some categories that compare the damage to the building and the damage to the household properties of the affected households. This test category is not used because economic damage evidence alone might not be enough to explain the whole range of social susceptibility as outlined in chapters 2, 3 and 4.2. Furthermore, this analysis is the domain of the original authors and has been analysed extensively (Kreibich et al. 2005a; Kreibich et al. 2005b). For the purpose of this study, the question 'Did you have to leave your home due to the flood?' is identified as a much better discriminator of people severely affected by the flood in terms of social vulnerability. This question does not focus on the economic perspective only, but captures a broader scope of exposure, susceptibility, and capacities. The people who had to leave their home were especially exposed to floods, and had to cope with finding an interim shelter and with the recovery phase after the flood. For this they needed financial resources but also social networks, such as friends and relatives.

Some of those people (N = 765) who had to leave their home had to seek emergency shelter (N= 70). This is an especially interesting sub-group because it can be assumed that these persons lacked alternative social networks or financial resources. Since the questionnaire contains no questions about the exact reasons for each decision of the single individuals in the survey, these are only assumptions. However, they can be compared to findings on social vulnerability in evacuation groups (Cutter et al. 2003; Chakraborty et al. 2005 and Chapter 2.4). Therefore, 'people forced to leave their home' and 'people who had to seek emergency shelter' are appropriate test categories for eliciting different social group profiles. They permit comparison of those who had to leave and those who were able to stay in their homes, despite being affected by the flood.

The third test category is taken from the question 'are you satisfied with the status of damage regulation'. The answers were expressed in a positive to negative range from one to six. This range is transformed into binary coding for enabling bivariate comparison. Indirectly, financial needs and satisfaction with administration are to a certain degree identified by this dependent variable. This type of susceptibility measure therefore complements the other two dependent variables that capture evacuation needs.

4.3.2 Statistical analysis

The binary logistic regression analysis is a statistical model which is used for predicting a binary dependent variable using one or more independent variables. The dependent variable is the test category for flood impact, for example, whether the people had to leave their home or not. The independent variables are demographic variables such as age, income, job situation, etc. Both interval and categorical variables can be used, yet categorical variables with more than two parameter values have to be transformed into dichotomous sub-variables (Fromm 2005: 5). Logistic regression analysis is used for explaining differences between groups or for predicting membership of groups. No assumptions on (normal-) distributions have to be met, while multi-collinearity should be avoided and monotony of the variables should be observed (Fromm 2005: 6, 12). The following variables are selected for the binary logistic regression analysis according to the theoretical categories in the BBC framework susceptibility, capacity, and exposure (see Table 7). Three binary dependent variables allow testing of adverse outcome: if people had to leave their home or not, if people had to seek a public emergency shelter, and if people were content with the damage restoration after the flood. The binary logistic regression is computed in SPSS 14.0 and STATA 10.0 SE.

Selection: First, variables are selected, missing values defined, then cross-tables and correlation are checked. The number of cases per variable is high enough to permit logistic regression analysis (Fromm 2005: 6) and the number of missing values is tolerable. Missing values are not satisfactory for the varibale income. Income is a sensitive issue in questionnaires and the high number of missing responses is not surprising. Therefore, this variable has to be interpreted with care. The ordinal variables, such as home ownership, school, job, or income, are arranged in logical order of the respective sub-variables. This logical order is consistent in the sense that it ranges from negatively attributed income or education levels to positively attributed levels. However, *job types* has to be treated with caution. While this ordinal variable is also oriented in a logical order, it would be misleading to attribute absolute negative and positive directions to it. Only those job types present in the data set of the factor analysis are selected. In this case, unemployed persons are of special interest. Also, a *high qualification employees* sub-variable is created from doctors, lawyers, tradesmen, businessmen, and magistrates.

In order to avoid multi-collinearity only those variables that are not highly correlated with each other are selected for the regression. The variable 'persons under 14 years of age per household' (pop14) is included in addition to the so-named age variable. The reason for this decision is the limited range (16 to 95 years) of the age variable in this data set. This is due to the survey methodology, whereby only persons older than 15 years were interviewed as representatives of one household. In order not to omit children, who are an interesting group, the variable pop14 is added as it includes persons younger than age 14. Urbanity is calculated according to the definition of rural areas for the respective variable of the first data set of the Federal Offices (BBR 2007). Rural areas are regions with up to 150 persons per km² per municipality. These areas are calculated in the GIS using the federal statistical data. They are added to the second data set as a binary variable (urbanity) separating urban from rural areas. The dependent variable of damage regulation is transformed into a binary variable from the range of answers from one to six (one = very satisfied, two = satisfied; … six = not at all satisfied).

Methodology: The logistic regression is computed for the three binary dependent variables individually. Each dependent variable is analysed with the same preselected sub-set of independent variables (see Table 11). From the set of independent variables a sub-set is selected after scrutiny of three criteria; whether they are contained in the first data set of the factor analysis as well, whether each sub-variable contains enough cases (Fromm 2005: 6), and whether the bivariate distributions already indicate strong differences. The resulting set of independent variables (see Table 11) is tested against each of the three dependent variables separately (see Tables 13, 15, and 17 further below). The aim is to validate as many variables of the factor analysis set as possible.

Table 10: Variables and sub-variables for input into the logistic regression analysis

Variable label	Explanation phh = per household	Scaling	Min/max values	Number of cases	Missing values
independent variables					
age	Age in years	interval	16-95 years	1663	34
gender	Female gender	binary	0; 1	1697	none
school	Education type	ordinal	1-7	1648	49
	1: No degree	binary			
	2: Elementary school degree	binary			
	3: Secondary school degree	binary			
	4: Polytechnic degree	binary			
	5: Technical college degree	binary			
	6: High school degree	binary			
	/: University degree	binary			
income	Income class phh	ordinal	1-6	1351	342
	1: Income of up to 500€ per month	binary			
	2: Income from 500 to 1000€	binary			
	3: Income from 1000 to 1500€	binary			
	4: Income from 1500 to 2000€	binary			
	5: Income from 2000 to 3000€	binary			
	6: Income 3000€ and more	binary			
job	Job type	ordinal	1-13	1629	68
	1: Doctor, lawyer	binary			
	2: Commerce, trade, business	binary			
	3: Magistrate	binary			
	4: White collar employee	binary			
	5: Farmer	binary			
	6: Blue collar worker	binary			
	7: Apprenticeship, student	binary			
	8: Family member, assistance	binary			
	9: Retired	binary			
	10: Home maker	binary			
	11: Parental leave	binary			
	12: Advanced training	binary			
unemployed	13: Unemployed	binary	0; 1		
high_qual_employed	recoded: high qualification employed = sub-classes 1,2,3	binary	0; 1		
pop14	Number of persons under 14 years of age phh	interval	0-5 phh	1697	none
pphh	Persons per household	interval	1-11 phh	1674	23
rooms	Number of rooms per household	interval	1-32	1653	44
ownership	Ownership		0; 1	1697	none
	Tenant, renter		0		
	Owner of the home / house Owner of the apartment	binary	1		
urbanity	Urbanity of the region	binary	1; 0	1697	none
dependent variables					
leave_home	Persons who had to leave their home due to the flood	binary	1; 0	1690 (N yes =765)	7
emergency_shelter	Persons who had to leave their home and seek shelter in public emergency shelters	binary	1; 0	1690 (N yes=70)	7
damage regulation	Persons who express satisfaction with the status of damage regulation after the flood	binary	1; 0	1167 (N yes = 974)	530

Source: all GFZ / Deutsche Rück 2002, except urbanity calculated by the author

Table 11: Sub-set of independent variables and sub-variables used for all three logistic regressions with the three dependent variables

Independent variables or sub-variables
age
gender
high_school_degree
elementary_school
income_very_high
income_1000
high_qual_employed
unemployed
retired
pop14
pphh
rooms
home ownership
urbanity

Source: Author

The quality of the statistical model is analysed by the Hosmer and Lemeshow Test which describes the model-goodness of fit of the input data for values with significance values above 0.05 (Backhaus et al. 2006: 457). The same variables are tested within a linear regression model in SPSS to identify multi-collinearities. Tolerance values above zero and Variance Inflation Factors (VIF) lower than 10 suggest no difficulties with multi-collinearity of the model (Nardo et al. 2005). Outliers that could distort the model are identified by z residuals and removed (see Table 12). The respective confidence intervals for the variables are observed to see whether they are either below or above one. This supports the view that these independent variables deliver a valid explanation (Fromm 2005: 24). Error margins are indicated by the quality tests described above, or by the confidence intervals. Additionally, Jackknife replication tests (Backhaus et al. 2006: 454) and bootstrapping analyses with 1000 repetitions (Moore and MacCabe 2006: 14-27) are applied to test the model stability.

Table 12: Data description and model tests of the logistic regression for the three dependent variables

Dependent variable	Cases included; (missing values)	Prediction after running the model; (initial prediction)	removed outliers (exceeding 2 standard deviations)	Hosmer and Lemeshow Test	Variance inflation factor
leave_home	960 (737)	57.0% (50.1%)	0	0.7	2.3
emergency_shelter	958 (739)	95.5% (95.5%)	2	0.6	2.3
damage regulation	765 (932)	85.6% (85.6%)	9	0.6	2.3

Source: Author

The main purpose of the logistic regression is to show whether there is a significant difference in the independent variables. The independent variables contain demographic susceptibility characteristics (e.g. age of persons) and are checked against dependent variables that contain binary yes/no cases. For example, independent variables such as *age* are checked within the full logistic regression model against the dependent variable *leave_home* to establish whether age is a factor that characterizes human groups as more vulnerable. The logistic regression provides two types of measurement that are of interest here. First, the regression model indicates which independent variables are significant within the full model; only these are selected for calculating the probabilities. Second, the probabilities calculated for the minimum and maximum values per independent variable predict the direction of impact of the dependent variable. This direction can be positive or negative, meaning that flood impact either rises with increasing values, such as higher income, or is inversely related to it. Only those variables that are significant for the test are displayed. The probabilities are used here only for the identification of the direction of influence of flood impact. The probabilities are not used for weighting or relative ranking of the variables since this is only an explorative approach. Further uncertainty analyses and additional confirmative analyses of flood impact cases would be a prerequisite for justifying the use of exact numerical values for weighting and ranking.

4.3.3 Results

Logistic regression no. 1 for leave_home: Table 13 reveals that three variables, *rooms*, *home ownership*, and *urbanity* are significant for the regression model at the 0.05 significance value. The range of the confidence intervals of *rooms* is low, while *ownership and* *urbanity* have a range large enough to expect a strong explanation of difference

From 14 independent variables the figures for rooms, home ownership, and degree of urbanity can best explain the distribution of those who had to leave their home and those who did not (see Table 14 and Figure 9).

Table 13: Significance and confidence intervals of the independent variables for the explanation of the dependent variable *leave_home*

Disasters per year [nb/year]		95.0% C.I.for EXP(B)	
	Sig.	Lower	Upper
age	.750	.988	1.017
gender	.960	.770	1.316
high_school_degree	.205	.887	1.753
elementary_school	.590	.660	1.266
income_very_high	.631	.752	1.599
income_1000	.601	.706	1.824
high_qual_employed	.468	.588	1.276
unemployed	.691	.668	1.837
retired	.250	.834	2.006
pop14	.637	.762	1.181
pphh	.580	.818	1.119
rooms	.024	.877	.991
home ownership	.019	1.066	2.053
urbanity	.000	1.272	2.261
Constant	.599		
Variable(s) entered on step 1: age, gender, high_school_degree, elementary_school, income_very_high, income_1000, high_qual, unemployed, retired, pop14, pphh, rooms, ownership, urban_rural.			

Source: Author

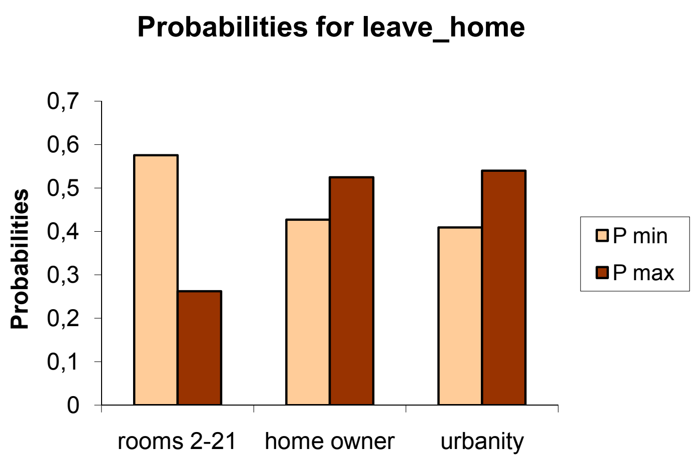
Table 14: Calculated probabilities and confidence intervals for leave_home

Variable	P min	P max	Change	95% CI change min	95% CI change max
rooms [2;21]	0.5755	0.2624	-0.3131	-0.5506	-0.0756
home ownership	0.4272	0.5245	0.0973	0.0167	0.1779
urbanity	0.4091	0.5399	0.1309	0.0608	0.201

Source: Author

The probability for the dependent variable (leave_home, answer 'yes') can increase or decrease for each independent variable. Therefore, the variable *rooms* (number of rooms 2-21) shows an inverse relationship of probability (see Figure 9). The higher the number of rooms, the lower the proportion of those in the group who had to leave their home. In other words, people living in apartments with fewer rooms had to leave their homes more often.

Figure 9: Minimum and maximum probabilities for the dependent variable *leave_home*



Source: Author

The higher the number of home owners in comparison to tenants the more likely it was that these households had to leave their home due to the flood. Persons in rural areas (up to 150 people per km²: definition of BBR 2007) were less affected than residents in urban areas.

Logistic regression no. 2 for *emergency_shelter*: Table 15 reveals that two variables, age and home ownership are significant for the regression model at the 0.05 significance value.

From 14 independent variables, *age* (from 16-95) and *home ownership* can best explain the distribution of those who had to seek emergency shelter and those who did not (see Table 16; Figure 10). Higher age was a reason to seek emergency shelter. The higher the number of home owners in comparison to tenants the more likely it was that these households did not have to seek emergency shelter due to the flood. This contradicts the prediction direction of ownership in the dependent variable *leave_home*.

Table 15: Significance and confidence intervals of the independent variables for the explanation of the dependent variable *emergency_shelter*

Disasters per year [nb/year]	95.0% C.I.for EXP(B)		
	Sig.	Lower	Upper
age	.012	1.010	1.081
gender	.957	.502	1.920
high_school_degree	.480	.272	1.845
elementary_school	.507	.357	1.664
income_very_high	.218	.086	1.748
income_1000	.233	.698	4.386
high_qual_employed	.211	.696	5.149
unemployed	.461	.473	5.210
retired	.620	.484	3.377
pop14	.878	.500	2.248
pphh	.597	.541	1.423
rooms	.961	.841	1.200
home ownership	.003	.175	.707
urbanity	.619	.419	1.678
Constant	.003		
Variable(s) entered on step 1: age, gender, high_school_degree, elementary_school, income_very_high, income_1000, high_qual, unemployed, retired, pop14, pphh, rooms, ownership, urban_rural.			

Source: Author

Table 16: Calculated probabilities and confidence intervals for *emergency_shelter*

Variable	Case	P min	P max	Change	95% CI change min	95% CI change max
age	Pr(y=yeslx):	0.0067	0.1785	0.1718	-0.0537	0.3974
home ownership	Pr(y=yeslx):	0.0636	0.0233	-0.0402	-0.0752	-0.0052

Source: Author

Table 17: Significance and confidence intervals of the independent variables for the explanation of the dependent variable *damage regulation*

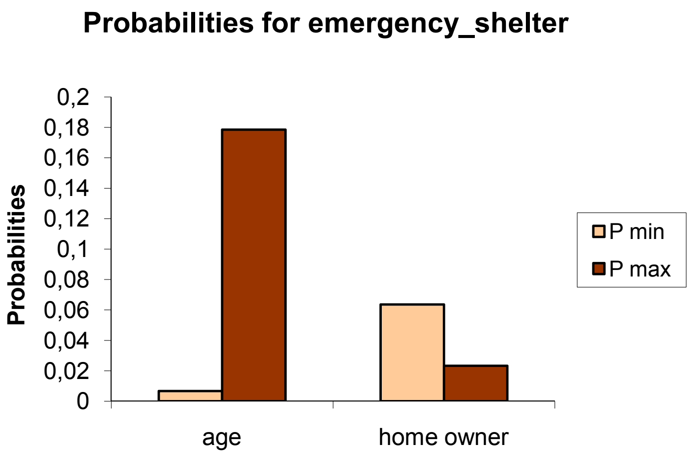
Disasters per year [nb/year]		95.0% C.I.for EXP(B)	
	Sig.	Lower	Upper
age	.619	.982	1.030
gender	.623	.726	1.706
high_school_degree	.715	.501	1.606
elementary_school	.019	.325	.905
income_very_high	.459	.431	1.463
income_1000	.605	.421	1.656
high_qual_employed	.413	.665	2.697
unemployed	.020	.221	.881
retired	.183	.316	1.247
pop14	.527	.783	1.614
pphh	.442	.708	1.163
rooms	.229	.862	1.036
home ownership	.683	.516	1.543
urbanity	.645	.710	1.737
Constant	.007		
Variable(s) entered on step 1: age, gender, high_school_degree, elementary_school, income_very_high, income_1000, high_qual, unemployed, retired, pop14, pphh, rooms, ownership, urban_rural.			

Source: Author

Logistic regression no. 3 for **damage regulation:** Table 17 shows that two variables, *elementary_school* and *unemployed*, are significant for the regression model at the 0.05 significance value.

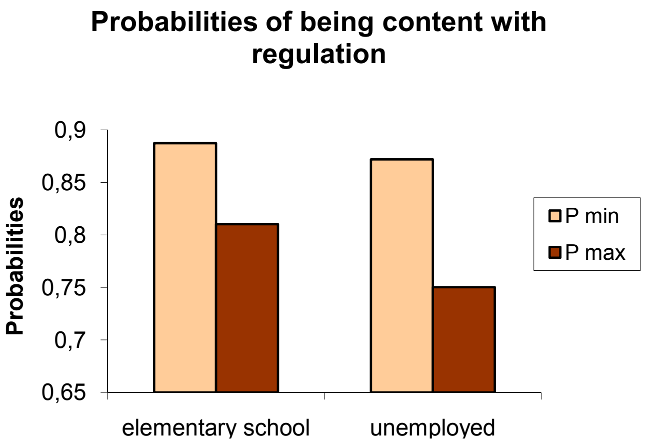
From 14 independent variables, *elementary school* and *unemployment* can best explain the distribution of satisfaction with damage regulation (see Table 18; Figure 11). Persons with low education background (elementary school or Hauptschule qualification) were more dissatisfied with damage regulations. The same observation was made for unemployed people.

Figure 10: Minimum and maximum probabilities for the dependent variable *emergency_shelter*



Source: Author

Figure 11: Minimum and maximum probabilities for the dependent variable *damage regulation*



Source: Author

Table 18: Calculated probabilities and confidence intervals for *damage regulation*

Variable	Case	P min	P max	Change	95% CI change min	95% CI change max
elementary school	Pr(y=yeslx):	0.8873	0.8102	-0.0771	-0.1453	-0.0089
home ownership	Pr(y=yeslx):	0.8719	0.7502	-0.1217	-0.2457	0.0024

Source: Author

4.3.4 Discussion

> "Not everything that can be counted counts, and not everything that counts can be counted."
>
> Albert Einstein

Potential: The purpose of the analysis of the questionnaire data is to find evidence of social susceptibility linked to a real flood event impact. For this purpose the independent input variables for the logistic regression analysis are of paramount interest. They are tested against dependent variables that discriminate negative or positive outcomes of the flood impact on affected people. The independent variables and sub-variables are scrutinized by comparing distribution percentages, significance values regarding the usefulness for logistic regression analysis, and finally by binary logistic regression of a full variable set model. Some trends can be interpreted from the data and linked to certain assumptions of family type, income groups, etc. Since no additional qualitative information is available on the reasons why the people had to leave their homes, seek emergency shelter, or were satisfied with damage regulations, these interpretations are limited in validity. Due to the lack of qualitative information it seems advisable to focus solely on the outcome of the regression analysis. The following table summarizes the outcomes produced by the regression models regarding positive or negative trends regarding the dependent variables (see Table 19). The observations made are confirmed by several trial runs of different compositions of the variables. Additionally, Jackknife replication tests and bootstrapping with 1000 repetitions underscore the stability of the results for the dependent variables *leave_home* and *emergency_shelter*, while *damage regulation* was not stable with the current variable set in the bootstrap test.

The summarized outcomes (see Table 19) suggest safe and unambiguous assumptions on five variables regarding increased or reduced susceptibility towards flood impact. The sixth variable, *home ownership*, is ambiguous. Here it is interesting to differentiate between the measurement categories. Home owners are generally more affected by having to leave their home. On the other hand they are less likely to take the last option of going to public emergency shelters. It seems necessary to differentiate the contexts that the three dependent variables are capturing. While *leave_home* tends to indicate general exposure, *emergency_shelter* sheds light on special needs groups or susceptibility. *Leave_home* therefore differentiates the general population and the spatial context of the region and the dwelling type. Higher age is an indicator when it comes to extreme measures such as having to evacuate to public emergency shelters. Satisfaction with damage regulation is a measure of the group of people who feel disadvantaged regarding *damage regulation*. This captures several facets, financial needs, administration problems, and perceptions of the people themselves. Persons with a lower education level and the unemployed seem to have less coping capacity compared to the average of all persons affected by the floods in 2002.

Table 19: Summarized outcomes of the regression analysis

	leave_home		emergency_shelter		damage regulation	
Test scenario	More affected	Less affected	More affected	Less affected	More satisfied	Less satisfied
Binary logistic regression – significances and probabilities at the 0.05 level	home ownership, urbanity	rooms	age	home owner-ship		elementary school qualification, unemployed

Source: Author

Limitations: The results can serve as a validation basis of the factor analysis and the selection of variables for a SSI (Fekete 2009b). Of course, at the same time, certain conditions and limitations of validation must be emphasized. Although the research area for this questionnaire is relatively large and covers three federal states, it is still difficult to generalize the results for the whole territory of Germany. More case studies are necessary to cover other regions in Germany. The questionnaire contains vital data categories, but was not specifically designed for the purpose of validating a SSI or the data of this study. Therefore, not all variables can be covered for validation.

The choice of the dependent variables is based on the assumption that the fact that someone has to leave his home or seek emergency shelter is a severe impact. Although this type of measure is used in literature to identify social vulnerability (Chakraborty et al. 2005) there has been insufficient exploration of how far it reveals social susceptibility or vulnerability in Germany. Therefore, damage regulation satisfaction is additionally chosen to elicit the coping problems of the indirect economic, administrative, and perception types. The selection of variables, the exclusion of sub-variables, and the setting of thresholds is to a similar degree dependent on the assumptions and decisions of the author, as is the case in the factor analysis. Having made all these necessary disclaimers it is satisfying that the overall picture agrees to a great extent with the findings of previous studies in Germany (see Table 3) and other countries and the grouping of the factor analysis in chapter 4.2.6. Therefore, the directions of impact of table 19 are useful to justify the use of the variables that characterize age, settlement, apartment type, education, and financial deficiencies for the construction of a SSI.

4.4 Validation of the social susceptibility factors

The objective behind the validation is to find evidence of whether the construction of a SSI without direct relation to disaster impact or hazard parameters is valid. That means that first, test categories for revealed social susceptibility have to be found. Second, the independent variables that are the input data for social susceptibility indicators have to be checked for validity. Third, the methodology of grouping variables to indicators has to be checked. Only then can conclusions be drawn on the construction of an index composed of the single indicators and the patterns of social susceptibility that are indicated by such an index for spatial regions, such as counties.

From 41 variables and sub-variables that were used for input in the first data set (federal statistics) of the factor analysis, nine variables can be directly validated with the results of the logistic regression observations. Nine of the 41 variables of the factor analysis are covered by the data set of the questionnaire (see Table 20).

Table 20: Comparison of the nine variables of the federal statistics with the variables of the logistic regression

Variables of the logistic regression	Variables of the factor analysis from the first data set
Urbanity (urban areas have more than 150 persons per km² per municipality)	Population per settlement area
Home ownership	One and two-family homes
Urbanity (rural areas have less than 150 persons per km² per municipality)	Rural population
Rooms [2;21]	Small apartments
Age	Residents from age 30 to 50
Age	Residents age 65 and older
Unemployed	Unemployment
Rooms [2;21]	Floor space pp
Elementary school	Graduates with only elementary education
Source: GFZ and Deutsche Rück household survey 2002, urbanity definition after BBR 2007	*Destatis 2006a*

The validation procedure comprises two steps (see Table 21): first, the independent variables of the factor analysis (census data) are checked for validity by using the independent variables of the independent second data set and by running a logistic regression model. Since the second data set did not capture exactly the same demographic variables, only a few independent variables of the first data set are also available from the second data set (household survey). The logistic regression analysis reveals that six independent variables of the second data set are able to discriminate susceptibility. These six variables capture demographic as well as spatial parameters that are also captured by nine independent variables of the first data set. That means that in the first step, nine variables have been validated as having a significant effect in determining susceptibility.

It would be unsafe to suggest that the full model of 41 variables of the first data set is validated by this process. However, at least nine variables of the first data set can be assumed to describe susceptibility. The remaining 32 independent variables are not significant within the regression model or cannot be tested as they are not contained in the second data set. Of course, this does not imply that they cannot be significant within another model or are not meaningful.

Table 21: Procedure of validation

Data	Step 1	Step 2
Data set 1 Data set to be validated: Census data Data set 2 Independent second data set used for the validation: Household survey	Validation of the social susceptibility variables (data set 1) by flood impact analysis (data set 2) = Section 4.3	Validation of the social susceptibility factors (data set 1) by repetition of the factor analysis with the reduced variable set of the census data (data set 1) = Section 4.4

Source: Author

In the second step of the validation, the factor analysis is repeated with the subset of nine independent variables of the federal statistics. The objective behind this second step of validation is to check whether the factors (or social susceptibility indicators) obtained without any direct disaster relation are similarly revealed by the reduced set of nine validated variables.

In this second step, the factor analysis is rerun with the nine variables of the federal statistical data that are validated by the results of the logistic regression. The nine variables accord with the six variables of the logistic regression analysis (see Table 19). The factor analysis test carries a satisfying KMO of 0.7. The anti-image matrix reveals high correlations over 0.6 off-diagonal only for ages above 64 years and ages 30-50. Three factors with eigenvalues above one show up in the scree plot, and these three components explain 78.8 per cent of the cumulative variance (see Table 22). Each component explains about one third of the total variance in a Varimax rotation with Kaiser Normalization.

Table 22: Variance of the factor analysis with the validation data set

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	3.130	34.780	34.780
2	1.992	22.129	56.909
3	1.963	21.816	78.725

Source: Author

The three factors as grouped in the rotated component matrix (see Table 23) display the same factors that have been identified with the full variable set of 41 variables of the full federal statistics set (see Table 9). This excellent result reveals that the groupings are generally valid. Some of the interpretations of what these factors explain can be improved with the results of the logistic regression validation by the second data set. For example, urban areas are likely to be more affected. Urban areas and smaller apartments or floor space characterize urban areas and are more susceptible, as is tested with the second data set. Rural areas are less populated, yet it cannot be concluded that these areas are not prone to harm. In particular, the high ratio of one and two-family homes indicates a high ratio of home ownership, which was found to be an indication of susceptibility in the sense of having to leave their home in the 2002 flood. This should warn against stereotyping rural areas as safer, and supports the ambiguous picture of this factor, regional conditions, as is also shown by the factor analysis of the 41 variables (see Table 9).

The second component clearly separates elderly people from mid-aged adults. The group of 30 to 50 year olds is a surrogate for younger adult age groups in this case. The other adult age groups were excluded to avoid partial correlations, but trial runs of the factor analysis had shown that old age is always dichotomous to younger age. However, there is no conclusion possible about people younger than 16 years, since this group was not shown to be significant in the logistic regression. Old age indicates fragility and need of assistance, as shown by the probabilities of the emergency shelter group (see Table 16; Figure 10).

The third factor depicts unemployed and lower education groups as opposite to greater floor space. All three variables are validated in their direction of susceptibility measurement by the second data set of the household questionnaire.

Table 23: Rotated Component Matrix of the nine variables of the federal statistics that are validated by the logistic regression

	Component		
	1	2	3
Population per settlement area	-.951		
One and two-family homes	.856		-.358
Rural population	.831		
Small apartments	-.788		
Residents from age 30 to 50		-.935	
Residents aged 65 and older		.913	
Unemployment		.383	.853
Living space pp	.416		-.716
Graduates without Hauptschule qualification			.697
Factor name	Regional conditions	Fragility	Socio-economic conditions
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in four iterations			

Source: Author

Therefore, this third factor describes financial deficiencies in terms of employment, employment qualifications, and living standards.

The same observation of factors can be made with a factor analysis of all 15 variables that are indirectly related to the validated variables in the second data set, and with a factor analysis of the 14 variables of the second data set themselves.

4.5 Social Susceptibility Index

4.5.1 Data

The data set used for the SSI is the federal statistical data (BBR 2007; Destatis 2006a). Only those variables are selected that have a counterpart in the validated second data set. At the same time, the condition must be met that only variables or sub-variables are selected that are already in the selection of the 41 variables for the first factor analysis. This implies that sub-variables, such as *residents of age 18 to 25*, cannot be included, since they were excluded in the first factor set due to high partial correlations. Variables such as *residents below 6 years of age* are not included since the second data set gives no evidence of a direction within the tested models. Other variables such as *population per settlement area* are redundant for the index creation, since they are already contained inversely in *rural population*. For the set of 41 variables this variable was necessary to identify groupings. For the index, this variable, *population per settlement area*, is dropped. The same redundancy is met with the sub-variable *residents from age 30 to 50*. The variable *residents from age 65 and older* already includes age as a factor. Therefore, *residents from age 30 to 50* can be deleted. The variable *home ownership* is related to *one and two-family homes*. Since the direction towards susceptibility is ambiguous in the regression models, this variable (*home ownership*) is treated as neutral and excluded from the composition of the index.

Table 24: Variables used for the construction of the Social Susceptibility Index

	Component		
	1	2	3
Population per settlement area	-.951		
One and two-family homes	.856		-.358
Rural population	.831		
Small apartments	-.788		
Residents from age 30 to 50		-.935	
Residents aged 65 and older		.913	
Unemployment		.383	.853
Living space pp	.416		-.716
Graduates without Hauptschule qualification			.697
Factor name	Regional conditions	Fragility	Socio-economic conditions
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in four iterations. Dark grey marking indicates higher susceptibility as validated by the regression model; white marking indicates the opposite.			

Source: Author

4.5.2 Methodology

The groups derived from the factor analysis are the basis for the selection and aggregation of the SSI (see Table 24). Each factor delivers one indicator, and the indicators are aggregated into the index. In order to enable negative indications of susceptibility but also positive directions of prevailing capacities, each factor must have the potential to indicate both directions equally. The variables are first standardized to equal intervals from zero to one. Missing values are replaced with the average value of the variable so that in the average of all negative or positive variables, no trend is suggested. Since there are more negatively attributed variables

$$Indicator = \frac{sum\ (var\ pos) - sum\ (var\ neg)}{N\ (var)}$$

in the set of the factor analysis (see Table 24), the respective negative and positive variables are first aggregated separately. In this way, they either represent susceptibility or capacities. The averages for each negative or positive variable group are calculated separately. Only then are the positive and negative halves of each factor aggregated. The resulting direction of susceptibility/capacities is different for each county. The three factors are used as the three indicators of social susceptibility.

var pos = variables with positive factor loads

var neg = variables with negative factor loads

Variable ranges (min/max.): 0 to 1

Indicator range (min/max.): -1 to 1

The indicator **fragility** is the rate of *residents of age 65* and *older*. The indicator **socio-economic conditions**, is aggregated per county as: *floor space per person – (unemployment + graduates without Hauptschule qualification)* /2. The indicator **regional conditions** is aggregated per county as: *rural population – small apartments*. All indicators range from minus one to one as the maximum possible range. Zero is the average, and indicates no direction of either increased or decreased susceptibility. The SSI is an aggregation of the simple sum of the three indicators. Positive and negative deviations of both negatively and positively directed

$$SVI = Indicator\ 1 + Indicator\ 2 + Indicator\ 3$$

variables must be able to level out. Negative resulting values indicate a relatively higher susceptibility of the county; positive values indicate the opposite. The results can theoretically achieve a maximum range of minus three to three. The result is the susceptibility map of figure 12 (further below). This displays the counties in Germany, coded in colours by defined intervals (0.2). Green colours indicate prevailing positive capacities; red colours indicate increased potential susceptibility of the counties.

SSI range (max.): 3 (lowest susceptibility) to -3 (highest susceptibility)

The main result of the susceptibility assessment of chapter 4 is the SSI (see Figure 12), composed of three indicators, and validated by an independent second data set. The SSI identifies counties in Germany with a potentially strong or weak social susceptibility to floods. Since social susceptibility is regarded as independent of the individual river flood hazard, this index contains no hazard information. The three indicators that compose the SSI are groupings derived from the factor analysis. The set of 41 demographic variables of the federal statistics in the first exploratory factor analysis is successfully validated by the second data set of the questionnaire on flood-affected households. This set of 41 input variables could be reduced to six variables. These six variables compose the same factors that are derived from the 41 variables. The three resulting factors are used as indicators of social susceptibility, named *fragility, socio-economic conditions*, and *regional conditions*. The SSI is aggregated from these three indicators with equal weighting.

4.5.3 Results

The individual results are:

- A composite SSI
- The SSI choropleth map
- Three indicators of social susceptibility: fragility, socio-economic conditions and regional conditions
- A validated set of demographic predictors (six variables) of social susceptibility
- An extended set of theoretically founded demographic predictors (41 variables) of social susceptibility.

The variable sets serve as checklists for the identification of social susceptibility. This checklist uses standard census data and it is demonstrated that even without direct flood impact evidence, the derived susceptibility factors are valid.

Social Susceptibility Index (SSI)
Data Sources: BBR 2007: INKAR 2006; Statistisches Bundesamt Deutschland (Destatis 2006a): Statistik regional; BKG 2007: county shape files

Description:
The SSI is an index that is aggregated by equal weighting and simple summation from three main indicators of social susceptibility:
- fragility: elderly persons above 64 years per total population
- socio-economic conditions: unemployed persons and graduates with only basic education per total population; apartment living space per person
- regional conditions: degree of urbanity or rural area, measured by population density lower/higher than 150 persons per km² and the number of apartments with 1-2 rooms per total number of apartments

Indicator creation: the six input variables are normalized to values from 0 to 1 and by simple summation the three indicators are created. The SSI contains value ranges from 1,8 to -1,8 and is displayed in defined equal intervals in 0,2 steps. The indicators contain value ranges from -1 to 1 and are displayed in defined equal colour intervals in 0,1 steps.

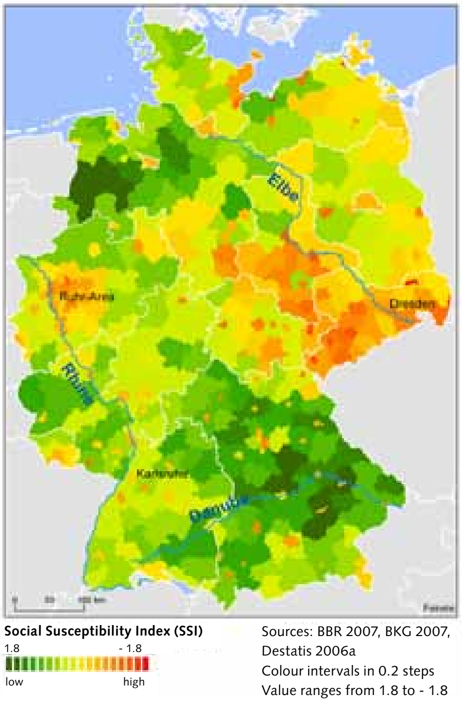
Description:

Low SSI counties are characterized by strengths towards river-floods. These strengths are prevailing capacities for river flood mitigation, for example, financial capacities for private preparedness measures and recovery from floods by high-income sources. Physical fragility of elderly citizens is typically low. These counties also lack indications for a potential exposure to floods like high population density. Counties with high SSI are characterized by predominating weaknesses towards river floods. These weaknesses are lack of capacities and high degrees of susceptibility.

Hazard context:

The SSI detects potential strengths and weaknesses of counties, not the actual river flood exposure or -risk. The SSI contains no hazard information and therefore no actual exposure. However, the SSI is not an index for any kind of natural hazard, since the variables are selected and aggregated only after flood impact evidence. The input variables for the indicators are created after verified unequal flood impact to different social groupsand settlement types. Counties have distinct profiles of social susceptibility, composed of demographic characteristics and land use. The strength of the SSI is its independence from direct hazard information. It identifies key aspects of flood impact and –risk not identified by hazard assessments. The computation of actual exposure by hazard information is carried out for the SIFVI.

Figure 12: Main result of the social susceptibility assessment, the map of the Social Susceptibility Index per county



Sources: BBR 2007, BKG 2007, Destatis 2006a
Colour intervals in 0.2 steps
Value ranges from 1.8 to - 1.8

Source: Author

Social Susceptibility Index per county in Germany

Objective:
identifies demographic patterns of susceptibility and capacities regarding stresses such as river floods

Aggregation:
the simple sum of three indicators
- fragility
- socio-economic conditions
- regional conditions

Indicator fragility:
ratio of elderly residents (>64 years)

Indicator socio-economic conditions:
floor space per person;
(un)employment ratio;
education type

Indicator regional conditions:
population density; housing type

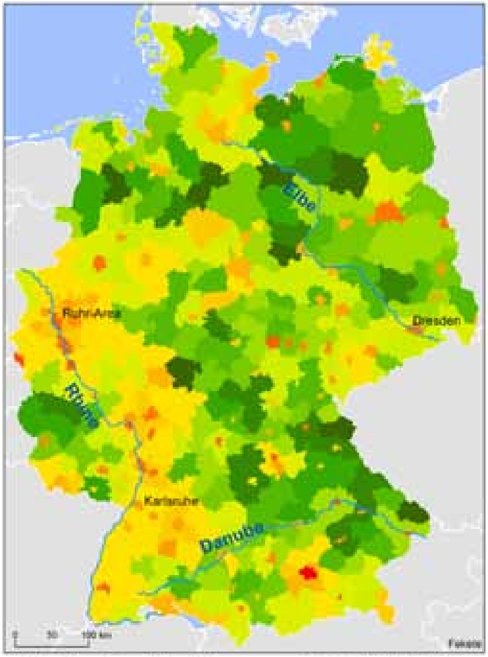
Data:
census data of the Federal Statistical Office in Germany

Table 25: Overview of the map products of the Social Susceptibility Index

Composite Map	Composite Social Susceptibility Index (SSI) map		
Components	SSI indicator regional conditions	SSI indicator fragility	SSI indicator socio-economic conditions
Input variables	population density; housing type	ratio of elderly residents (>64 years)	floor space per person; (un)employment ratio; education type

Source: Author

Figure 13: Map of the Social Susceptibility Index indicator *regional conditions* per county



SSI Indicator Regional Conditions
1.0 - 1.0
low high

Sources: BBR 2007, BKG 2007, Destatis 2006a
Colour intervals in 0.1 steps
Value ranges from 1 to - 1

Indicator "regional conditions" per county in Germany

Objective:
describes patterns of social susceptibility related to settlement density and – type

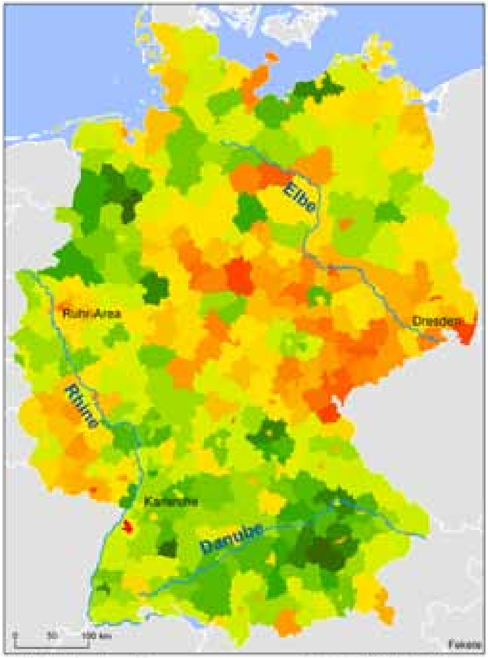
Aggregation:
the sum of two variables:
• population density
• housing type

Data:
census data of the Federal Statistical Office in Germany

Standardization:
ratios per county;
equal intervals from 1 to -1

Source: Author

Figure 14: Map of the Social Susceptibility Index indicator *fragility* per county



Indicator "fragility" per county in Germany

Objective:
describes patterns of social susceptibility related to age of the population
Consists of the ratio of elderly residents of 65 years and older

Data:
census data of the Federal Statistical Office in Germany

Standardization:
ratios per county;
equal intervals from 1 to -1

SSI Indicator Fragility
1.0 - 1.0
low high

Sources: BBR 2007, BKG 2007, Destatis 2006a
Colour intervals in 0.1 steps
Value ranges from 1 to - 1

Source: Author

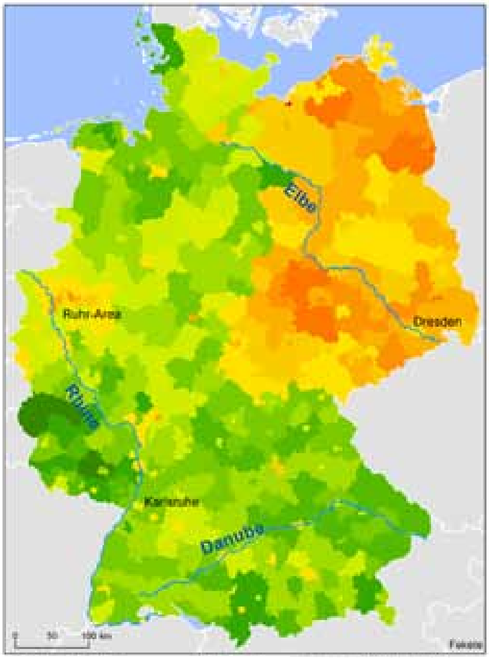
This suggests that this methodology can be applied in other countries and regions as well. The reduced and validated variable set enhances the feasibility of such an approach, since even by a small number of variables, social susceptibility can be detected.

It is interesting to observe the concentration of higher susceptibility regions in places such as the Ruhr area close to the western border and in the eastern part of central Germany. It is therefore not only urban areas with high population density that are highlighted as susceptible, but also some rural areas. However, there is a slight general tendency for urban areas to be more susceptible. The scrutiny of the single indicators that compose the index (see Table 25) reveals that socio-economic conditions or fragility are not concentrated in urban areas only, while indicator three, regional conditions, highlights urban areas. The maps of figure 13, 14, and 15 illustrate the contribution of the single factors to the overall index, but at the same time demonstrate their potential to highlight different areas. These areas indicate diverging aspects of susceptibility and are helpful in identifying more specific susceptibility information, such as concentration of elderly people, socio-economic conditions, or regional conditions.

The indicator **regional conditions** (see Figure 13) has a tendency to highlight urban counties all over Germany as more susceptible. Urban regions are a heterogeneous landscape of urban problems but also of strengths regarding social susceptibility. For example, urban areas are characterized by a high concentration of people but also by higher education and more doctors per resident.

The **fragility** indicator shows a heterogeneous pattern of the distribution of elderly people in Germany (see Figure 14). As in the composite SSI, the indicator **fragility** also depicts the eastern part of central Germany as containing a relative higher proportion of elderly people. These are areas where river floods, but also flash floods and other natural hazards, such as heatwaves, are likely to kill and adversely affect the health of more people than in other regions in Germany.

Figure 15: Map of Social Susceptibility Index indicator *socio-economic conditions* per county



SSI Indicator Socio-economic Conditions
0.7 - 0.8
low high

Sources: BBR 2007, BKG 2007, Destatis 2006a
Colour intervals in 0.1 steps
Value ranges from 0.7 to - 0.8

Indicator "socio-economic conditions" per county in Germany

Objective:
describes patterns of social susceptibility related to living conditions and financial resources

Aggregation:
the sum of three variables:
- floor space per person
- (un)employment
- education

Data:
census data of the Federal Statistical Office in Germany

Standardization:
ratios per county;
equal intervals from 0.7 to -0.8

Source: Author

The indicator of **socio-economic conditions** clearly identifies eastern Germany as more susceptible (see Figure 15). This is an obvious result since the ratio of unemployment and related social welfare has generally been higher in the east since the German reunification. Some regions, such as the Ruhr area and some urban areas in western Germany, are characterized by higher susceptibility due to fragility.

4.6 Social and Infrastructure Flood Vulnerability Index

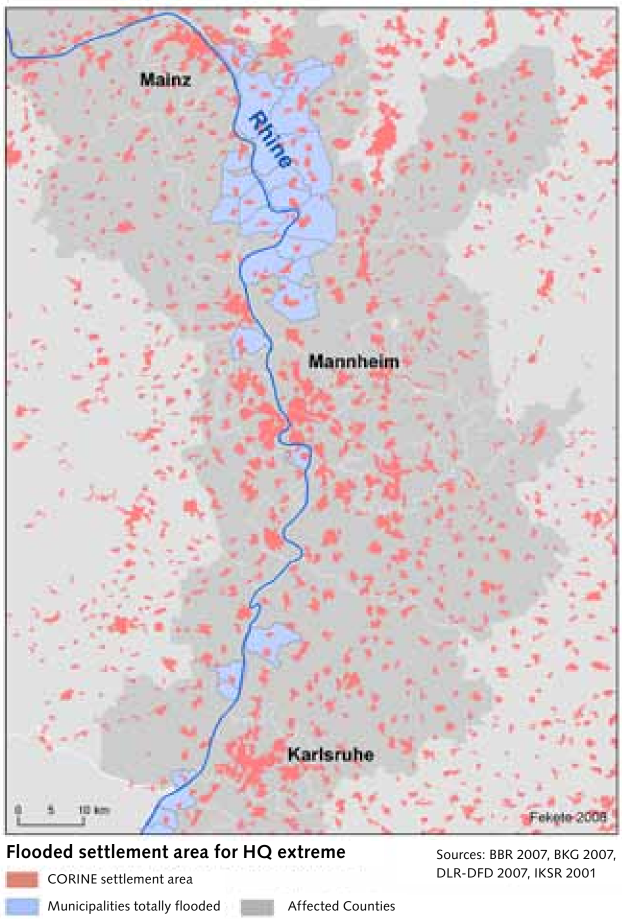
The objective of constructing a SIFVI is to identify regions which have not only high social vulnerability but at the same time a high flood hazard potential. Additionally, infrastructure is a key source of vital resources such as energy, and is therefore added to the SSI. The reasons for including a measure of critical infrastructure are first, the importance of this infrastructure for society; second, critical infrastructure is a key topic of current civil protection and disaster assistance efforts in Germany (BMI 2006; BBK 2009); and third, critical infrastructure is not covered by the other project partners of DISFLOOD. This index combines the susceptibility index with an index of infrastructure and flood hazard information, in this case extreme event scenarios of maximum inundation areas of three major watercourses in Germany. The three rivers, the Danube, Elbe, and Rhine are of interest because of the large areas along these rivers which are exposed to floods. Historically, several disastrous floods happened along those three rivers (see Table 1; Chapter 2.1). Susceptibility, as conceived in this study, stands out by identifying areas independently of direct hazard impact. It is of special interest to demonstrate how this approach can be integrated into traditional flood risk identification. Hazard maps are just one data source that can be integrated into a flood vulnerability index.

4.6.1 Exposure assessment

The flood hazard data consists of hazard maps that are provided for the river Danube by the State Office for Environment in Bavaria (LfU Bavaria 2007); for the river Elbe by the State Office for Environment and Geology in Saxony (LfUG Saxony 2007); for Saxony-Anhalt by the State Management Agency for Flood Protection and Water Management (LHW Saxony-Anhalt 2007) with data from the Elbe Atlas (ELLA 2007); and for the river Rhine by the International Commission for the Protection of the Rhine (IKSR 2001). These hazard maps display the inundation areas of statistical extreme event scenarios. The development of these maps is still in process; therefore, the maps do not yet show all areas of the three rivers. This data gap also sets limits on the application of this assessment for other great rivers in Germany, not to mention the smaller ones. The extreme event scenarios are not consistent; they comprise statistical return periods of 100 (occasionally up to 200) years of flooding for the river Danube, and 500 years of floods for the rivers Elbe and 200 to 500 year floods for the Rhine, depending on the section of the river (see the detailed description in IKSR 2001). Despite the heterogeneity of the data, this set is the most comprehensive on maximum flood inundation scenarios to date and is therefore the best solution for analysing large areas along river channels in Germany. However, since extreme flooding scenarios for the river Danube are still under development, and the 200-year areas are still scarce, it was decided to exclude the river Danube from the final index. As soon as more extreme inundation scenarios are completed, the river Danube and other rivers in Germany can be used for the calculation of the index, as the social susceptibility information is already computed.

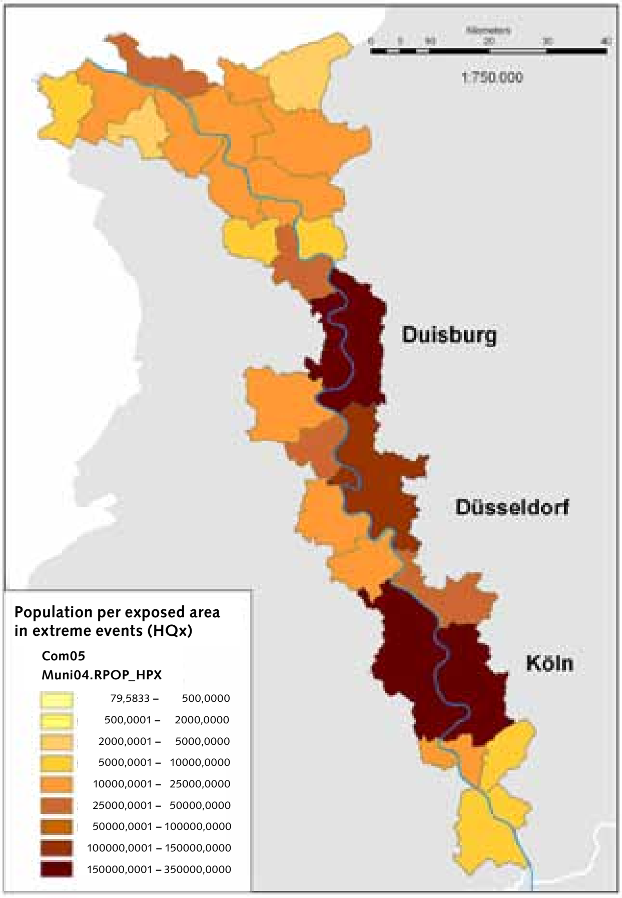
The exposure of the counties is calculated as the percentage of settlement area inundated in the given extreme event scenario. This provides a measure that allows for ranking of the counties in terms of how severe the impact on the population is likely to be. This exposure is analysed in the GIS by overlaying the digital vec-

Figure 16: Municipalities with settlement areas totally flooded in an HQ extreme scenario (blue polygons) in the middle section of the Rhine river



Source: Author

Figure 17: The number of exposed residents per municipality

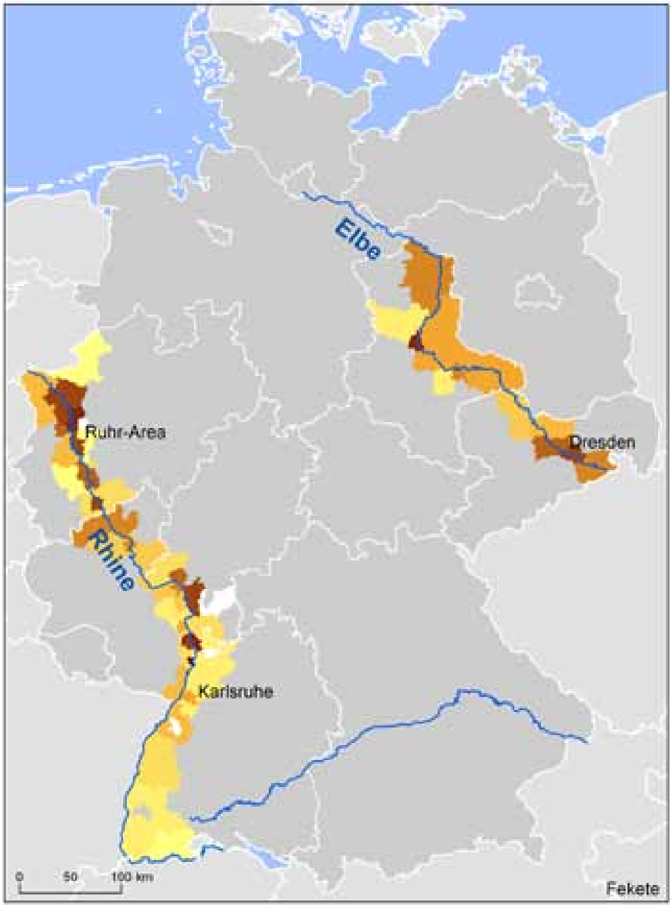


Source: Author

tor polygon data of the inundation areas with the settlement polygon data of the land use classification data set of CORINE 2000. The CORINE Land Cover (CLC) data set is provided by the German Aerospace Centre (DLR-DFD 2007) and covers settlement areas greater than 25 hectares, as captured by satellite remote sensing (Keil et al. 2005).

The exposure analysis shows that several villages and even whole municipalities are exposed to flooding (see Figure 16). A total of 7.5 million of 16.4 million people living in those 73 counties (including the inundation scenarios HQ100 and HQ200 for the Danube) are exposed to river flooding alone, disregarding flash floods and the inundation areas of other rivers and tributaries. The accuracy of these figures depends on the resolution and quality of the available data. Since the CLC captures only settlements above 25 hectares, these numbers are probably

Figure 18: Map of the percentage of the counties exposed to floods
(no extreme flood data for the Danube)



Exposure degree to floods

0.01 1.10

low high

Sources: BBR 2007, BKG 2007,Destatis 2006a
DLR-DFD 2007, IKSR 2001, LfUG Saxony 2007
LHW Saxony-Anhalt 2007
Colour intervals in 0.1 steps
Value ranges from 0.01 to 1.1

Source: Author

underestimated. For the purpose of comparing the exposure with the susceptibility index, the county level has to be used. The exposure information is therefore aggregated to a percentage of settlement area per county (see Figures 17 and 18). Fifty-seven of 62 counties bordering the Elbe and Rhine, for which hazard information of extreme event scenarios greater than HQ200 is available, are at least partly prone to flooding (see Figure 18).

Exposure Information

Data sources:

The flood hazard data consists of hazard maps that are provided for the river Elbe by the State Office for Environment and Geology in Saxony (LfUG Saxony 2007); for Saxony-Anhalt the State Management Agency for Flood Protection and Water Management (LHW Saxony-Anhalt 2007) with data from the Elbe Atlas (ELLA 2007); and for the river Rhine by the International Commission for the Protection of the Rhine (IKSR 2001).The settlement areas are provided by the CORINE land cover data 2000, DLR-DFD 2007.

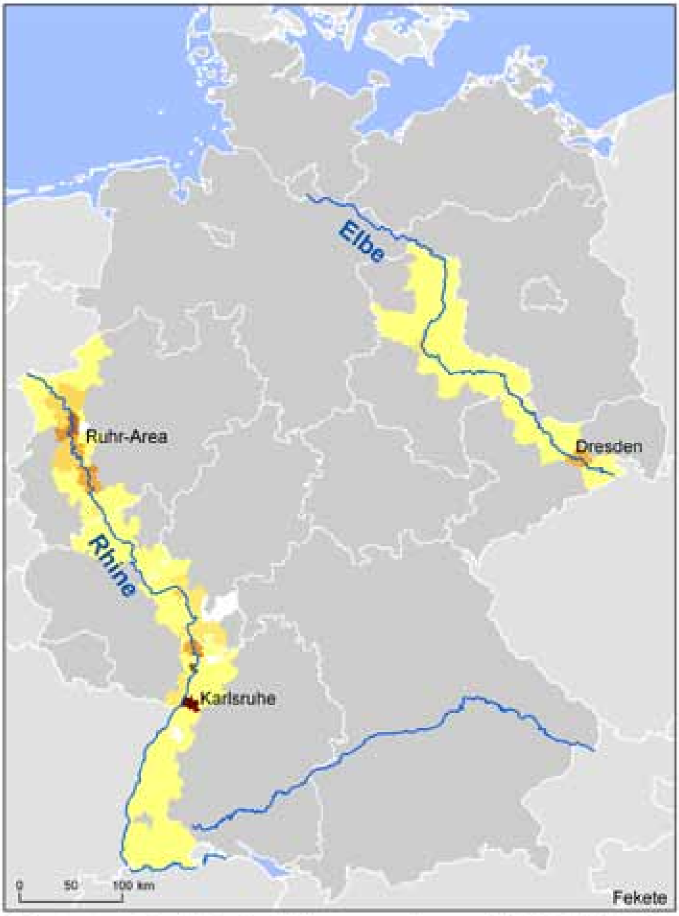
Description:

The exposure of settlements to river floods is calculated as the ratio of CORINE settlements per county inundated by the HQ extreme data scenarios. The HQ extreme scenarios are statistical recurrence estimations of a 200-year plus safety margin flood event, or an up to 500-year flood event, depending on the data source.

The exposure map depicts urbanized areas and lowland areas downstream as especially exposed, for example the lower Rhine at the border with the Netherlands in the west of Germany (see Figures 17 and 18). Since Saxony-Anhalt is characterized by lowland terrain as well, the inundation areas are also wide in lateral spread here. The Dresden area in the south of eastern Germany is especially exposed because it contains tributaries from steeper terrain.

As an additional information layer, the location and ratio of the critical infrastructure per county is calculated in the GIS (see Figure 19). The data on critical infrastructure is provided by the Federal Agency for Cartography and Geodesy (BKG 2007; Basis-DLM). It contains infrastructure that can be categorized as important supply infrastructure, in this case power plants, electricity facilities, long-distance heating, and water supply. Some of the infrastructure items also bear important supply functions but are at the same time secondary hazards themselves since they pose the threat of potential contamination when inundated. In this category are refineries, dumpsites, sewage facilities and waste treatment facilities. Certainly, an in-depth analysis of the real danger and exposure of these infrastructure elements would be necessary as well as the inclusion of other infrastructure items. This data set can therefore serve only as a demonstrator for the extension and advancement of the whole vulnerability index. The point data of the eight infrastructure classes is analysed in the GIS by calculating the number of all critical infrastructure items per

Figure 19: Map of the Infrastructure Density Index per county



Infrastructure Density Index (IDI)

0.01 1.00

low high

Sources: BBR 2007, BKG 2007,
Destatis 2006a
Defined intervals in 0.1 steps
Value ranges from 0.01 to 1.00

Source: Author

Infrastructure Density Index (IDI)

Data Sources: BKG 2007:

point data of selected infrastructure (BASIS DLM**)**

Description:

The IDI is an index that is aggregated by equal weighting and simple summation of two types of infrastructure:

- supply infrastructure: power plants, electricity facilities, long-distance heating and water supply
- contamination infrastructure: refineries, dumpsites, sewage facilities and waste treatment facilities

The IDI contains value ranges from 0 to 1 and is displayed by defined intervals

county. The infrastructure items are summed up and the result is rescaled to the range of zero to one, where zero indicates low density of critical infrastructure and one signifies the maximum amount of critical infrastructure observed in the data. The map shows that only a few areas have a higher than average concentration of critical infrastructure (see Figure 19). This additional infrastructure information will therefore not significantly change the pattern shown by the susceptibility index in the overall flood vulnerability index.

4.6.2 Flood vulnerability index calculation and results

The flood vulnerability index is calculated as the product of the SSI, the IDI, and the exposure area. Of course, this index shows only certain aspects of vulnerability, not all. The reason for this is that the vulnerability of the economy and of the ecosystem will be assessed separately by other project partners of DISFLOOD. Therefore, the scope of this study is mostly on the social aspects of vulnerability. It also integrates critical infrastructure for two purposes: first, to illustrate that generally this index can be extended to include all vulnerability aspects necessary to capture flood vulnerability; second, because critical infrastructure is a key element determining the adverse effects of floods on society.

Prior to the calculation, the SSI is transformed to a range wherein the minimum value is for lowest susceptibility and the highest value is for highest susceptibility. The exposure degree is multiplied by ten to put it into the same value range as the

$$SIFVI = (SSI - 3) * (Exposure\_area*10) * (IDI*10)$$

SSI and to facilitate the multiplication. The result is rescaled to the range of zero to one, where zero indicates no vulnerability and one signifies the maximum vulnerability observed in the data. The resulting vulnerability index thus is dependent on the prevalence of the degree of exposure. If there is zero exposure, there is no vulnerability. The larger the exposure area, the higher the vulnerability. The vulnerability degree is also ameliorated by the susceptibility profile of each county. Lower susceptibility buffers the vulnerability to a certain degree, while high susceptibility exacerbates the vulnerability.

**The value 3 is subtracted from the SSI to harmonize it with the other data*

The resulting SIFVI map (see Figure 20) is composed of the SSI map (see Figure 12), the IDI map (see Figure 19) and the exposure area map (see Figure 18). Urban counties but also the lowland counties of eastern and western Germany, as well as the Dresden area are characterized by higher vulnerability to river flooding. Counties coloured in white show no exposure as measured by the available data sources. For counties along the Danube, the hazard data is still lacking, so no exposure and therefore no vulnerability could be computed.

Like the other indices, the SIFVI (see Figure 20) uses a standardized procedure of data harmonization, standardization, equal weighting, and ranking. This SIFVI is open to additional vulnerability data such as environmental vulnerability, but also to additional hazard information, such as flood depth, velocity, etc. The methodology of quantified parameters and the simple aggregation technique enable an aggregation of this index with other vulnerability information, such as economic damage and vulnerability of buildings.

Social and Infrastructure Flood Vulnerability Index (SIFVI)

Description:

The SIFVI is an index that is aggregated by equal weighting and multiplication of three components:

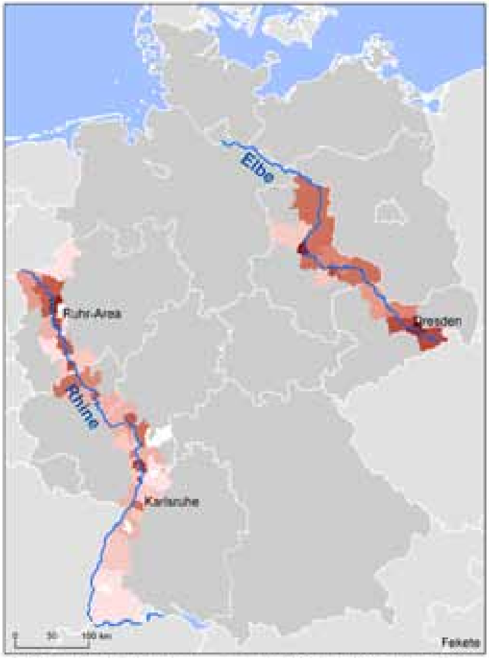
- **SSI: Social Susceptibility Index**
- **IDI: Infrastructure Density Index**
- **Exposure information**

Aggregation:

*SIFVI= (SSI - 3) * (Exposure_area*10) * (IDI*10)*

The SSI is subtracted by 3 to transform all values to a positive range in order to enable multiplication. The SIFVI is standardized to value ranges from 0 to 1.1 and is displayed in defined equal intervals in 0.1steps.

Figure 20: Main result of the vulnerability assessment, the map of the Social and Infrastructure Flood Vulnerability Index per county



Social and Infrastructure Flood Vulnerability Index (SIFVI)

0.01 1.00

low high

Sources: BBR 2007, BKG 2007,Destatis 2006a
DLR-DFD 2007, IKSR 2001, LfUG Saxony 2007
LHW Saxony-Anhalt 2007
Colour intervals in 0.1 steps
Value ranges from 0.01 to 1.1

Source: Author

Description:

Flood vulnerability is the vulnerability of the population per county facing river floods, and is composed of the hazard and the vulnerability components. Disaster occurs when either the hazard or the social vulnerability is especially high. It is aggravated by additional harm to infrastructure, and disaster is most serious when all factors come into play together.

Hazard context:

The flood vulnerability is directly dependent on hazard information. When there is no indication of an actual exposure to river floods there is no indication of flood vulnerability.

Social and Infrastructure Flood Vulnerability Index per county in Germany

Objective:
To identify the vulnerability to river floods by the social and infrastructure vulnerability, considering the hazard exposure per county

Aggregation:
Multiplication of
- SSI
- IDI (Infrastructure)
- Exposure to floods

SSI:
Social Susceptibility Index, measuring fragility, socio-economic conditions and regional conditions

IDI:
Index for supply infrastructure, but also for potentially contaminating infrastructure

Actual exposure:
Settlement area per county inundated by a statistical extreme event scenario (200-500-year flood)

Data:
Census data of the Federal Statistical Office in Germany, land cover data, hazard maps

Standardization:
Ratios per county;
equal intervals from 0 to 1.1

The following individual results have been obtained:

- A composite SIFVI
- The SIFVI choropleth map
- An exposure map of the settlement area and population threatened by extreme flood scenarios
- The SSI choropleth map per exposed county
- An index of critical infrastructure per exposed county

The SIFVI delivers an index, as well as information about its components per county. This information is available on the DISFLOOD platform on NaDiNe (http://nadine.helmholtz-eos.de/projects/disflood/disflood_de.html), where users, both the public and experts, can access the colour-coded map and documentation. Only counties where exposure information is available from hazard maps carry values of the SIFVI. However, for all counties in Germany, the values of the SSI and its components are available.

5. Synthesis – Reflection of strengths and limitations of the assessment

> A theory is something nobody believes, except the person who made it.
> An experiment is something everybody believes, except the person who made it.
>
> Albert Einstein

This synthesis is a quality assessment of this study that compares the findings to the background of the knowledge before the assessment, and reflects on how these findings confirm or modify the theoretical considerations about social vulnerability in Germany. The key aspects of the vulnerability assessment in this study are discussed concerning the methodology, the results, and the implications for the theoretical research perspectives.

Quality assessment involves comparing whether the study design assumptions are still relevant after analysing the data (Van den Berghe 1995: 26). The vulnerability concept has proven to be a valuable lens to identify latent patterns of social groups towards natural hazards such as floods. The conceptual assumptions about the construction of indicators are justified in the sense that a vulnerability index could be constructed for the context of river floods. The feasibility of the theoretical as well as the methodological approach was shown. Data availability over large areas, such as a whole country, and the depth of data resolution together form a major obstacle to carrying out such an approach in other countries, especially in developing countries.

The objectives of achieving a composite vulnerability index are realistic only to a limited extent. While it is technically feasible, the validation is a major challenge. It is a luxury to have an independent second data source available, as in this study. Moreover, one big unsolved question remains – which test categories should be applied for 'validating' or 'verifying' social vulnerability. In this study, three test categories were used; *leave_home, emergency_shelter* and *damage regulation* satisfaction. However, no definite conclusion can be drawn from this set of categories about whether social vulnerability is adequately described. At this point it must be stressed that the approach in this study is only a modest attempt at finding out possible ways to measure social vulnerability. It is a starting point for the falsification referred to by Thomas Kuhn and the development of better approaches.

An indication of the vibrancy of the topic of vulnerability is the ongoing theoretical discussion in the scientific community. The lack of a unified definition and lack of 'real theory' stems from the complex topic. Overlaps exist with similar approaches such as sustainable development. For scientific housekeeping it is useful to question whether each term can be easily replaced by another already existing term. This simple lesson should be an objective for multi-disciplinary research groups who attempt to integrate terms such as risk, damage, vulnerability, susceptibility, probability, or uncertainty. In many cases, one term can be replaced by another term with the prefix "potential of…" or "degree of…". In such cases it should be considered whether terms such as vulnerability describe more than a "degree of damage" or "hazard potential". Vulnerability should describe a phenomenon that is unique, new, and more than the sum of its parts. Therefore in this study, the components which make vulnerability a specifically composed phenomenon are in focus. This helps to identify the contribution of susceptibility, capacities, and exposure factors to the overall vulnerability. It stresses the identification of areas not determined by high hazard potential only, but characterizes areas that are threatened by their internal predisposition.

The main players in social susceptibility and vulnerability are the people. This fact is stressed by the SSI in a way that is novel to traditional risk and disaster management in Germany. The maps developed in this approach are an attempt to introduce this topic and enable access of lay people and experts alike. The factors that render people vulnerable include a number of characteristics, such as lack of physical fitness, social background, and dwelling type.

5.1 Discussion of the methodology of indicators

Science means three things: it is a special method of finding things out, it is the body of knowledge, and it is new technology or applications (Feynman 2007: 5). Vulnerability indicators are in this respect the technical application of the vulnerability concept (see Chapter 3). The systematization of the technical application is guided by the conceptual frame, yet there are many technical specifications that shape the result of the vulnerability analyses. These technical specifications are either beneficial or constraining for the realization of the conceptual idea.

5.1.1 Selection process

The selection process by which variables or sub-variables are included or excluded is the most difficult element of the technical application of this study. This selection is based on the BBC framework and the analytical categories of exposure, susceptibility, and capacities. Still, the technical procedure is subject to arbitrary and subjective decisions (Briguglio 2003: 11; Nardo et al. 2005: 13). Additionally, the concept is underpinned by international studies, and an evaluation of the German setting (see Chapter 2.4) is provided. However, the selection of variables is to a certain extent due to the subjective scope and assumptions of the author. Only those sub-variables are selected for which arguments from literature can be found, even if some of them are only indirectly related to the variable. For example, unemployment is not a variable used in other studies; however, it is an important feature identified for the context of Germany (see Chapter 2.4). Other sub-variables might have been overlooked – not because they do not represent social vulnerability, but because they have not been recognized as such. Additionally, economic damage, buildings, and values were not the main scope of this type of vulnerability assessment (see Chapter 3). Moreover, of course many variables are not included due to lack of data coverage. For this reason, a number of aspects outlined in the BBC framework (see Figure 6) could not be captured. Nevertheless, the BBC framework was a precondition for the successful integration of all aspects of vulnerability, including exposure, susceptibility, and capacity parameters.

Exclusion from the factor analysis or logistic regression does not mean these variables cannot be integrated into a composite index. While the procedure of exclusion due to trial experience is disputed in the theory of the statistical methodology (Nardo et al. 2005: 40, 43), it might be common practice, yet rarely stated. By stating it here explicitly, it should not be assumed that the selected variables and the sub-variables are the one and only ideal solution. The selection is a result of the state of the art values, objectives, experience, and findings of the scientific community and the author. Also, if more variables on risk perception, flood experience, insurance cover, disabilities and illnesses had been available, they would certainly have been included and would possibly have shifted the overall profile of vulnerability.

> "In many instances vulnerability will be defined through the availability of datasets rather than because the data truly represents vulnerability."
>
> (King 2001)

It must be emphasized however, that the constraints described here are a normal part of critical scientific evaluation. It is a pity that occasionally in scientific studies the constraints and failures of measurement are not described explicitly enough, since this hinders advancement of the methodology.

Lack of evidence on thresholds for the creation of sub-variables is a problem. For example, only for the extreme ends of the age profiles arguments could be found. Still, most arguments of previous studies are also based on assumptions only, and a convincing linkage to causality in dividing demographic age groups is lacking. For ages above 64, the relation of increased health problems to the typical age of retirement has been described, as well as an increase of fragility above 75 years of age (Tapsell et al. 2002). While this seems plausible, evidence for the vulnerability of very young age groups could not be found and there is almost no literature on adults and other age groups.

The ambiguousness of the variables is both a problem and an opportunity for interpretation. It is disturbing at first that certain variables such as urban area do not allow for a stereotype characterization to be only a negative or positive measurement of vulnerability. However, especially when putting these variables into context with other variables such as income, education, age, etc. for example, in the factor analysis or regression analysis, certain relations and patterns appear. This shows, on the one hand, that urban areas cannot be simplified as problem areas. This accords with findings of local studies of the river Elbe which conclude that vulnerability is difficult to capture with a single variable (Steinführer and Kuhlicke 2007: 115). On the other hand, the variable urbanity is only valid in the context of the specific variable set of the full regression model – in other words in the context of the other variables such as selected age groups, income groups, etc. This means that certain variables describe complex phenomena that allow no uniform interpretation, and which are dependent not only on the local context but also on the context of other variables that are being observed.

5.1.2 Aggregation and weighting

> "Composite indicators are useful in their ability to integrate large amounts of information into easily understood formats, and are valued as a communication and political tool. However, the construction of composites suffers from many methodological difficulties, with the result that they can be misleading and easily manipulated."
>
> (Freudenberg 2003: 3)

One drawback of a composite indicator is the loss of information on single indicator extremes. To a certain extent this can be compensated by weighting and normalization methods of the variables, for example z-scores (Nardo et al. 2005: 18), Pareto-ranking (Rygel et al. 2006) or other methods (Nardo et al. 2005: 59, 64). Alternatives include multi-variate statistical techniques, decision tree analysis, counting the indicators that exceed a threshold (Downing et al. 2005: 6), or data envelopment analysis (Clark et al. 1998: 71). On the other hand these technical solutions also involve an increase in technical complexity and reduce comprehensibility for non-experts (Gall 2007). Weighting generally introduces the problem of subjectivity.

Weighting schemes are often either arbitrary or unreliable (cf. Cardona 2005: 65) and "… weighting is subjective in nature" (Simpson and Katirai 2006: 4). The level of subjectivity in weighting can be reduced by mathematical procedures, such as standard regression analysis, factor analysis, or by the Delphi method of asking experts (Schmidt-Thomé 2006: 156). However, even these techniques reach their limits in large-scale studies (Schmidt-Thomé 2006: 86) and the human factor of choice in the selection and implementation process remains. In addition, 'objectivity' remains a difficult goal, even when the average of several 'subjective' opinions is collected and revised repeatedly. Some studies state that weightings are arbitrarily chosen even when using methods such as regression analysis (Briguglio 2003: 8). There are also warnings against using highly sophisticated aggregation and calculation methods in constructing indices such as the Human Development Index, since they hinder interpretation (Gall 2007) and sometimes even produce statistical artefacts (Lüchters and Menkhoff 1996).

Advanced weighting techniques are advisable when there is a sound theoretical argument for why some extreme values or specific variables should be weighted higher than other variables. When such an argument is missing, simplification and standard techniques seem advisable. Therefore, equal weighting, simple sum aggregation, and equal interval normalization are considered the best solutions for the approach in this study.

> "A mathematical combination (or aggregation as it is termed) of a set of indicators is most often called an 'index' or a 'composite indicator'. It is often a compromise between scientific accuracy and the information available at a reasonable cost."
> (Cardona 2005: 65)

> "[…] it is hard to imagine that debate on the use of composite indicators will ever be settled […] official statisticians may tend to resent composite indicators, whereby a lot of work in data collection and editing is "wasted" or "hidden" behind a single number of dubious significance. On the other hand, the temptation of stakeholders and practitioners to summarize complex and sometime elusive processes (e.g. sustainability, single market policy, etc.) into a single figure to benchmark country performance for policy consumption seems likewise irresistible."
> Andrea Saltelli, JRC, http://composite-indicators.jrc.ec.europa.eu/, accessed 13 June 2008

Table 26: List of pros and cons of composite indicators

Pros	*Composite indicators* • summarize complex issues • are easier to compare than separate indicators • help attract public interest • include more information, while reducing the amount of data • prepare the visualization and localization of vulnerability • enable regional comparability
Cons	*Composite indicators* • include the possibility of sending a misleading signal • include simplification and generalization • include subjective judgment in construction • are subject to misuse and are at the disposal of politics • increase the quantity of data needed • often do not document the process of aggregation transparently • have problems of measurement: absence of data, different methods of statistical compilation, and errors in measurement • have problems of the averaging procedure: composite indices and averaging may conceal divergences, and some variables may cancel out the effect of another variable • have problems of weighting: subjective discretion plays a role in assigning the values • are a trade-off between simple averaging and weighting • have problems of aggregation, for example vulnerable communities that differ in size; and hiding of disparities by generalizing parameters • have political aspects

Source: modified and supplemented after Saisana and Tarantola 2002 and Briguglio 2003: 11

It is important to describe both benefits and limitations of social vulnerability indicators (Briguglio 2003; Cardona 2005; Nardo et al. 2005). Composite indicators have many advantages, such as summarizing complex phenomena, showing directions for development, and allowing comparison across places or identification of areas for action (see Table 26).

5.1.3 Comparison with other social development indicators

The monitoring of the demographic composition of Germany by social indicators is not a new phenomenon (Zapf 1979). Neither is the monitoring of social-environment relations in Germany, such as sustainable development (Birkmann 2004) or of the flood risk in an economic or hazard parameter-related sense (see Chapters 2.2 and 2.3). Social vulnerability assessment as conceived in this study strives at the explicit linkage of social to natural phenomena. The aim is to make these phenomena measurable in the sense of making them comparable by a semi-quantitative approach. This exploratory pilot approach is a potential starting point for longer-term monitoring of both social and environmental changes over time. However, one must be aware that the theoretical frame, as well as the political scope of using such indicators are also subject to changes over time.

'Quality of life' indicators aim at estimating the 'degrees of well-being' of the population (Bunge 1975; Zapf 1979). The scope of these indicators is to widen the previously economy driven demographic monitoring of physical (environmental), biosocial (health), psychological, technical, social, political and cultural aspects (Bunge 1975: 75). A number of observations are comparable to recent social-environmental indicator approaches like social vulnerability assessment. The goal of an indicator is to derive information by observing and comparing one variable with another, usually unobservable symptom (Bunge 1975: 65). Thus, even methodologically, the indicator approach of 'quality of life' indicators is similar to the social vulnerability indicators. The elicitation of latent symptoms such as weaknesses or strengths of humans against natural hazards is technically achieved by the factor analysis in this study. The resulting factors are the indicators of social vulnerability in Germany. Nevertheless, indicators remain an indirect measurement tool that cannot explain causality, only patterns. The limitations of indicators are not only subject to the technical aggregation, or the ambiguous character (Bunge 1975: 67) of each indicator or variable. The quality of an index and its components largely depends on the quality of the theoretical framework. This obvious observation as well as the demand for improvements in this direction have been perpetuated over many types of social/environmental indicators (Bunge 1975: 75; King and MacGregor 2000) and are not specific weakness of social vulnerability indicators per se.

Many synergies are seen between the related fields of human well-being, development, human rights, and vulnerability (UNEP 2007: 303) assessments. However, the closeness of vulnerability to these fields is also regarded as a problem in the distinction of measurements by common human development, sustainability, well-being, and social vulnerability indicators (Gall 2007). This is to a great extent due to the similarity of the indices, caused by using similar construction techniques and input variables. For example, most country-level indicators have to rely on a small number of variables for which data is available, such as GDP or population density. This similarity blurs the distinction between social vulnerability and development measurements. The separation of various social-environmental indicator approaches is certainly hampered by the similarity of the theoretical concepts.

5.2 Evaluation of vulnerability in Germany

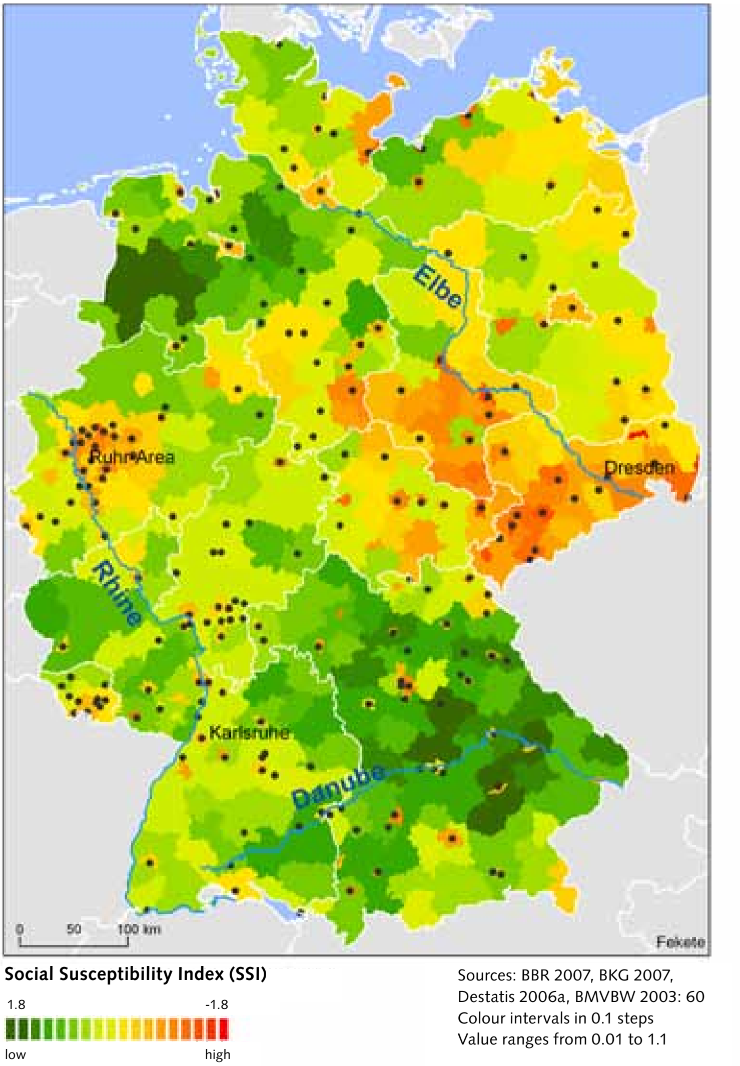
It is quite challenging to assess the situation of social vulnerability to river floods in Germany and how it ranges between localities and groups. Even more challenging is to assess this on a resolution as coarse as county level for the whole territory of Germany. Obviously, such an assessment demands for ground-truthing or validation by local studies. The feasibility of cross-validation by studies at local level has been demonstrated for this vulnerability assessment at county level (Fekete et al. 2009). Using a vulnerability framework and applying semi-quantitative methods allows for cross-scale comparability of both levels. The findings on social vulnerability from a questionnaire survey in Cologne are one source of arguments supporting the selection of the variables for the approach of this study (see Table 3). Similarly, the vulnerability profiles of households derived by the logistic regression in chapter 4.3 serve to validate the vulnerability profiles of counties. Apart from validating the content of the indicators, it can also be shown that the spatial patterns derived by the indices are not randomly distributed, as can be shown by spatial autocorrelation tests.

5.2.1 Other sources of validation

Of approximately 300 city quarters in 500 municipalities participating in governmental programmes regarding social focal point quarters (BMVBW 2003; http://sozialestadt.de, accessed 24 July 2008), around 29 are in the vicinity of the three major rivers, the Danube, Elbe, and Rhine. This is too few to make statistical tests on whether social problem zones are especially prone to exposure. However, the distribution of the locations displays a match with areas of high social susceptibility as detected by the SSI (see Figure 21). It must be emphasized that mainly cities and only a few rural areas participated in the programmes, and that only those city quarters with social focal points and which applied for the programme are recorded. Therefore, the map showing the locations of the programmes does not capture all the social focal points in Germany, yet probably includes most of the ones within urban areas. The map shows that the SSI in many cases identifies urban areas as highly susceptible when the density of social problem quarters is high, for example the Ruhr area, the Saarland, and around Frankfurt am Main. Due to the lack of equal representation of rural areas this cannot serve for a true validation of the SSI. The programme called "social city" (BMVBW 2003) is a useful source for probing the SSI since it captures social problem zones by using local information from the respective local administrations. It is quite interesting to observe that similar zones are detected by the SSI on the much coarser scale of counties.

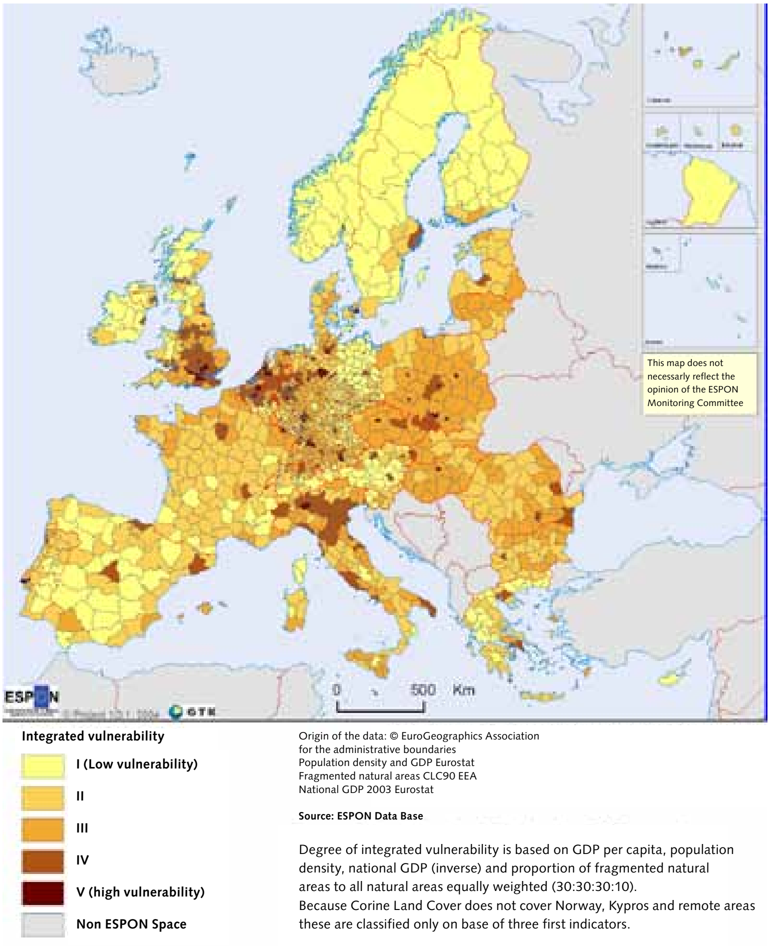
It is also interesting to analyse to what extent the assessment of social susceptibility and vulnerability in this study is comparable to existing social vulnerability indicators of Germany. Currently, only one approach is found to use a comparable spatial resolution and area coverage concerning semi-quantitative social vulnerability measurement in Germany. The European Spatial Planning Observation

Figure 21: Matching of the social focal programme locations with the Social Susceptibility Index in Germany



Source: social focal points by BMVBW 2003: 60

Figure 22: The ESPON integrated vulnerability map



Source: ESPON map from Schmidt-Thomé 2006: 89, with courtesy of the author

Network (ESPON) analysed natural and technological hazard and vulnerability patterns related to climate change impacts on European administrative monitoring areas (NUTS3 level, Schmidt-Thomé 2006). In Germany, this is the spatial level of counties. The ESPON integrated a vulnerability map that consists of four variables: GDP per capita, population density, national GDP (inverse), and proportion of fragmented natural areas to all natural areas.

The comparison of the ESPON integrated vulnerability map with the SSI (see Figure 12) and SIFVI (see Figure 20) maps of this study reveals similar patterns of pockets of vulnerability concentrated in urbanized areas (see Figure 22). However, the intensity of the highest vulnerable class differs; some of the counties with the highest vulnerability class in the ESPON map are not displayed as highly vulnerable in the SSI and SIFVI maps. Similarly, lower classes of vulnerability also show different regional patterns.

The vulnerability map of the ESPON approach must be compared with the susceptibility map of this study. It is only a difference in terminology; what is depicted by the ESPON map as 'vulnerability' is captured in this study as 'susceptibility'.

It is also very difficult to technically compare the two maps, since the ESPON map is colour-coded by five classes of defined values and the SSI by 18 classes of defined equal intervals. The SSI can also be recoded into five classes but since the classification of the break values of the ESPON index is not explicitly described (Schmidt-Thomé 2006: 88), a real comparison is not feasible. After comparing the ESPON map with the five class codings of the SSI it seemed more appropriate to keep the higher range of classes of the SSI. Due to the difficulties of comparison one must be careful about interpretation. The SSI shows a higher resolution of sub-classes of susceptibility. It distinguishes regions not only of negative susceptibility but also regions with predominant coping capacities. Furthermore, the SSI is built upon an advanced theoretical background of social vulnerability and contains three indicators built on a depth of nine validated variables in the SSI.

While the SSI of this study cannot compete with the coverage of Europe of the ESPON approach, it successfully demonstrates that the depth of information can be improved for the spatial resolution of counties in Germany. Even more importantly, the results of the validation in this study help to confirm the validity of social vulnerability indicators concerning natural hazards (see Chapter 4.3). Moreover, the validation step confirmed that social susceptibility (and vulnerability) indicators can be measured by a reduced set of variables. This enables a more theoretically as well as methodologically underpinned application of social vulnerability indices on the basis of reduced data sets. This finding is especially valuable for monitoring use of indicators on large-scale areas where data availability is often a problem.

5.2.2 Limitations of expert interviews

For even more extensive verification, expert interviews and field trips were conducted. While some interesting insights were gained, it was difficult to find experts versed in both social issues and flood mitigation. By telephone interviews, randomly picked disaster managers of municipalities and counties were asked about topics such as preparedness measures against floods, and potentially threatened persons. The interviews revealed a strong emphasis on technical preparedness measures, especially in Bavaria along the river Danube, but also in some cases along the rivers Elbe and Rhine. The interviewed persons were mostly convinced that the population in the respective area was well informed by the administration about the flood hazard. It was found difficult to get the experts to answer questions on persons who were especially in need of assistance or especially threatened. Most were quite willing to talk about weaknesses and areas for improvement in the local disaster management, but most of these issues had to do with technical measures, which did not provide much insight into social vulnerabilities. Most interviewees identified residents closer to the river as more threatened, and few described special needs groups, such as immobile people, as especially vulnerable, without previous questions suggesting such facts.

In April 2006 a field trip was conducted to the river Elbe which had recently flooded parts of the City of Dresden and the nearby Cities of Meißen and Pirna. Interviews were carried out with disaster managers of the City of Dresden and the relief organization 'German life saving community' (DLRG) in Meißen. The interviews revealed that the greatest concerns of the relief organizations were information flow and communication difficulties between several levels of administration. This suggests further research of institutional vulnerability and information networks is needed. Major cities, such as the City of Dresden were found to be better equipped with technical information systems but also commanded more diverse levels of disaster management as compared to smaller cities, such as Meißen. Transboundary communication with Czech colleagues was another topic where the city of Dresden has direct access, whereas the volunteers of the relief organization in Meißen expressed lack of information access.

For the purpose of generating an overview on counties in Germany it was found difficult to make use of singular expert information. Field trips and random sample interviews allow for unmatched detailed information and the generation of crucial new aspects about root causes of vulnerability. However, it was difficult to find evidence about characteristics of potentially affected citizens among flood experts and disaster managers. Most information was found to be locally specific and not generalizable for whole regions. There are clear constraints about the use of singular local evidence for building indices for large areas, such as those considered in this study. These local facts are valuable and in individual cases might be more important than the more general facts measured by an index. However, other patterns might be responsible for large-scale disasters. In order to validate such large-scale patterns, the requirements are a large sample size and monitoring over many years, both of which are costly and time-consuming (King and MacGregor 2000: 54). The recurrence of several hazard cases is certainly not to be hoped for. It is perpetuated among experts however, that such repetitive events are necessary to improve the awareness of the population (Vogt 2006) and the investment activity of administrations (Bednarz 2008). Such events are also windows of opportunity for the observation of flood preparedness, awareness, and institutional vulnerability. However, social vulnerability as addressed in this study will only be revealed in the case of a disaster. Since delay in addressing this issue is inadvisable, indices such as the SSI and SIFVI are crucial to proactively identify potential disaster areas and potential disaster victims before any impact. Even if this index information is preliminary and amendable, it is an important basis for further research activities and counselling of disaster management teams and decision makers.

5.2.3 Limitations of weightings by experts

After the construction of the indicators, experts in the field of vulnerability and floods were asked to give feedback on the approach. They were provided with a questionnaire wherein the variables used for the indicator approach were listed. The experts were asked to comment on whether the variables indicated higher or lower vulnerability to floods. Additional flood parameters and perception of importance of technical and non-technical measures were further points covered in the questionnaire. Finally, they were asked to weight the social vulnerability indicator in relation to the hazard information to construct a vulnerability index. This survey consisted of several steps of feedback from the experts, a methodology known as the Delphi method and one which is commonly applied for the weighting of such indices (Schmidt-Thomé 2006). Several pre-tests were run with colleagues and experts working in the field of vulnerability assessment, most of whom were also knowledgeable about flood hazards.

The survey revealed very interesting results. Most experts made similar assumptions about the indication of vulnerability of each variable. The strength of indication of the variables as well as the weighting of the final index were slightly related to the background of experience of the experts, i.e. whether they had more of a natural science or social science background. Even more interesting however were the comments on the questionnaire. Many experts observed that it is a very difficult task to obtain both hazard expertise and social demographic knowledge. Many felt more comfortable answering only a limited number of the questions and expressed difficulties with the weighting of all aspects. The ambiguity of the variables was noted as a major constraint. Many were uncomfortable about assigning degrees of vulnerability to certain variables, such as the unemployed or the group of foreigners per county.

Several experts refused to stereotype certain social groups without any evidence. This example shows the limitations of validation of such an index by the assumptions of experts, when no concrete evidence is available. Three experts refused to fill out the questionnaire, while 12 experts commented on these aspects but completed the questionnaire. These concerns persisted throughout several pre-test rounds with modifications of the questionnaire in consultation with the experts. Therefore, the idea of weighting of the variables or the index was abandoned. Improving such a questionnaire exceeded the initial scope and temporal resources of this study but is a future field of advancement.

The experience with the Delphi method shows that social vulnerability is still a field that few experts are familiar with and too few case studies exist to make precise assumptions. It is especially difficult to find experts with expertise in both hazard and vulnerability fields and for areas as large as whole river basins or for the whole of Germany. Before such a survey is thoroughly conducted with a sufficiently large sample of experts, it seems more prudent to rely on quantitative validation by a real case event as carried out in chapter 4.3. It is an especially interesting interim result that there seems to be no established body of knowledge about differences of social groups with regard to potential disaster impact. This work is therefore a pilot study in an area where more research is needed.

5.3 Reflections on theory

Vulnerability research is a concept that has been exposed to several modifications and is becoming an increasingly well-established application. It bears some resemblance to the term ‘sustainability’ not only because both have similar goals but also because of the confusion about what it actually means. Some authors have already lamented that the term is at risk of becoming meaningless because it is not defined precisely enough (Cannon 2006). However, it can already be described as a mature concept as, due to the plethora of definitions, researchers have agreed not to agree. The consensus is to state the view of vulnerability definition and theoretical frame for orientation before elaborating on the findings. Still, the quest for a unifying theoretical foundation behind it is a major demand on social vulnerability assessments (King and MacGregor 2000: 52).

Vulnerability is a fine example of interdisciplinary science. In the context of “natural hazards”, food security, climate change, etc., several scholarly disciplines strive for integration of disciplines. This is necessary in complex and messy real world problems such as “natural disasters” that can seldomly be reduced to a single explanation. One-sided hazard-oriented technical solutions have been criticized in the International Decade of Natural Disaster Reduction of (IDNDR) as not sufficient to treat humanitarian crises (Wisner et al. 2004: xvii). The same could probably be said about approaches focusing only on social science. However, at the same time it must be stated that interdisciplinary work is a field full of “landmines”. It is difficult to find a common language between natural science, social science, and engineering. It is not uncommon to meet researchers who have simply given up talking to “the other side”. Still, vulnerability and resilience are spearheading interdisciplinary human-environment science with an intensive push for advancement of theory and collaboration with other scientists and decision makers on the application of vulnerability assessments to the mushrooming number of reports on disasters of natural origin.

‘Measuring’ social vulnerability is certainly a bone of contention for qualitatively-oriented social scientists, such as anthropologists. The background of technically-driven worldviews and reduction of human culture and social complexity to a ‘black box’ looms behind the ‘measurement’ or quantification of human weaknesses in the face of disasters of natural origin. However, social vulnerability also provides an exciting impetus to try to find tools that enable natural and social scientists to integrate their findings. This study hypothesizes that modern GIS, maps, and semi-quantitative indicators are such tools. However, this is only the technical application, the engineering side of integrative research. These tools are mere containers for integrating ideas. What is even more interesting is advancing what is actually measured. Vulnerability maps can be quickly assembled, but a thorough investigation of the content is paramount. The tools only provide an interface, a platform for communicating the theoretical assumptions.

To what extent was the theoretical background helpful for identifying social vulnerability in Germany? First of all, social vulnerability opens a path of investigation aside from traditional flood risk perspectives. While ‘root causes’ and ‘dynamic pressures’ in societies are a common field of sociology and other social sciences, the bridge to natural hazards is still quite under-researched in Germany. The conceptual BBC framework guides the perspective of interconnections and main categories to be looked at. The theoretical sub-categories of vulnerability – susceptibility, capacities, and exposure – are especially helpful for structuring the identification of vulnerability among the social groups depicted by the statistical variables. 'Susceptibility' is a research lens that is especially helpful for identifying attributes of humans that can be weighed against each other, and thus helping to build a more precise argumentation for why different groups are more or less vulnerable. The capacities of humans are a difficult theoretical category, since they often represent the opposite of the susceptibility of the people. Still, it is helpful in some areas to explicitly search for positive attributes that might be overlooked by a mere negative research focus. This bifocal consideration of positive as well as negative attributes helps to uncover unsuspected coherences. For example, the affluent are not in all respects safer; they are even more exposed when residing in expensive homes alongside water-fronts. Social networks are not only positive attributes; in some cases tradition may hinder taking early warning seriously.

> "It is not important to forecast the future, but to be prepared for it"
>
> Perikles 500 B.C.

The limitations of precise prediction of social vulnerability lie in the complexity of the problem itself. Social interactions are already complex in the sense of defying reduction to a set of axioms. While patterns of social interaction are observable, it is doubtful whether they are any better for precise prediction than 'cargo-cults'. The indicators in this study are merely indirect measures of a reduced set of observations. Especially in the context of the social interactions with the environment, one must refrain from activities such as predicting the exact timing or extent of potential disasters. Flooding risk is non-linear, non-deterministic, and contains chaotic features, thus making it difficult to predict the probability of flood events. Features of flood risk are hydrological and hydraulic parameters. Another feature is the social system, of which some say (Richardson 2005: 622) that "it is nigh to impossible to get such an accurate appreciation of its current state. If we could view its current state directly its future evolution would be quite easy to ascertain (…)". An elegant way out of this dilemma is formulated by Cardona: "(…) the concept underlying this methodology is one of controlling risk rather than obtaining a precise evaluation of it (physical truth)." (2005: 2).

Constructing a social vulnerability index is a trade-off between direct evidence that is often not available, and indirect assumptions that are always preliminary. The construction of a social vulnerability index is not intended to examine causality or elicitation of truths. Such an index is always an indirect surrogate of a phenomenon. While it has been successfully demonstrated that the social vulnerability index identifies social groups that could be tested on the historic flood disaster of 2002, it cannot be assumed that another event would not reveal a different picture. This situation is comparable to the term "centennial flood". The public audience confuses this statistical measure with causality in the sense that such a flood is expected only once every 100 years. There can never be a real prediction of the exact timing of such weather events as it cannot be predicted to 100 per cent accuracy which social group will be affected most. Each disaster is different, and continuous improvement of measurements can only help to verify but never to absolutely predict the extent, timing, and characteristics of a disaster.

Stressing these limitations of prediction is especially important in a multi-disciplinary arena where the aims of natural scientists conflict with the perceptions of social scientists. This is an obstacle in interdisciplinary work, when one side wants to measure exactly and predict by reduction and precise definitions, while their counterparts believe in the impossibility of reduction and the limitations of quantification. Flood vulnerability is a difficult topic here since it combines both fields and represents a problem that is always subject to changing perceptions. Flood vulnerability as presented in this study is a negotiated balance of human perception of the environment and threats posed by hazards. This balance is fragile and subject to change since many of the scientific and political aims of decision makers are themselves constantly subject to change.

6. Transfer

The development of social vulnerability indicators is not an end in itself (King and MacGregor 2000: 52). The developed indices are constructed to enable methodological and conceptual coupling with other information and scientific fields. Some of these couplings and mutual benefits have already been accomplished, and there are many directions for which the application of the SSI and SIFVI are promising.

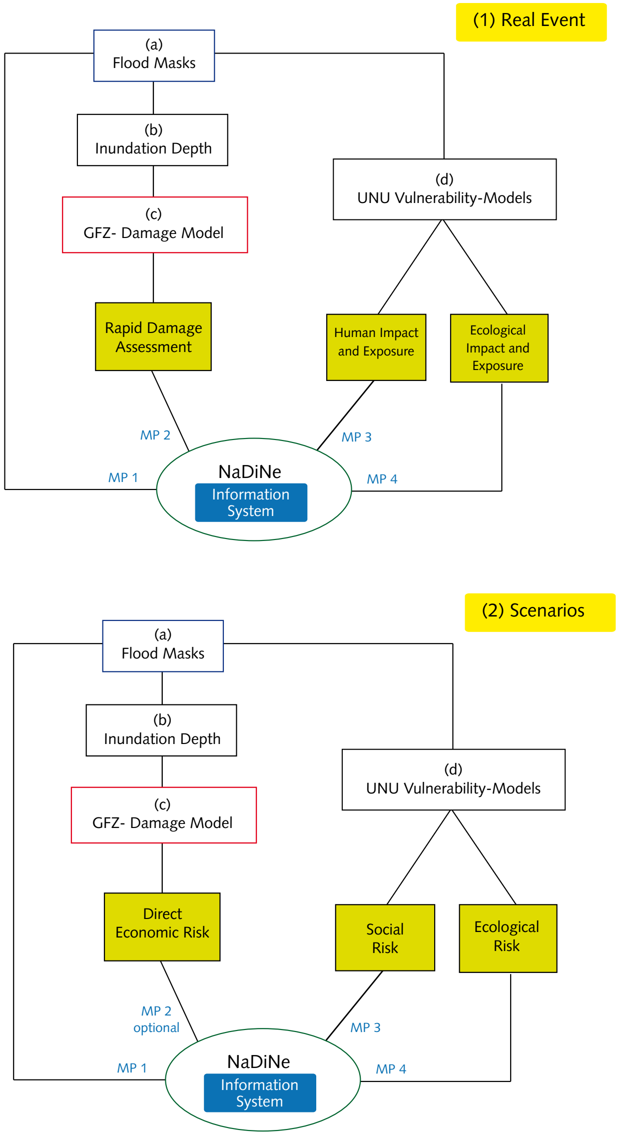
6.1 The DISFLOOD project

This study is one major package in the project 'Disaster Information System for Large-Scale Flood Events Using Earth Observation' (DISFLOOD, Damm et al. 2006). The project is a platform for multi-disciplinary and multi-institutional research. It is a joint effort of DLR, GFZ, and UNU-EHS. The project, as financed by the Helmholtz society, started in late 2005 and ended in 2008. The internet platform created by the project targets extreme river floods in Germany by assessing hazard and vulnerability parameters. At the same time, DISFLOOD is a pilot study to combine different methods such as remote sensing, hydraulic hazard models, and economic damage models with social and environmental vulnerability indicators. The outcome is an online information system that is available on the NaDiNe website (http://nadine.helmholtz-eos.de/nadine_en.html). The prime target groups of NaDiNe are experts working on flood protection, regional planners, and scientists. Moreover, the interactive hazard and vulnerability maps are also accessible by the public to a certain degree.

A major innovation is that the social vulnerability map for the whole territory of Germany is available and combinable with hazard information. The construction of the social vulnerability map by a semi-quantitative indicator approach allows merging of other quantitative information of the project partners. The hazard information is either derived from hazard scenarios (statistical precipitation or inundation estimations) or, as another innovation, by real event mapping by remote sensing data. This map package 1 (MP1, see Figure 23) is created by the project partners DLR and GFZ for the two principal application cases; for a real event (part 1 of the flow chart in Figure 23) and for scenarios (part 2 of Figure 23). The real event mapping delivers exact and timely documentation of the hazard extent for large areas in the case of an event. Such information has been lacking until today; former flood events are hardly documented in a concise and comparable way. This hazard information is then merged with the vulnerability maps that have already been computed. This step enriches the hazard layer with information about the impact on society (MP 3, see Figure 23) and the environment (MP 4, see Figure 23). This allows for a rapid overview of the potential impact of the flood, and highlights areas of special concern for evacuation, emergency measures, and recovery priorities. Additionally, the rapid economic damage estimation developed by the GFZ can be computed for buildings and related values in the affected area (MP 2, see Figure 23). Such rapid damage assessment locates flooded regions, settlements, and respective population density, and the social vulnerability profile per affected county.

Aside from the real event case, the social vulnerability map is an important input for longer term planning using scenarios (part 2 of Figure 23). Scenarios of hazard events are, for example, the historic flood event sets of the GFZ or the hazard inundation maps used in this study (see Chapter 4.6.1). The hazard information of the GFZ partner for historic flood event sets will cover the whole territory of Germany. The official extreme event hazard inundation maps are at present available for the river Rhine, the river Elbe within the federal states Saxony and Saxony-Anhalt, and, only to a limited extent for parts of the river Danube (see Chapter 4.6.1). Combining these hazard scenarios (MP1, see Figure 23) with the SSI (MP3, see Figure 23), an SIFVI can be computed (see Chapter 4.6). Additionally, this index can be merged with the socio-environmental vulnerability index (MP 4, see Figure 23) of the project partner at UNU-EHS (Damm 2008). This creates a combined risk index of disaster by flooding for both the human and the environmental sectors. It allows for a more holistic estimation of potential impacts of hazards on a coupled human-environment system. This risk index is an important planning tool for directing hazard prevention in the context of sustainable development, adaptation to climate change, and demographic development of Germany. As an option, the direct economic risk for buildings and related values from the GFZ can be computed for specific regions and then compared with those regions containing high social and socio-environmental vulnerability. This range of different aspects allows for a more precise analysis of the different impacts of a flood. For example, regions with a high economic vulnerability are not automatically congruent with areas of high environmental impact or areas where the most socially vulnerable population resides. DISFLOOD thus provides a concise body of information for decision makers to identify vulnerability mitigation priorities in different sectors; society, environment, and economy. The modular composition of the indicators permits the analysis and display of special fields of interest, for example, the location of especially vulnerable persons. The easily comprehendible maps alleviate the implementation of such complex information for flood experts and politicians alike. DISFLOOD is therefore a true multi-disciplinary platform that transforms complex scientific interrelationships into accessible information

Figure 23: Workflow within the DISFLOOD project for 1) a real event and 2) scenarios



Source: DISFLOOD team

6.2 Future research needs

One field of advancement for this study could be to obtain data with finer resolution of settlement areas and the connection to exposure areas. With the available data resolution it cannot be established, for example, whether the hospitals of a county are located far enough away from potential inundation areas or whether a social focal point with prevailing low-income groups is located within an exposed area. However, when hazard maps are available, a rough estimation of the affected population and their specific county profile can be accomplished. It would certainly be desirable to obtain data at higher spatial resolution.

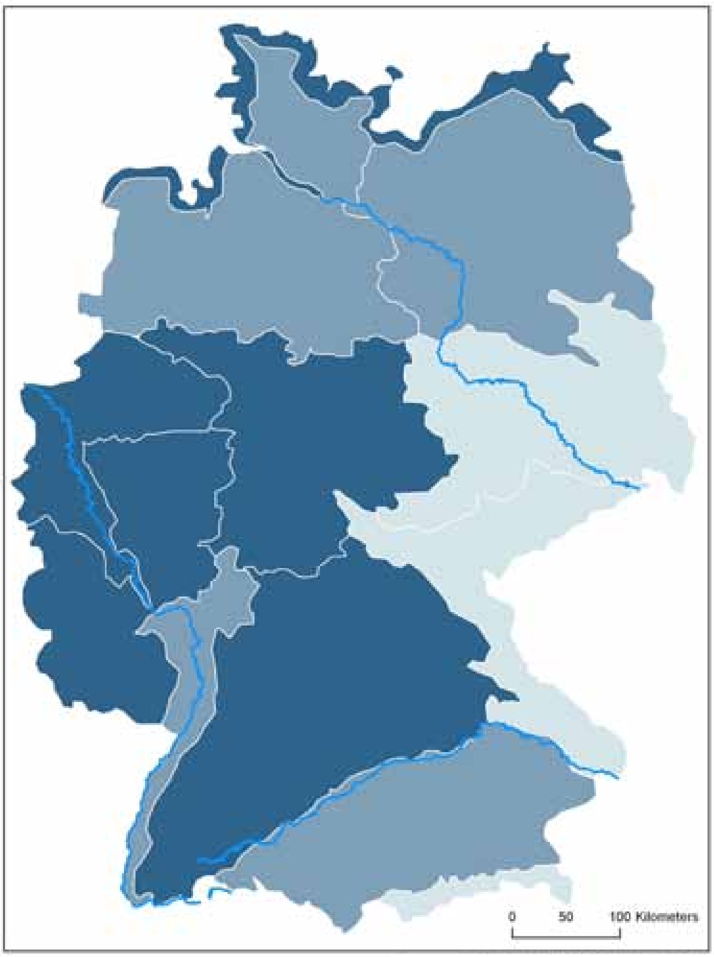
Hazard: Hazard scenarios are an important field for applications of social vulnerability indices. Apart from traditional flood hazard parameters such as inundation depth, velocity, or debris load, it is especially interesting to construct temporal scenarios, for example day and night time, when the distribution of the population is different and the surprise factor of a flood higher. Another example is seasonal differences, where a devastating flood in winter results in the cut-off of electricity and heating. Other areas for hazard scenarios are coastal zones or flash floods, but also secondary hazards such as cascading effects on drinking water. Climate change is one recent concern, although it is just one among many processes such as deforestation and population growth to which an increasing number of people will be exposed until 2050 (UNU 2004). The fourth IPCC report only increased the interest in researching the vulnerability of societies that will be subject to major transformations by extreme events (IPCC 2007: 541). The methodology of semi-quantitative indicators on the background on a common vulnerability research framework is especially appropriate for cross-scale analyses of climate change hazard impacts, but also of impacts on the population. The SSI and SIFVI, as developed in this study, can be combined with climate change scenarios to identify regions in Germany and Europe where increased variability of precipitation patterns coincide with vulnerable populations. This approach is currently attracting much research interest (EEA 2005; Zebisch et al. 2005) and is a field for scientific and political collaboration opportunities across institutional and disciplinary borders.

Recent climate change scenarios (see Figure 24) suggest that the western parts of Germany and the coast will experience increased winter precipitation. Summer precipitation will decrease in some regions and seasonal patterns will shift in Germany while at the same time convective precipitation and storm events are expected to increase regionally (cf. Zebisch et al. 2005: 190; Spekat et al. 2007).

Social vulnerability: Demographic change is a key driver transforming the pattern of social vulnerability in Germany. As a main driver of demographic change in Germany (see Chapter 2.4), the ageing of the population is of major concern since it increases the proportion of vulnerable people in Germany. The distribution of a projected increase in the ageing population is not uniquely dispersed over Germany (see Figure 25). Regions with less economic prosperity, especially in the east of Germany, are especially prone to this change. The whole population and social system is affected by the declining number of working age people who pay taxes and thus provide medical care for the elderly. Since the elderly are those most dependent on assistance, for example in the case of evacuation (see Chapter

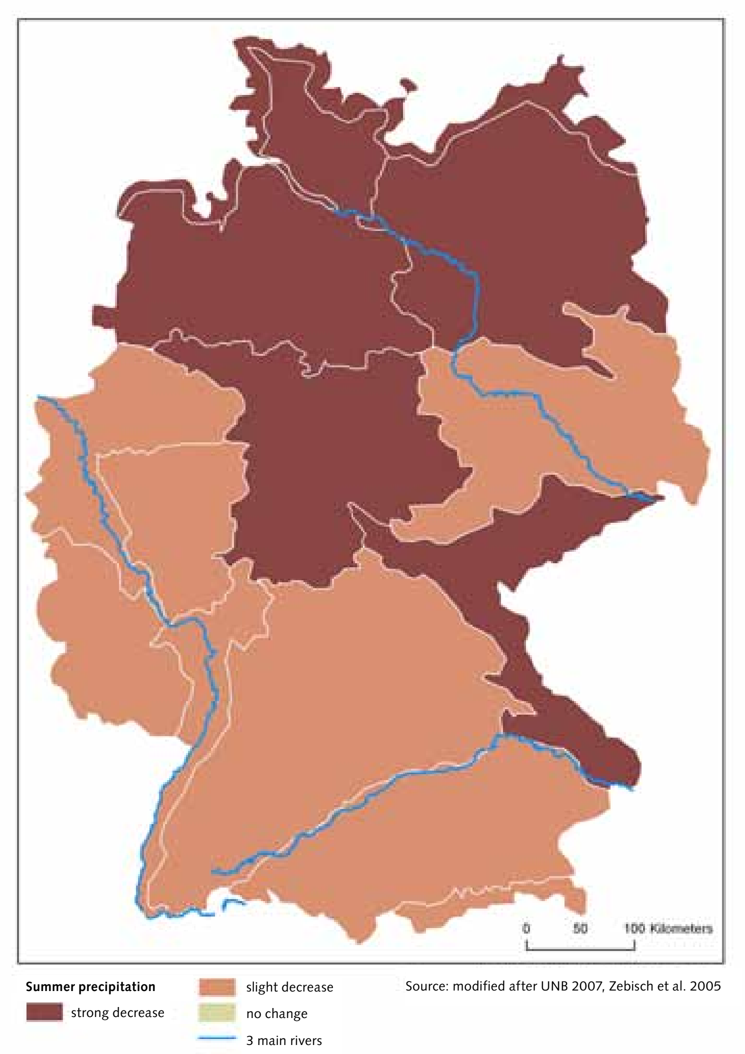
4.3), places with a higher ratio of population increase are priority areas for disaster mitigation planning. The SSI is one tool for monitoring and projecting static as well as dynamic compositions of society in relation to various hazard and demographic change scenarios.

Figure 24: Regional impacts of climate change precipitation scenarios



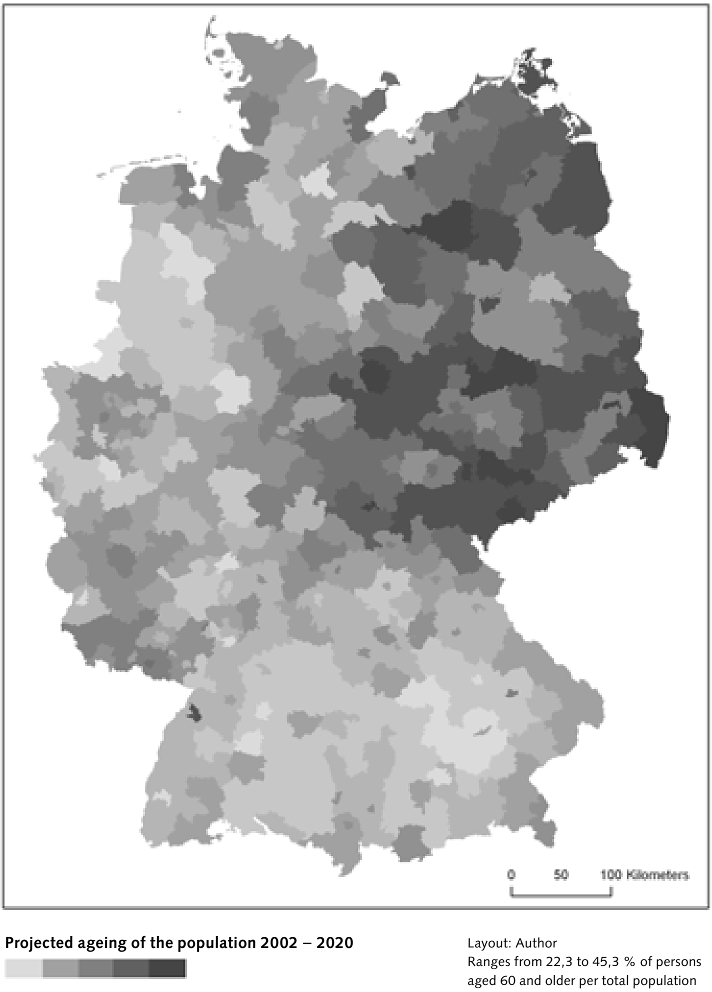
Winter precipitation
no change
slight increase
strong increase
3 main rivers

Source: modified after UNB 2007, Zebisch et al. 2005



Source: SRES scenario A2, in Spekat et al. 2007: 70

Figure 25: Projection of the ageing of the population in Germany from 2002 to 2020



Projected ageing of the population 2002 – 2020

Layout: Author
Ranges from 22,3 to 45,3 % of persons aged 60 and older per total population
Ranking in 10 intervals in natural breaks (jenks)

Source: Modified from BBR 2006, 2007

This example is just one area for further exploration of the versatility of the social vulnerability indices. Demographic monitoring and natural hazard mitigation will continue to receive attention in the future. Scientists and decision makers will need to explain complex vulnerabilities and developments to the public. The social vulnerability maps presented in this study are an important contribution to this explanation.

6.3 Recommendations for decision makers

The presented study reveals advancements in scientific methods and results that can be used for overarching political objectives, such as disaster risk reduction. Such outcomes and tools can be conveyed to decision makers by using the language of project management. Decision makers – a target group of this study – are disaster managers, flood experts, and land use planning authorities. A common structure for the implementation of project results and objectives is the logical framework approach. This project management approach is endorsed by the European Commission (EuropeAid 2004) and the Australian Government (AusAID 2005), for example.

The logical framework matrix (see Table 27, cf. EuropeAid 2004: 73: AusAID 2005: 3) structures research activities, results, purpose, and overall objective in a vertical hierarchy. The simple 4x4 matrix provides an overview of what these points are in the project, by which indicators they can be measured and verified, and what risks and assumptions are behind them. The logical framework matrix identifies activities necessary to achieve the results of the social vulnerability assessment. Project management and external decision maker appraisal is important to meet the assumptions and avoid the risks in achieving the overall objective. The individual steps can be monitored by the indicators and means of verification.

Achievements and benefits of this study are:

- The successful demonstration that a social vulnerability assessment in Germany can be carried out
- The enhancement of common hazard and vulnerability approaches by developing information about the vulnerable population
- It provides an information tool that can be combined with other data sources
- It provides maps that are easy to interpret
- It provides an information system that is accessible on a web-based platform.

Challenges identified in this study are:

- Data availability and spatial resolution of data can be still improved, even for countries such as Germany
- Awareness about the availability and versatility of social vulnerability assessments must be raised

Table 27: Logical framework matrix of this study

Project Description	Indicators (of how it is achieved and measured)	Means of Verification	Assumptions and Risks
Overall objective: Disaster risk reduction as a topic of the Hyogo Framework of Action; human security policy of the UN	*- Not appropriate for the study itself to provide and collect this information -*		
Purpose: Capacity-building of knowledge and awareness about social vulnerability. Inter-disciplinary integration with hazard and risk perspectives.	Access to the information. Transparency. Documentation, publications within the time frame of the project and after.	Publication of thesis in the UNU-EHS Graduate Research Series. Publications in peer-reviewed scientific journals. Oral and poster presentations at national and international conferences and meetings. Contribution and integration into the International Flood Initiative (IFI) Reports.	Connection of the scientific output to the target group and stakeholders must be accomplished. Awareness and need for such information must be assessed.
Results: Disaster Information System. Social vulnerability Indices. Social vulnerability profiles of counties in Germany. Checklist for social vulnerability measurement	Project delivery by the project end in 2008. Work packages delivery and implementation. Quality control by scientific review.	DISFLOOD Information System of DLR, GFZ and UNU-EHS on the NaDiNe website. Doctoral theses	Project coordination and identification of common frame, methods, and goals are necessary in a multi-disciplinary project. Funding and allocation of resources are important.
Activities: Flood impact review. Review and assessment of social problems. Development of a conceptual framework. Vulnerability assessment	Theoretical framework of vulnerability. Statistical analyses. GIS analyses.	Data sources of literature. Census data. Remote sensing data. GIS data.	Data availability and information depth for such large-scale areas is often a problem. Access to data is difficult due to various administrative hierarchies in Germany. Time and resources constrain more in-depth data collection.

Source: Author

- Integrative multi-disciplinary scientific projects require openness and engagement from all project partners and all scientific disciplines to accept new ideas.

Observations on the application of the scientific results:

- The results can be viewed on any web browser by the public and documentation is provided in standard text formats, as well as in scientific publications
- Certain target groups, such as flood or vulnerability experts, disaster managers, or spatial planners can get access to certain data by request
- Expert knowledge, special software, and data access are necessary for reproducing the results and for longer-term monitoring
- Social vulnerability is a topic concerned with the reduction of disaster risk and mitigating the impact of natural hazards.

For the successful implementation of the scientific results in national or regional policies, however, a specific applicability study would be recommendable. There is a need to identify the institutional structures and terminology first, before translating the scientific results into policies and decisions. Otherwise, there is a risk of misunderstanding due to the different systems and languages of communication that exist between science and policy. While the risks and assumptions behind the indices and methodology are stated in this study, they might not be understood by the stakeholders. Although much effort has been invested in creating maps that are easily comprehensible visually, the hazard of misconception cannot be ruled out. Therefore, it is necessary that implementation of social vulnerability aspects into policies or decisions is supervised by an expert. Mutual communication between stakeholders, decision makers, and experts is the key to the successful use of complex disaster risk information.

7. Conclusion

This study demonstrates the merits and feasibility of carrying out a semi-quantitative social vulnerability assessment in Germany. On county-scale, patterns specific to the composition of social vulnerability towards river floods have been identified, transformed into quantifiable indicators, and validated by an independent second data set. Social vulnerability as a concept applied in other countries has been successfully applied and advanced regarding the validation of such an index. This assessment of social vulnerability captures not only exposure and susceptibility but also indicates capacities of humans to mitigate and adapt to disasters.

There can be no analysis of risk management, resilience, and adaptation options without first understanding vulnerability. Vulnerability is a detector of the susceptibility and capacities of any system. Social systems in the context of a hazard are determined by their physical location, temporal development, and their internal and external influences and exchanges. This place-based notion of complex problems can be measured by the exposure of this system to external threats.

However, place-based exposure only becomes a problem when certain negative and positive, passive and active abilities and conditions coincide. Joint analysis of the exposure, susceptibility, and capacities of a system at risk provides a broad research lens that helps to capture aspects that might have been neglected by traditional hazard or risk analyses so far.

The SSI as well as the SIFVI are excellent tools for starting a monitoring process that captures social dynamics in Germany and links them to environmental processes. The comprehensibility and versatility of these indices and maps provide decision makers with information about complex phenomena that can be used for the development of strategies and policies. The risks and assumptions behind the construction of these indices will be a valuable guideline for experts and scientists working in the field of natural hazards and associated human-environment systems. The study contributes to the overall objective of disaster risk reduction that is acknowledged on the global level by the Hyogo Framework for Action.

There are limitations and challenges when it comes to transferring the approach of this study. Data availability and the spatial and temporal resolution of the data are limitations for capturing certain social aspects, such as flood experience, preparedness, or risk perception for the large research area. The hazard scenarios are limited to inundation extent, and full data coverage was not available for two of the three major rivers, the Danube and Elbe – only for the Rhine. Within the methodology, the challenges lie with an objective selection of the variables and the weighting procedure, even when a comprehensive conceptual framework guides the systematization. It is in the nature of indicators and quantification that the actual phenomena are only indirectly measured and often generalizations must be made. Therefore, the indicators are valid only for describing average characteristics of the demographic composition of counties, not for capturing the vulnerability of single households. As with every analytical concept, many assumptions are made, and readers are encouraged to regard the results of this study not as definite, but rather as a starting point for improvement and further research.

The assessment of social vulnerability is not an end in itself and does not stop at the description of potential demographic weaknesses and strengths. Social vulnerability is one dimension of vulnerability besides the vulnerability of infrastructure, of the environment, and others. Social vulnerability is also one element of disaster risk assessment and provides crucial information for supplementing hazard assessments. The versatility of the developed SSI is exhibited by integrating it with vulnerable infrastructure and an extreme event hazard scenario. The outcome is a SIFVI which highlights areas of specific vulnerability of flood impact aggravated by social deficiencies. Applications for this index and the methodology already exist within the DISFLOOD project. Within this project, advanced hydrologic modelling and real event rapid hazard mapping by remote sensing are input for the further advancement of the hazard estimation. In another part of the DISFLOOD project, a vulnerability assessment of the social-ecological dimension has been conducted (Damm 2010, Graduate Research Series vol. 3, UNU-EHS). By combining the two vulnerability assessments and the two hazard estimation methods, a truly multidisciplinary, holistic, and balanced approach to flood vulnerability is accomplished.

This study contributes to recent research activities around social vulnerability in three respects. First, it increases information about social vulnerability in Germany. Second, the methodology fosters the integration of social vulnerability with more technical and hazard-oriented approaches. Third, it aligns with the research direction of interdisciplinary science that is especially important in the field of the human-environment nexus. Vulnerability, resilience, climate change, and sustainability are high on the agenda of national policy and research. These are fields where advancement in information depth and awareness are prerequisites for developing strategies for the future in the light of population growth and environmental strain. Knowledge of complex relationships translated into measurable indicators will be a key field for the identification and valuation of future action priorities.

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Abbreviations and acronyms

BBC model	Vulnerability framework of the authors Bogardi, Birkmann, and Cardona
BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe
BBR	Bundesamt für Bauwesen und Raumordnung (Federal Office for Building and Regional Planning)
BFG	German Federal Institute of Hydrology
BMI	Bundesministerium des Innern (Federal Ministry of the Interior)
BMVBW	Bundesministeriums für Verkehr-, Bau- und Wohnungswesen
CI	Confidence Interval
CLC	CORINE land cover
CRED	Centre for Research on the Epidemiology of Disasters
DFID	UK Department for Intenational Development
DIS	Disaster Information System
DISFLOOD	Disaster Information System for Large-Scale Flood Events Using Earth Observation
DSS	Decision Support System
DKKV	Deutsches Komitee für Katastrophenvorsorge e.V. (German Committee for Disaster Reduction)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)
DLR-DFD	German Aerospace Centre – German Remote Sensing Data Center
DRM	Disaster Risk Management
DSS	Decision Support System
EEA	European Environment Agency
ESPON	European Spatial Planning Observation Network
EWS	Early Warning System
FIG	The International Federation of Surveyors
GDP	Gross Domestic Product

GFZ	Deutsches GeoForschungszentrum Potsdam (German Research Centre for Geosciences Potsdam)
GIS	Geographic Information System
hh	household
IDI	Infrastructure Density Index
IDNDR	International Decade of Natural Disaster Reduction
IKSE	Internationale Kommission zum Schutz der Elbe
IKSR	Internationale Kommision zum Schutz des Rheins (International Commission for the Protection of the Rhine)
IPCC	Intergovernmental Panel on Climate Change
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
MSA	Measure of Sampling Adequacy
MUNLV	Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen
NaDiNe	Natural Disasters Networking Platform
PAR model	Pressure And Release model
PCA	Principal Component Analysis
pp	per person
pphh	per person per household
SEI	Stockholm Environment Institute
SIFVI	Social and Infrastructure Flood Vulnerability Index
SSI	Social Susceptibility Index
SV	Social Vulnerability
UBA	Umweltbundesamt (Federal Environment Agency)
UNDP	United Nations Development Programme
UN/ECE	United Nations and Economic Commission for Europe
UN/ISDR	United Nations International Strategy for Disaster Reduction
UNU	United Nations University
UNU-EHS	United Nations University Institute for Environment and Human Security

VA	Vulnerability Assessment
VI	Vulnerability Index
VIF	Variance Inflation Factor
WBGU	Wissenschaftliche Beirat der Bundesregierung Globale Umweltveränderungen (German Advisory Council on Global Change)
ZEF	Centre for Development Research

References

Acosta-Michlik, L. (2005): *Intervulnerability Assessment. Shifting Foci from Generic Indices to Adaptive Agents in Assessing Vulnerability to Global Environmental Change (A Pilot Project in the Philippines)*. Report on a Project of the Advanced Institute on Vulnerability to Global Environmental Change., University Catholic of Louvain (UCL). Department of Geography, Louvain-la-Neuve, Belgium.

Adger, W.N. (2006): Vulnerability. In: *Global Environmental Change.* vol.16. pp. 268 – 281.

Anderson, M.B.; Woodrow, P.J. (1998): *Rising from the Ashes: Development Strategies in Times of Disaster,* Lynne Rienner, Boulder.

AusAID (2005): *AusGuideline. Activity design 3.3. The Logical Framework Approach*. Australian Government.

Backhaus, K.; Erichson, B.; Plinke, W.; Weiber, R. (2006): *Multivariate Analysemethoden.* 11th edition, Springer, Berlin.

Baden-Württemberg (2005): *Hochwassergefahrenkarten in Baden-Württemberg.* Innenministerium; Umweltministerium; Wirtschaftsministerium Baden-Württemberg, Stuttgart.

Barredo, J.I. (2007): Major flood disasters in Europe: 1950-2005. In: *Natural Hazards*. vol. 42, pp. 125 – 148.

Baumert, J.; Artelt, C.; Klieme, E.; Neubrand, M.; Prenzel, M.; Schiefele, U.; Schneider, W.; Tillmann, K.-J.; Weiß, M. (2003): *PISA 2000 – Ein differenzierter Blick auf die Länder der Bundesrepublik Deutschland – Zusammenfassung zentraler Befunde*. OECD PISA Deutschland, Max-Planck-Institut für Bildungsforschung, Berlin.

BBK (2009): *Schutz Kritischer Infrastruktur: Risikomanagement im Krankenhaus.* Praxis im Bevölkerungsschutz, Bd. 2, Bonn.

BBR (2002): *Handlungsschwerpunkte von Raumordnung und Städtebau zur langfristig vorbeugenden Hochwasservorsorge.* Positionspapier. Abteilung I Raumordnung und Städtebau, Bonn.

BBR (2004): *Bauliche Schutz- und Vorsorgemaßnahmen in hochwassergefährdeten Gebieten.* Bonn.

BBR (2005): *Raumordnungsbericht 2005*. Berichte Band 21, Bonn.

BBR (2006): *Raumordnungsprognose 2020/2050. Bevölkerung, private Haushalte, Erwerbspersonen, Wohnungsmarkt.* Berichte Band 23, Bonn.

BBR (2007): *INKAR 2006. Indikatoren, Karten und Graphiken zur Raum- und Stadtentwicklung in Deutschland und in Europa.* Bonn.

Bednarz, K. (2008): Telephone interview. 4 March 2008.

Bernard, H.R. (2006): *Research Methods in Anthropology. Qualitative and Quantitative Approaches.* 4th edition. Altamira Press, Oxford.

Birkmann, J. (2004): *Monitoring und Controlling einer nachhaltigen Raumentwicklung. Indikatoren als Werkzeuge im Planungsprozess.* Dortmunder Verlag für Bau- und Planungsliteratur, Dortmund.

Birkmann, J. (2005): *Danger Need not Spell Disaster. But how Vulnerable Are We?* Research Brief No. 1/2005, UNU, Tokyo.

Birkmann, J. (2006): Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions. In: Birkmann, J. (Ed.) *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*. UNU Press, Tokyo. pp. 9 – 54.

Birkmann, J. (2007): Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. In: *Environmental Hazards*. vol. 7, pp. 20 – 31.

Birkmann, J.; Krings, S.; Renaud, F. (2008): Assessment of Vulnerability to Floods at Local Level with a Special Focus on Human-Environmental Systems and Critical Infrastructures. *Proceedings of the 4th International Symposium on Flood Defence 6-8 May 2008. Managing Flood Risk, Reliability & Vulnerability*, Toronto, Ontario, In: Simonovic, S. P.; Bourget, P. G.; Blanchard, S. F. (Eds.), Institute for Catastrophic Loss Reduction, Toronto.

Blackbourn, D. (2006): *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany.* Jonathan Cape, Random House, London.

BMI (2006): *Schutz Kritischer Infrastrukturen - Basisschutzkonzept.* Berlin. p. 60.

BMVBW (2003): *Strategien für die Soziale Stadt*. Deutsches Institut für Urbanistik, Berlin.

Bogardi, J.J. (2004): Hazards, risks and vulnerabilities in a changing environment: the unexpected onslaught on human security? In: *Global Environmental Change.* vol. 14, pp. 361 – 365.

Bogardi, J.J.; Birkmann, J. (2004): Vulnerability assessment: the first step towards sustainable risk reduction. In: Malzahn, D.; Plapp, T. (Eds.): *Disasters and Society - From Hazard Assessment to Risk Reduction Logos*, Universität Karlsruhe, Germany, Berlin, pp. 75 – 82.

Bohle, H.-G. (2007): *Living with Vulnerability. Livelihoods and Human Security in Risky Environments.* InterSecTions No. 6/2007. UNU-EHS, Bonn.

Bohle, H.-G. (2007): Vieldimensionale Geographische Entwicklungsforschung: das Beispiel der geographischen Verwundbarkeitsforschung. In: Gebhardt, H.; Glaser, R.; Radtke, U.; Reuber, P. (Eds.): *Geographie – Physische Geographie und Humangeographie.* Spektrum Akademischer Verlag, Heidelberg, pp. 797 – 815.

Briguglio, L. (2003): *Some Considerations with Regard to the Construction of an Index of Disaster Risk with Special Reference to Islands and Small States, Indicators for Disaster Risk Management.* Information and Indicators Program for Disaster Risk Management, Inter American Development Bank.

Bröhl, P. (1996): *Ein Leben am Rhein.* Band 3, Schriftenreihe der Bürgervereinigung Ensen-Westhoven e.V., Köln.

Brooks, N. (2003): *Vulnerability, Risk and Adaptation: A Conceptual Framework*. Working Paper 38, Tyndall Centre for Climate Change Research, Norwich.

Bühl, A.; Zöfel, P. (2002): *SPSS 11. Einführung in die moderne Datenanalyse unter Windows.* 8th edition, Pearson Studium, München.

Bühner, M. (2006): *Einführung in die Test- und Fragebogenkonstruktion.* 2nd edition. Pearson Studium, München.

Bundesgesetzblatt (2005): *Gesetz zur Verbesserung des vorbeugenden Hochwasserschutzes*. Vom 3. Mai 2005. Jahrgang 2005, Teil I Nr. 26, Bonn.

Bunge, M. (1975): What is a quality of life indicator? In: *Social Indicators Research.* vol. 2, pp. 65 – 79.

Cannon, T. (2006): Vulnerability analysis, livelihoods and disasters. In: Ammann, W. J.; Dannenmann, S.; Vulliet, L. (Eds.): *Coping with Risks due to Natural Hazards in the 21st Century*. Taylor & Francis, London, pp. 41 – 49.

Cao, C.; Lam, N.S.-N. (1997): Understanding the Scale and Resolution Effects in Remote Sensing and GIS. In: Quattrochi, D. A.; Goodchild, M. F. (Eds.): *Scale in Remote Sensing and GIS*. Lewis Publishers, Boca Raton, pp. 57 – 72.

Cardona, O.D. (2005): *System of Indicators for Disaster Risk Management. Program for Latin America and The Caribbean.* Main Technical Report, Inter-American Development Bank. Sustainable Development Department, Washington, D.C.

Chakraborty, J.; Tobin, G.A.; Montz, B.E. (2005): Population evacuation: assessing spatial variability in geophysical risk and social vulnerability to natural hazards. In: *Natural Hazards Review*. pp. 23 – 33.

Clark, G.E.; Moser, S.C.; Ratick, S.J.; Dow, K.; Meyer, W.B.; Emani, S.; Jin, W.; Kasperson, J.X.; Kasperson, R.E.; Schwarz, H.E. (1998): Assessing the vulnerability of coastal communities to extreme storms: the case of Revere, MA., USA. In: *Mitigation and Adaptation Strategies for Global Change*. vol. 3, pp. 59 – 82.

Cutter, S.L. (1996): Vulnerability to environmental hazards. In: *Progress in Human Geography*. vol. 20 (4), pp. 529 – 539.

Cutter, S.L.; Boruff, B.J.; Shirley, W.L. (2003): Social vulnerability to environmental hazards. In: *Social Science Quarterly*. vol. 84 (2), pp. 242 – 261.

Cutter, S.L.; Mitchell, J.T.; Scott, M.S. (2000): Revealing the vulnerability of people and places: a case study of Georgetown County, South Carolina. In: *Annals of the Association of American Geographers.* vol. 90 (4), pp. 713 – 737.

Damm, M. (2010): *Mapping Social-Ecological Vulnerability to Flooding. A sub-National Approach for Germany.* Graduate Research Series vol. 3, UNU-EHS, Bonn.

Damm, M. (2008): A Socio-Ecological Vulnerability Assessment for Germany. In: Simonovic, S. P.; Bourget, P. G.; Blanchard, S. F. (Eds.): *Proceedings of the 4th International Symposium on Flood Defence 6-8 May 2008. Managing Flood Risk, Reliability & Vulnerability*, Toronto, Ontario, Institute for Catastrophic Loss Reduction, Toronto.

Damm, M.; Fekete, A.; Uhlemann, S.; Zwenzner, H. (2006): Development of an Information System for Large-Scale Flood Events Supported by Remote Sensing (Project DISFLOOD). In: Jüpner, R. (Ed.): *Beiträge zur Konferenz "Strategien und Instrumente zur Verbesserung des vorbeugenden Hochwasserschutzes" 23. – 25. November 2005 in Tangermünde.* Band 6 (2006), Magdeburger Wasserwirtschaftliche Hefte, Shaker, pp. 133 – 141.

Destatis (2006a): *Statistik regional 2006.* Federal Statistical Office, Germany.

Destatis (2006b): *Statistik lokal 2006.* Federal Statistical Office, Germany, <http://www.destatis.de/download/d/veroe/statistiklokal2006.pdf>, 5 March 2008.

Deutsche Rück (1999): *Das Pfingsthochwasser im Mai 1999*. Deutsche Rückversicherung AG, Düsseldorf.

Deutsche Rück (2002): *Das Extremhochwasser im August 2002 in Deutschland.* Deutsche Rückversicherung AG, Düsseldorf.

DFID (2000): *Sustainable Livelihoods Guidance Sheets.* Section 1.

Dikau, R.; Weichselgartner, J. (2005): *Der unruhige Planet. Der Mensch und die Naturgewalten*. Darmstadt.

DKKV (2003): *Lessons Learned. Hochwasservorsorge in Deutschland. Lernen aus der Katastrophe 2002 im Elbegebiet.* DKKV 29, Bonn. p. 151.

DLR-DFD (2007): *CORINE Land Cover 2000.* Oberpfaffenhofen.

Dombrowsky, W.R.; Brauner, C. (1998): *Defizite der Katastrophenvorsorge in Industriegesellschaften am Beispiel Deutschlands.* 3a, International Decade for Natural Disaster Reduction (IDNDR), Bonn.

Downing, T.E.; Aerts, J.; Soussan, J.; Barthelemy, O.; Bharwani, S.; Ionescu, C.; Hinkel, J.; Klein, R.J.T.; Mata, L.J.; Martin, N.; Moss, S.; Purkey, D.; Ziervogel, G. (2005): *Integrating Social Vulnerability into Water Management*. SEI Working Paper and NeWater Working Paper No. 4, Oxford.

Dwyer, A.; Zoppou, C.; Nielsen, O.; Day, S.; Roberts, S. (2004): *Quantifying Social Vulnerability: A Methodology for Identifying those at Risk to Natural Hazards*, Record 2004/14, Geoscience Australia, p. 92.

EC (2007): Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. In: *Official Journal of the European Union.* <http://ec.europa.eu/environment/water/flood_risk/key_docs.htm>.

EEA (2005): *Vulnerability and Adaptation to Climate Change in Europe.* Technical report No 7. Copenhagen.

ELLA (2007): *Elbe-Atlas.* Atlas Labe. Dresden, Gemeinschaftsinitiative ELLA vertreten durch das Sächsische Landesamt für Umwelt und Geologie (LfUG).

EuropeAid (2004): *Aid Delivery Methods. Volume 1. Project Cycle Management Guidelines*. European Commission, Brussels. p. 158.

Fekete, A. (2009a): *The Interrelation of Social Vulnerability and Demographic Change in Germany*. Paper accepted for the IHDP Open Meeting 2009, Bonn, Germany.

Fekete, A. (2009b): Validation of a social vulnerability index in context to river-floods in Germany. In: *Natural Hazards and Earth System Sciences.* vol. 9, pp. 393 – 403.

Fekete, A.; Damm, M.; Birkmann, J. (2010): Scales as a challenge for vulnerability assessment. In: *Natural Hazards.* vol. 55, pp. 729 – 747. DOI10.1007/s11069-009-9445-5.

Felgentreff, C.; Glade, T. (Eds.) (2008): *Naturrisiken und Sozialkatastrophen.* Spektrum Akademischer Verlag, Berlin.

Few, R. (2003): Flooding, vulnerability and coping strategies: local responses to a global threat. In: *Progress in Development Studies*. vol. 3 (1), pp. 43 – 58.

Feynman, R.P. (2007): *The Meaning of it All*. Penguin, London.

FIG (2006): *The Contribution of the Surveying Profession to Disaster Risk Management*. A publication of FIG Working Group 8.4. Copenhagen, Denmark.

Freistaat Sachsen (2002): *Bericht der Sächsischen Staatsregierung zur Hochwasserkatastrophe im August 2002*. 1.Teil Bericht des SMI zur Hochwasserkatastrophe im August 2002 vom Februar 2003.

Freudenberg, M. (2003): *Composite Indicators of Country Performance: A Critical Assessment.* STI Working Paper, OECD – Organization for Economic Co-operation and Development. p. 34.

Fromm, S. (2005): *Binäre logistische Regressionsanalyse. Eine Einführung für Sozialwissenschaftler mit SPSS für Windows.* Bamberger Beiträge zur empirischen Sozialforschung, Schulze, G.; Akremi, L., Bamberg.

Füssel, H.-M. (2007): Vulnerability: a generally applicable conceptual framework for climate change research. In: *Global Environmental Change*. vol. 17, pp. 155 – 167.

Gall, M. (2007): *Indices of Social Vulnerability to Natural Hazards: A Comparative Evaluation.* PhD dissertation, University of South Carolina.

Geipel, R. (1992): *Naturrisiken. Katastrophenbewältigung im sozialen Umfeld.* Wissenschaftliche Buchgesellschaft, Darmstadt.

Gibson, C., Clark C.; Ostrom, E.; Ahn, T.-K. (2000): The concept of scale and the human dimensions of global change: a survey. In: *Ecological Economics*. vol. 32, pp. 217 – 239.

Hahn, H.; Villagrán de Leon, J.C.; Hidajat, R.; Schaef, T.; Bollin, C. (2003): *Component III: Indicators and other disaster risk management instruments for communities and local governments, Regional Policy Dialogue.* Natural Disasters Network. III Meeting. Comprehensive risk management by communities and local governments, Inter-American Development Bank, Washington, D.C.

Hewitt, K. (1983): *Interpretations of Calamity: From the Viewpoint of Human Ecology (The Risks & Hazards Series 1).* Allen & Unwin Inc., Winchester.

IKSE (2003): *Aktionsplan Hochwasserschutz Elbe*. Magdeburg.

IKSR (2001): *Rheinatlas.* Koblenz.

IKSR (2002): *Hochwasservorsorge – Maßnahmen und ihre Wirksamkeit.* Koblenz.

IPCC (2007): *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Parry, M. L.; Canziani, O. F.; Palutikof, J. P.; van der Linden, P. J.; Hanson, C. E., Cambridge University Press, Cambridge, UK. p. 976.

Jäger, H. (1994): *Einführung in die Umweltgeschichte.* Wissenschaftliche Buchgesellschaft, Darmstadt.

Jensen, J.R. (2005): *Introductory Digital Image Processing. A Remote Sensing Perspective.* 3rd edition, Prentice Hall, Upper Saddle River.

Jonkman, S.N. (2007): *Loss of Life Estimation in Flood Risk Assessment. Theory and Applications.* PhD thesis, Delft University of Technology.

Kaly, U.L.; Pratt, C.R.; Mitchell, J. (2004): *The Demonstration Environmental Vulnerability Index (EVI)*. SOPAC Technical Report 384, South Pacific Applied Geoscience Commission. p. 323.

Keil, M.; Kiefl, R.; Strunz, G. (2005): *CORINE Land Cover 2000 – Germany. Final Report*. DLR-DFD, Oberpfaffenhofen.

King, D. (2001): Uses and limitations of socioeconomic indicators of community vulnerability to natural hazards: data and disasters in Northern Australia. In: *Natural Hazards*. vol. 24, pp. 147 – 156.

King, D.; MacGregor, C. (2000): Using social indicators to measure community vulnerability to natural hazards. In: *Australian Journal of Emergency Management.* Spring 2000. pp. 52 – 57.

Kleinosky, L.R.; Yarnal, B.; Fisher, A. (2007): Vulnerability of Hampton Roads, Virginia to storm-surge flooding and sea-level rise. In: *Natural Hazards*. vol. 40, pp. 43 – 70.

Kreibich, H.; Petrow, T.; Thieken, A.; Müller, M.; Merz, B. (2005b): Consequences of the extreme flood event of August 2002 in the city of Dresden, Germany. In: IAHS Publ. 293 (Ed.): *Sustainable Water Management Solutions for Large Cities* (Proceedings of symposium S2 held during the Seventh IAHS Scientific Assembly at Foz do Iguaçu, Brazil, April 2005).

Kreibich, H.; Thieken, A.H.; Petrow, T.; Müller, M.; Merz, B. (2005a): Flood loss reduction of private households due to building precautionary measures – lessons learned from the Elbe flood in August 2002. In: *Natural Hazards and Earth System Sciences.* vol. 5, pp. 117 – 126.

Kron, W. (2006): *Steigendes Hochwasserrisiko. Von den Ursachen zur Vorsorge.* Münchener Rück. <http://www.um.baden-wuerttemberg.de/servlet/is/20099/Kron.pdf?command=downloadContent&filename=Kron.pdf>, 14 May 2008.

Kropp, J.P.; Block, A.; Reusswig, F.; Zickfeld, K.; Schellnhuber, H.J. (2006): Semi-quantitative assessment of regional climate vulnerability: the North-Rhine Westphalia study. In: *Climatic Change*. vol. 76, pp. 265-290.

Kuhlicke, C.; Steinführer, A. (2007): *Wider die Fixiertheit im Denken – Risikodialoge über Naturgefahren. Reaktion auf B. Merz, R. Emmermann. 2006*. Zum Umgang mit Naturgefahren – Reagieren zum Risikomanagement. 15/4: 265 - 274. GAIA, 16, 2. pp. 91 – 92.

Lass, W.; Reusswig, F.; Kühn, K.-D. (1998): *Disaster Vulnerability and "Sustainable Development". Integrating Disaster Vulnerability in the CSD's list of Indicators: Measuring Sustainable Development in Germany.* German IDNDR Committee for Natural Disaster Reduction, Bonn.

LfU Bavaria (2007): *Flooding Areas in Bavaria.* State Office for Environment in Bavaria (Bayerisches Landesamt für Umwelt).

LfUG Saxony (2007): *Elbe-Atlas.* State Office for Environment and Geology in Saxony (Sächsisches Landesamt für Umwelt und Geologie).

LHW Saxony-Anhalt (2007): *Elbe-Atlas.* State Management Agency for Flood Protection and Water Management (Landesbetrieb für Hochwasserschutz und Wasserwirtschaft Sachsen-Anhalt).

Longley, P.; Goodchild, M.F.; Maguire, D.J.; Rhind, D.W. (2005): *Geographic Information Systems and Science*. 2nd edition, Wiley & Sons, Chichester.

Lüchters, G.; Menkhoff, L. (1996): Human development as a statistical artifact. In: *World Development*. vol. 24 (8), pp. 1385 – 1392.

Marcinek, J. (1997): Allgemeine Hydrologie. In: Hendl, M.; Liedtke, H. (Eds.): *Lehrbuch der Allgemeinen Physischen Geographie.* Klett-Perthes, Gotha. pp. 449 – 510.

Martens, T.; Ramm, K. (2007): *Newsletter 2: Weitere Ergebnisse der Telefonbefragung*. INNIG Teilprojekt 3, <http://innig.rtens.net/modules/Downloads/hjiu3443/INNIG_TP3_Newsletter_2.pdf>, 28 May 2008.

Masozera, M.; Bailey, M.; Kerchner, C. (2007): Distribution of impacts of natural disasters across income groups: A case study of New Orleans. In: *Ecological Economics.* vol. 63, pp. 299 – 306.

Meentemeyer, V. (1989): Geographical perspectives of space, time, and scale. In: *Landscape Ecology.* vol. 3 (3/4), pp. 163 – 173.

Merz, B. (2006): *Hochwasserrisiken. Grenzen und Möglichkeiten der Risikoabschätzung.* Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Merz, B.; Emmermann, R. (2006): Zum Umgang mit Naturgefahren in Deutschland: Vom Reagieren zum Risikomanagement. In: *GAIA.* vol. 15 (4), pp. 265 – 274.

Meyer, V.; Haase, D.; Scheuer, S. (2007): *GIS-based Multicriteria Analysis as Decision Support in Flood Risk Management*. UFZ Discussion Papers 6/2007, Department of Economics, Leipzig.

Moore, D.S.; MacCabe, G.P. (2006): *Introduction to the Practice of Statistics.* Freeman, New York.

Morrow, B.H. (1999): Identifying and mapping community vulnerability. In: *Disasters.* vol. 23 (1), pp. 1 – 18.

Mudelsee, M.; Börngen, M.; Tetzlaff, G.; Grünewald, U. (2003): No upward trends in the occurrence of extreme floods in central Europe. In: *Nature*. vol. 425, pp. 166 – 169.

Müller, M. (2002): *Geodaten im Risikomanagement – Zonierungssysteme bei der Deutschen Versicherungswirtschaft (GDV).* <www.gdv.de/Downloads/Veranstaltungen_2002/Endfassung_Mueller.rtf>, <http://www.mplusm.at/ifg/download/Mueller.pdf>, 12 January 2006.

MunichRe (2004): *Megacities – Megarisks. Trends and Challenges for Insurance and Risk Management.* Knowledge Series, Munich.

MUNLV (2003): *Leitfaden Hochwasser-Gefahrenkarten.* Düsseldorf.

Nakamura, T.; Hutton, C.; Kunbao, X.; Gavidia, J. (2001): *Assessment of Vulnerability to Flood Impacts and Damages.* United Nations Centre for Human Settlements UNCHS (Habitat). p. 39.

Nardo, M.; Saisana, M.; Saltelli, A.; Tarantola, S.; Hoffman, A.; Giovannini, E. (2005): *Handbook on Constructing Composite Indicators: Methodology and User Guide.* OECD Statistics Working Paper.

Neugebauer, G. (2007): *Politische Milieus in Deutschland. Die Studie der Friedrich-Ebert-Stiftung.* Dietz, Bonn. p. 145.

Olfert, A.; Greiving, S.; Batista, M.J. (2006): Regional Multi-risk Review, Hazard Weighting and Spatial Planning Response to Risk – Results from European Case Studies. In: Schmidt-Thomé, P. (Ed.): *Geological Survey of Finland. Special Paper 42. Natural and Technological Hazards and Risks Affecting the Spatial Development of European Regions.* pp. 125 – 151.

Openshaw, S. (1984): *The Modifiable Areal Unit Problem*. Geo Books, Norwich.

Pfeil, J. (2000): *Maßnahmen des Katastrophenschutzes und Reaktionen der Bürger in Hochwassergebieten*. DKKV, Bonn.

Plapp, T. (2004): Local Experience of Disaster Management and Flood Risk Perception. In: Malzahn, D.; Plapp, T. (Eds.): *Disasters and Society – From Hazard Assessment to Risk Reduction*. Proceedings of the International Conference, University of Karlsruhe (TH) Germany. July 26 – 27, 2004, Logos, Berlin, pp. 391 – 398.

Plate, E., J.; Merz, B.; Eikenberg, C. (2001): Naturkatastrophen: Herausforderung an Wissenschaft und Gesellschaft. In: Plate, E., J.; Merz, B. (Eds.): *Naturkatastrophen. Ursachen – Auswirkungen – Vorsorge.* Schweizerbart, Stuttgart. pp. 1 – 46.

Plate, E.J. (2001): *Risikomanagement in Forschung und Praxis. Erstes Forum Katastrophenvorsorge "Extreme Naturereignisse und Vulnerabilität"* Freiburg im Breisgau, 29. – 30. September 2000, Goldammer, J. G. DKKV, Bonn.

Pohl, J. (2002): Hochwasser und Hochwassermanagement am Rhein. In: *Geographische Rundschau.* vol. 1, pp. 30 – 36.

Quarantelli, E.L. (Ed.) (1998): *What is a Disaster? Perspectives on the Question.* Routledge, London.

RESCDAM (2000): *The Use of Physical Models in Dam-Break Flood Analysis.* Final report of Helsinki University of Technology, Finnish Environment Institute, RESCDAM – Development of Rescue Actions Based on Dam-Break Flood Analysis. p. 57.

Research and Assessment Systems for Sustainability Program (2001): *Vulnerability and Resilience for Coupled Human-Environment Systems: Report of the Research and Assessment Systems for Sustainability Program 2001 Summer Study.* 29 May – 1 June, Airlie House, Warrenton, Virginia. Research and Assessment Systems for Sustainability Program Discussion Paper 2001-17. Cambridge, MA: Environment and Natural Resources Program, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University.

Reusswig, F.; Grothmann, T. (2004): Präventiver Hochwasserselbstschutz von Privathaushalten und Unternehmen. In: Merz, B.; Apel, H. (Eds.): *Risiken durch Naturgefahren in Deutschland: Abschlussbericht des BMBF-Verbundprojektes Deutsches Forschungsnetz Naturkatastrophen (DFNK).* GeoForschungsZentrum, Potsdam. pp. 93 – 106.

Richardson, K. (2005): The hegemony of the physical sciences: an exploration in complexity thinking. In: *Futures.* vol. 37, pp. 615 – 653.

Rothman, K.J.; Greenland, S.; Poole, C.; Lash, T.L. (2008): Causation and Causal Inference. In: Rothman, K. J.; Greenland, S.; Lash, T. L. (Eds.): *Modern Epidemiology.* Third edition, Lippincott Williams & Wilkins, Philadelphia. pp. 5 – 31.

Rygel, L.; O`Sullivan, D.; Yarnal, B. (2006): *A Method for Constructing a Social Vulnerability Index. In: Mitigation and Adaptation Strategies for Global Change.* vol. 11 (3), pp. 741 – 764.

Saisana, M.; Tarantola, S. (2002): *State-of-the-art Report on Current Methodologies and Practices for Composite Indicator Development*. JRC – Joint Research Centre. European Commission, Ispra.

Schier, W. (1990): D*ie vorgeschichtliche Besiedlung im südlichen Maindreieck*. Teil I: Text und Tafeln. Teil II: Katalog und Karten. Materialheft zur Bayerischen Vorgeschichte Reihe A, Bd. 60, Kallmünz.

Schmidt-Thomé, P. (Ed.) (2006): *Final Report. The Spatial Effects and Management of Natural and Technological Hazards in Europe – ESPON 1.3.1.* ESPON – European Spatial Planning Observation Network.

Schmidtke, R.F. (2004): *Hochwasserverschärfung und Vulnerabilität.* KLIWA-Symposium 2004, Bayerisches Landesamt für Wasserwirtschaft, München.

Schneiderbauer, S. (2007): *Risk and Vulnerability to Natural Disasters – From Broad View to Focused Perspective.* PhD thesis. FU Berlin. <http://www.diss.fu-berlin.de/2007/498/>, 12 May 2008.

Schneiderbauer, S.; Ehrlich, D. (2006): Social Levels and Hazard (in)dependence in Determining Vulnerability. In: Birkmann, J. (Ed.): *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies.* UNU Press, Tokyo. pp. 78 – 102.

Simpson, D.M.; Katirai, M. (2006): *Indicator Issues and Proposed Framework for a Disaster Preparedness Index (DPi)*. Working Paper 06-03, Center for Hazards Research and Policy Development, University of Louisville. p. 49.

Smith, K.; Ward, R. (1998): *Floods. Physical Processes and Human Impacts.* John Wiley & Sons, Chichester.

Spekat, A.; Enke, W.; Kreienkamp, F. (2007): *Neuentwicklung von regional hoch aufgelösten Wetterlagen für Deutschland und Bereitstellung regionaler Klimaszenarios auf der Basis von globalen Klimasimulationen mit dem Regionalisierungsmodell WETTREG auf der Basis von globalen Klimasimulationen mit ECHAM5/MPI-OM T63L31 2010 bis 2100 für die SRES-Szenarios B1, A1B und A2.* Endbericht Im Rahmen des Forschungs- und Entwicklungsvorhabens: "Klimaauswirkungen und Anpassungen in Deutschland - Phase I: –Erstellung regionaler Klimaszenarios für Deutschland" des Umweltbundesamtes, UBA - Federal Environmental Agency.

Steiner, J. (2007): *Fire and Ambulance Service in Germany and the Fire and Ambulance Service in Bonn.* PowerPoint Presentation, Bonn.

Steinführer, A.; Kuhlicke, C. (2007): *Social Vulnerability and the 2002 Flood.* Country Report Germany (Mulde River). Floodsite Report Number T11-07-08, UFZ Centre for Environmental Research, Leipzig.

Sterr, H.; Markau, H.-J.; Daschkeit, A.; Reese, S.; Kaiser, G. (2007): Risikomanagement im Küstenschutz in Norddeutschland. In: Felgentreff, C.; Glade, T. (Eds.): *Naturrisiken und Sozialkatastrophen – Grundlagen und Herausforderungen der Gefahren- und Risikoforschung.* Spektrum Akademischer Verlag, Berlin. pp. 337 – 352.

Storm, T. (1888): *Der Schimmelreiter.* Edition of 1998, Reclam, Stuttgart.

Strohmeier, K.P.; Kersting, V. (2003): Segregierte Armut in der Stadtgesellschaft. Problemstrukturen und Handlungskonzepte im Stadtteil. In: *Informationen zur Raumentwicklung.* vol. 3/4, pp. 231 – 246.

Tapsell, S.M.; Penning-Rowsell, E.C.; Tunstall, S.M.; Wilson, T.L. (2002): Vulnerability to flooding: health and social dimensions. In: *Philosophical Transactions of the Royal Society A.* vol. 360, pp. 1511 – 1525.

Thieken, A.; Kreibich, H.; Müller, M.; Merz, B. (2007): Coping with floods: preparedness, response and recovery of flood-affected residents in Germany in 2002. In: *Hydrological Sciences – Journal des Sciences Hydrologiques.* vol. 52 (5), pp. 1016 – 1037.

Thorwarth, A. (2001): Die Rolle der Medien. In: Plate, E., J.; Merz, B. (Eds.): *Naturkatastrophen. Ursachen – Auswirkungen – Vorsorge.* Schweizerbart, Stuttgart. pp. 422 – 432.

Thywissen, K. (2006): Components of Risk. A Comparative Glossary. *SOURCE No. 2/2006,* UNU-EHS, Bonn. p. 52.

Twigg, J. (2004): Disaster risk reduction: mitigation and preparedness in aid programming. In: *Good Practice Review 9.* Humanitarian Practice Network, Overseas Development Institute.

UBA (2006): *Was Sie über vorsorgenden Hochwasserschutz wissen sollten.*

UN/ECE (2003): *Best Practices on Flood Prevention, Protection and Mitigation. Guidelines on Sustainable Flood Prevention*.

UN/ISDR (2002): *Living with Risk. A Global Review of Disaster Reduction Initiatives*. UN/ISDR – Inter-Agency Secretariat of the International Strategy for Disaster Reduction, 2004 version, United Nations, Geneva.

UN/ISDR (2005a): *Proceedings of the Conference World Conference on Disaster Reduction. Building the Resilience of Nations and Communities to Disasters.* 18 – 22 January 2005, Kobe, Hyogo, Japan, United Nations, Geneva.

UN/ISDR (2005b): *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA).* United Nations, Geneva.

UNDP (2004): *Reducing Disaster Risk. A Challenge for Development. A Global Report.* Pelling, M.; Maskrey, A.; Ruiz, P.; Hall, L.. Geneva.

UNEP-GRID (2003): *Disaster Risk Index Analysis* Tool. <http://gridca.grid.unep.ch/undp/>, 14 May 2008.

UNEP (2007): *Global Environment Outlook Geo-4.* Environment for Development. Progress Press Ltd, Malta.

UNICEF (2008)*: Der UNICEF-Bericht zur Lage von Kindern in Deutschland. Zusammenfassung wichtiger Ergebnisse*. Press release, 26 May 2008, Berlin.

UNU (2004): *News Release. Two Billion People Vulnerable to Floods by 2050; Number Expected to Double or More in Two Generations Due to Climate Change, Deforestation, Rising Seas, Population Growth.* <www.unu.edu/news/ehs/floods.doc>, 13 May 2008.

Van den Berghe, W. (1995): *Achieving Quality in Training. European Guide for Collaborative Training Projects.* Tilkon, Wetteren, Belgium.

Vogt, R. (2006): *Gefährdungspotenziale & Investitionen im Hochwasserschutz. PowerPoint Presentation.* Rheinkonferenz Regionale 2010 in Wesseling 14 November 2006.

von Kirchbach, H.-P.; Franke, S.; Biele, H.; Minnich, L.; Epple, M.; Schäfer, F.; Unnasch, F.; Schuster, M. (2002): *Bericht der Unabhängigen Kommission der Sächsischen Staatsregierung. Flutkatastrophe 2002.* Dresden.

von Tümpling, W.; Rode, M.; Böhme, M. (2006): Schadstoffausbreitungsmodellierung und Risikobewertung im Raum Bitterfeld bei Extremhochwasser - Ein Überblick übe*r das Verbundprojekt. In: Jüpner, R. (Ed.): Beiträge zur Konferenz "Strategien und Instrumente zur Verbesserung des vorbeugenden Hochwasserschutzes" 23. – 25. November 2005 in Tangermünde.* vol. 6 (2006), Magdeburger Wasserwirtschaftliche Hefte, Shaker Verlag, pp.57-63.

Wachtendorf, T.; Kendra, J.M.; Rodríguez, H.; Trainor, J. (2006): The social impacts and consequences of the December 2004 Indian Ocean Tsunami: observations from India and Sri Lanka. In: *Earthquake Spectra.* vol. 22 (S3), pp. 693-714.

WBGU (2000): Specific vulnerabilities of regions and social groups. In: WBGU (Ed.): *Annual Report 1998. World in Transition: Strategies for managing global environmental risks.* Springer, Berlin. pp. 176 – 185.

Weichselgartner, J. (2001): *Naturgefahren als soziale Konstruktion.* PhD dissertation at the University of Bonn, Faculty of Mathematics and Natural Sciences.

Weichselgartner, J. (2002): About the capacity to be wounded: the need to link disaster mitigation and sustainable development. In: Tetzlaff, G.; Trautmann, T.; Radtke, K. S. (Eds.): *Extreme Naturereignisse – Folgen, Vorsorge, Werkzeuge.* DKKV, Bonn. pp. 150 – 158.

White, G.F. (1945): *Human Adjustment to Floods. A Geographical Approach to the Flood Problem in the United States.* PhD thesis, The University of Chicago, Chicago. <http://www.colorado.edu/hazards/gfw/images/Human_Adj_Floods.pdf>.

White, G.F.; Kates, R.W.; Burton, I. (2001): Knowing better and losing even more: the use of knowledge in hazards management. In: *Environmental Hazards.* vol. 3, pp. 81 – 92.

Wisner, B. (1998): Marginality and vulnerability. Why the homeless of Tokyo don't 'count' in disaster preparations. In: *Applied Geography*. vol. 18 (1), pp. 25 – 33.

Wisner, B.; Blaikie, P.; Cannon, T.; Davis, I. (2004): *At Risk – Natural Hazards, People´s Vulnerability and Disasters.* Second Edition, Routledge, London.

Wöst, F. (1992): *Hochwassergefahr und Gegenmaßnahmen – Wahrnehmung und Bewertung am Beispiel der Gemeinde Irlbach (Donau).* Unpublished, Diplomarbeit, Geographisches Institut der Technischen Universität München, München.

Wu, S.-Y.; Yarnal, B.; Fisher, A. (2002): Vulnerability of coastal communities to sea-level rise: a case study of Cape May County, New Jersey, USA. In: *Climate Research.* vol. 22, pp. 255 – 270.

Yarnal, B. (2007): Vulnerability and all that jazz: addressing vulnerability in New Orleans after Hurricane Katrina. In: *Technology in Society.* vol. 29, pp. 249 – 255.

Zapf, W. (1979): Applied social reporting: A social indicators system for West German society. In: *Social Indicators Research.* vol. 6, pp. 397 – 419.

Zebisch, M.; Grothmann, T.; Schröter, D.; Hasse, C.; Fritsch, U.; Cramer, W. (2005): *Climate Change in Germany. Vulnerability and Adaptation of Climate Sensitive Sectors.* UBA.

Assessment of Social Vulnerability to River Floods in Germany

by Alexander Fekete

Social vulnerability research looks into how impacts by hazards are determined by the characteristics of people. There are certain social characteristics that can be observed for groups of people that make them more or less susceptible to impacts by river floods, for example age, lack of financial means, or lack of social ties. At the same time, people possess a rich variety of capacities to prepare for flood damage, withstand, or recover from it.

This PhD dissertation investigates social vulnerability in a geographical approach for large regions in Germany. At county level, census data is analysed with regard to how social vulnerability shaped the impacts on people in the flood events of 2002. For this purpose, a social vulnerability index has been created for counties at the rivers Danube, Elbe, and Rhine. This index makes flood impacts on society visible and differentiates indicators for degrees of exposure, susceptibility, and capacities of people per county. It merges a flood inundation scenario with county demographics, and integrates natural and social science methods.

The results are acessible in a web-based geographical disaster information system, as part of the interdisciplinary research project DISFLOOD. The social vulnerability index and the DISFLOOD information system indicate risk areas in Germany with respect to river floods. This research provides insight on key factors that shape past and future disasters and sets the stage for future adaptation measures.

Alexander Fekete earned his PhD in Geography at the University of Bonn, Germany, while conducting his research within the structure of UNU-EHS.

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