ensure	**ENSURE PROJECT** *Contract n° 212045*

WP 1: State-of-the-art on vulnerability types

Del. 1.1.3: Methodologies to assess vulnerability of structural, territorial and economic systems

Task 1.3: State-of-art on vulnerability of socio-economic systems

Reference code: ENSURE – Del. 1.1.3

COOPERATION

The project is financed by the European Commission
by the Seventh Framework Programme
Area "Environment"
Activity 6.1 "Climate Change, Pollution and Risks"

Project Acronym: ENSURE

Project Title: Enhancing resilience of communities and territories facing natural and na-tech hazards

Contract Number: 212045

Title of report: Del. 1.1.3 State-of-art on vulnerability of socio-economic systems

Reference code: ENSURE – Del. 1.1.3

Short Description:

This report examines literature and case studies that have analysed economic systems. Vulnerability as well as social vulnerability, intended in different forms. Particular attention is devoted to understand in which context models and parameters have been developed, identifying those that have been proposed for developed or developing countries. Separate attention is given to the role of psychology, culture and collective value in vulnerability assessment.

Authors and co-authors:

- Anne van der Veen and Emile Dopheide, International Institute for Geo-Information Science and Earth Observation (ITC), Netherlands
- Dennis Parker, Sue Tapsell, John Handmer, Middlesex University Higher Education Corporation (MDX) United Kingdom
- Chris Gregg and Costanza Bonadonna, Université de Genève (UNIGE), Switzerland
- Floriana F. Ferrara, T6 Ecosystems srl (T6 ECO), Italy

Partners owning:

- International Institute for Geo-Information Science and Earth Observation (ITC), Netherlands
- Middlesex University Higher Education Corporation (MDX) United Kingdom
- Université de Genève (UNIGE), Switzerland
- T6 Ecosystems srl (T6 ECO), Italy

Contributions:

Made available to: All project partners, European Commission

Versioning

Version	Date	Name, organization
0.1	05/02/2009	ITC
0.2	02/09/2009	ITC
0.3		

Quality check

INTERNAL REVIEWERS:

Table of contents

List of Figures

List of Tables

State-of-art on vulnerability of socio-economic systems

1 Objectives

This section aims at collecting and reviewing from literature methodologies and case studies having analysed economic systems vulnerability as well as social vulnerability, including the psychological and cultural aspects of vulnerability.

This review should enhance the understanding of the context in which models and parameters have been developed and evolved. Where relevant, a distinction will be made between models and parameters that have been developed for developed and for developing countries.

A review of the evolution of research traditions in vulnerability analysis and an attempt to summarize the scope of terms, concepts and definitions in vulnerability forms an indispensable part of this task.

Possible linkages between socio-economic vulnerability and territorial vulnerability and some literature related to these are also drawn upon here.

Although initially an attempt was made to draw examples form a variety of hazard types; eventually the main focus of the report is on floods and partially on volcanoes.

2 Concepts and definitions

2.1 The concept of 'vulnerability'

Approaches in disaster reduction have become much more complex and emphasis has shifted from relief to mitigation. Consequently, vulnerability, resilience, and coping capacities have gained a more prominent role and more light is being shed on social, economic, political, and cultural factors next to the physical dimension of disasters (Thywissen, 2006).

'Vulnerability' has emerged as a central concept for understanding the condition or the predisposition of a system to suffer damage due to a hazard. Broadly speaking, the vulnerability of a system relates to its capacity to be harmed by a threat. Vulnerability can be seen as an internal property of a system, so not directly including the exposure to a threat (see also Gallopín, 2006), but still intrinsically linked with a threat. As threats can be of various nature and origin, discussions on the concept of vulnerability and the scope for measuring vulnerability should be understood within the context of these threats.

An alternative perspective, however, is that vulnerability is a condition or state in which economies or communities exist before a hazard threatens. Consequently, the vulnerability of economic systems to natural disasters may be expressed in terms of a potential to suffer economic or financial harm or loss, expressed either in terms of the magnitude of the consequences of the potential event, i.e. a monetary loss estimate, or in terms of sensitivity and resilience, i.e. the capacity to cope with the loss (Overseas Development Institute, 2005). This definition is derived from research which is mainly focused on the impact of disasters at the macro-scale of national economies and financial systems, and which thus focuses on the relationship between natural disaster impacts and level of economic and social development (Benson and Clay, 2004).

The above-mentioned distinction is highlighted in the following table, where we differentiate between biophysical vulnerability and social vulnerability (Adger *et al.*, 2004; Birkmann, 2006)

Biophysical vulnerability	**Social vulnerability**
Exposure to hazard	A state
Vulnerability in terms of the amount of (potential) damage caused to a system by a specific threat (climate related/hazard)	An internal state of the system before it encounters an hazardous event
Ultimate impact of the hazard	Not a function of hazard itself
Function of the frequency and severity of a given hazard	Condition of the exposed system

Table 1: A first differentiation into definitions of vulnerability

Although there are different schools of vulnerability research, such as the disaster risk community, the food security research or global environmental change research communities, the United Nations in its International Strategy for Disaster Reduction (UN /ISDR, 2004b) claims that a consensus can be seen in the fact that nowadays nearly everyone views vulnerability as an "internal side of risk" .

In this context vulnerability is an intrinsic characteristic of a system. That means the conditions of the exposed element or community at risk are core characteristics of vulnerability. Birkmann (2006) illustrates (see Table 1) how this concept of vulnerability as an intrinsic characteristic element of the system has widened to a concept that is primarily related to people (sphere 2 of Figure 1); developed towards a dualistic approach of susceptibility and coping capacity (sphere 3); to a multi-structure, including also adaptive capacity and the interaction with perturbations (sphere 4); and to the current debate which shows that vulnerability includes various thematic dimensions (sphere 5). In summary, while formerly vulnerability was primarily associated with physical aspects; nowadays vulnerability includes also economic, social, environmental and institutional aspects.

The above-mentioned typology and broadening of the vulnerability concept has led to confusions concerning definitions and concepts of vulnerability, best illustrated by Weichselgartner (2001) who includes a table of 23 different definitions of vulnerability, and Cutter (1996) citing 18 definitions. More recently, Thywissen (2006) presented a comprehensive review of the "Babylonian confusion" around the definition of the key concepts and terms in the field of disaster reduction, including vulnerability and resilience. In her comparative glossary of core terminology of disaster reduction, she presents 37 different definitions of 'vulnerability' which are used across multiple disciplines (see Appendix I).

As a consequence of this confusion, almost every aspect of vulnerability – including how to measure and gain estimates from it – is the subject of intense debate.

Additionally, a number of related concepts enter the vulnerability debate; which neither are defined in a uniform and crisp manner. Related concepts include: susceptibility, resistance, resilience, coping capacity, mitigation, adaptation, and adaptive capacity.

Before presenting and discussing various other variants of vulnerability it is thus necessary to present various scientific paradigms and consequent scientific language on the concept of vulnerability. It appears that there are different discourses (shared meanings) about the contested concept of vulnerability and resilience.

Figure 1: Spheres of the Concept of Vulnerability (Birkmann, 2006)

2.2 Disciplinary scientific paradigms and language

Definitions of vulnerability are necessarily contested by different scientists and there remains a lack of consensus on the meaning of the concept and the methods of operationalising it (Cutter, 1993; Cutter, 1996). The different views on vulnerability across and between disciplines (Adger, 2006) can partly be explained by the focus on different components of risk, responses to risk and welfare outcomes. Consequently, within the hazards literature, vulnerability has many different connotations, depending on the research orientation and perspective (Cutter, 1996). The term is used to mean different things by different authors (Adger, 1999). While social scientists tend to view vulnerability as representing the set of socio-economic factors that determine people's ability to cope with stress or change, climate scientists often view vulnerability in terms of the likelihood of occurrence and impacts of weather and climate related events (Nicholls *et al.*, 1999).

A same type of argument is used recently by Adger (2006) arguing that two major research traditions acted as seedbeds for ideas on vulnerability of social and physical systems: the analysis of vulnerability as lack of entitlements and the analysis of vulnerability to natural hazards.

In the field of disaster research, discourses (i.e. shared meanings) about the contested concepts of social and economic vulnerability and resilience emerge and multiply on an

almost daily basis, often merging fluidly with one another to varying degrees. Distinguishing between these discourses depends heavily upon the degree of resolution employed (Bankoff *et al.*, 2004). Characterizing them accurately requires considerable explanation. These discourses are rarely only about social or economic vulnerability, and may be intertwined with arguments about environmental or other forms of vulnerability or insecurity. Discourses on vulnerability appear to be far more numerous than on resilience (because interest in social resilience emerged rather recently), although it is perhaps artificial to separate these concepts. Some discourses, which clearly relate to vulnerability, hardly mention this term but instead use other closely related terms. The discourses identified below should be interpreted in these contexts (see Appendix II). Two levels of discourse are distinguished in Appendix II, Level 1 represents a coarser level of analysis, while Level 2 takes a finer-level approach to distinguishing between different discourses which all broadly fit into the social and political economy analysis discourse category identified at Level 1.

All in all we might conclude that the majority of definitions largely conceive vulnerability as *a function of susceptibility to loss and of the capacity to recover* – this capacity is then termed '*resilience*'. The term 'vulnerability' has been said to have negative connotations and according to some authors should be turned around and approached positively as 'resilience', or as the capacity to cope with or adapt to change. This is broadly similar to the concept of adaptive capacity which has been used and developed by climate change researchers (Adger *et al.*, 2004). Some writers prefer to use the term resilience in place of vulnerability because of these more positive connotations. See for wxample the United Nations International Strategy for Disaster Reduction (UN/ISDR, 2004a) which defines 'capacities' as the opposite of 'vulnerability'.

Particularly this relation between vulnerability and resilience is a debated one. In the context of environmental and hazard management, the concepts vulnerability and resilience are obviously related, but the specific nature of the relations is not obvious. Literature ranges from considering vulnerability

1. As the reciprocal of resilience, to
2. Seeing resilience as a component of vulnerability, to
3. Considering vulnerability as the static and resilience as the dynamic propensity of a system in relation to a threat.

We will come back to this issue in Section 3.

2.3 Economic systems vulnerability

Economic vulnerability is well-documented from the conceptual and empirical viewpoints (e.g. Briguglio, 1995 for small-island states; Atkins, 2000 for developing countries), and there is a discrete body of literature on the economic vulnerability of nation states to 'shocks' of various types, not necessarily natural or na-tech ones, but which illuminate the economic factors which may magnify or reduce economic impacts of disasters. Within this literature there is a particular focus on the economic vulnerability of small states (Atkins, 2000), including small island states, for example Papua New Guinea (e.g. Manning, 2004) and Malta (Briguglio *et al.,* 2004), which are more sensitive to 'exogenous shocks', arising out of their economic openness. Economic resilience is defined in this context as the policy-induced ability of an economy to withstand or recover from the effects of such shocks.

Most of this national scale literature focuses strongly on the distributional or social dimensions of economic vulnerability which relate to the capacity of people to cope with the impacts of disasters. There are examples of how the economic vulnerability to disasters of poor and socially disadvantaged groups can be increased or decreased by economic development (Overseas Development Institute, 2005).

The strong inter-relationships between economic and social systems vulnerability are well demonstrated in the disasters field by research which utilises a political economy paradigm. For example, in relationship to vulnerability analysis and flood disasters in developing countries, Cannon's concept of socio-economic vulnerability includes 'livelihood resilience' in which the key variables include income opportunities, assets and savings (Cannon, 2000). Poverty and the relationships between income and the daily costs of food are key determinants of social vulnerability in a case study of flood vulnerability at the city scale in Manila in The Philippines (Zoleta-Nantes, 2000).

There is a considerable body of literature on flood losses mainly aimed at methods for assessing flood loss or damage potential. This literature has recently been reviewed as part of the European Commission funded FLOODsite research programme (FLOODsite, 2007). Most of the research underpinning this literature is concerned with a 'unit-loss approach' in which detailed 'local' or property/building level damage data and other loss data are aggregated to describe flood damage potential or economic systems vulnerability at neighbourhood, settlement or sub-catchment level (e.g. Penning-Rowsell, 2005). This research acknowledges that some people will suffer a greater degree of harm than others from the same damage or financial loss and has developed a 'vulnerability index' to highlight the locations in which particularly vulnerable groups exist (Messner, 2006).

Economic system vulnerability is most commonly addressed at either the macro/national or micro/local scale in the literature (see for a recent example Jonkman, 2008). Regional scale assessments have been made by aggregating generalised unit flood loss data for homes and businesses (e.g. Office of Science and Technology, 2004).

A major contribution to the conceptual definition and measurement of the very much related concept of economic resilience is made by Rose (2007). Moreover what Rose (2007) defines as *static economic resilience* can be seen analogous to what others call the reciprocal of vulnerability, i.e. the exposure of a system to a shock and its potential to incur damage (Bockarjova, 2007).

Van der Veen and Logtmeijer (2005) investigated vulnerability and resilience by relating a high GIS resolution data framework to a low resolution macro economic model, where complementary economic sectors diminish macro disaster damage.

In the community of disaster research a more or less general type of methodology is applied: e.g. in assessing the vulnerability to earthquakes and floods researchers exchange their model specification. In a recent EU, US and Asia workshop on disaster management it appeared surprisingly that economists dealing with earthquakes, floods and hurricanes spoke the same language and could share a common methodology (Van der Veen, 2003; Van der Veen, 2004).

Good examples of applied research on earthquakes can be found in Okuyama (2004) and Rose (2007). For landslides we also see new methodologies incorporating notions of vulnerability (Sterlacchini, 2007).

In Appendix III we provide an overview of concepts used in the literature, which are related to economic systems vulnerability.

2.4 Social vulnerability[1]

Social vulnerability is determined by a complex range of social factors and is a multi-faceted concept incorporating issues such as livelihood, housing, security and gender. Social norms and customs, international, national, private and public law may regulate these constituents of vulnerability, and these constituents may differ from country to country. The nature of social vulnerability will depend on the nature of the hazard to which the human system in question is exposed. Much of the early work on social vulnerability was formulated in developing countries where the most vulnerable groups tend to be those who have not met their fundamental needs, such as adequate food, shelter and health care. Vulnerability is therefore seen as a function of social and economic wellbeing and subsequently the term has been applied increasingly within a socio-economic framework. Lately, researchers have seen the value of transferring this knowledge base to developed world contexts (Blaikie *et al.*, 1994).

From a scientific perspective, it would be useful to identify a list of *all* factors that influence social vulnerability, but from a practical perspective it could be useful to identify from this list a subgroup of factors that could be used to assess, monitor and change vulnerability. Possible criteria that such a subgroup of factors should fulfil include: 1) explain most of the variance in vulnerability, 2) have data that are accessible in a timely manner and at little to no expense (e.g. census data such as the decadal data collected by the US Census Bureau) and 3) able to be influenced through risk communication activities or adoption of protective action measures, including measures that both mitigate a hazard or the effects of a hazard.

There is general agreement in the hazards research community about some primary *factors* that influence social vulnerability, but there is substantial disagreement concerning the selection of variables that represent the broad concepts of these factors and measures for the variables. Some of the key factors thought to influence social vulnerability are summarized below in Table 2 (see also Cutter *et al.,* 2001; Tierney, Lindell and Perry, 1999; Putnam, 2000; Blaikie *et al.,* 1994).

[1] *Social vulnerability* in this section refers to the vulnerability of the social systems (next to economic systems and possibly institutional, psychological and cultural aspects of vulnerability) and is different from the 'social vulnerability' as presented in the previous Section 1 and Table 1, where the distinction is made between biophysical and social vulnerability. The latter distinction relates to the perception of vulnerability as an exposure (physical) or as a state (social vulnerability).

Factor	Examples
Lack of access to resources	*Information* (e.g. of hazards, protective action decision options, etc); *knowledge* (i.e., this translates to more informed and prepared citizens and includes understanding of warning sources (environmental, informal and formal) and mitigation, preparedness and response actions); and *technology* (e.g. warning communication devices such as radios, cell phones, televisions)
Limited access to	Political power and representation
Lack of social capital	Social networks and connections
Beliefs and customs	That neglect or ignore hazards or mitigation of hazards and their effects. Ethno-cultural differences, for example.
Building stock and age	Number, density and type of buildings and whether or not their age predates significant building design codes and enforcement.
Frail and physically limited individuals	Those who are unable to take protective actions or require outside assistance to do so (e.g. very young or old, sick, disabled)
Type and density of infrastructure and lifelines	Urban versus rural areas.

Table 2. Factors that influence vulnerability (adapted from Cutter, Boruff et al. *2003)*

Cutter *et al.* (2003) developed a list of characteristics that influence social vulnerability that are most often cited in the hazards and disaster literature. This list shows descriptions of the concepts, literature sources, and whether or not the characteristic correlates positively or negatively, or both, with social vulnerability. While the list of characteristics is a good reference for identifying *concepts* that could be explored to assess social vulnerability, again, there is no wide agreement on the selection of specific variables to measure these concepts.

The growing importance of the social dimension in disaster and hazard management can be well illustrated in relation to flood policies, which until recently was dominated by a technical worldview. Much flood defence has aimed at stopping or alleviating damage occurring through structural means (i.e. defence schemes). In addition, the response to hazards has been a 'command and control' mentality that focused on clean-up and the rescue of survivors. However, the social aspects of flood risk management have gained in importance in recent years (Mileti, 1999a). There is now a realisation that true flood prevention and mitigation will need to address not only the hydrological factors, but also the economic, social and political factors influencing wider society and underpinning the impact of damaging floods (White and Howe, 2002). Response to flooding has also changed to an emphasis on the reduction in loss of life and property through mitigation, preparedness, response and recovery (Cutter *et al.*, 2000). Vulnerability to flooding is now broadly recognised as being a function of both the physical environment and the socio-economic and political context (Parker, 2000). Key among those factors fostering coping capacity at various phases of the hazard cycle is social capital (Pelling, 1998; Cannon, 2000). Social capital is made up of the networks and relationships between individuals and social groups that facilitate economic well-being and security.

The social vulnerability approach to hazard and disaster management argues that society also creates conditions in which people face disasters differently (Blaikie *et al.*, 1994). Social

vulnerability is partially the product of social inequalities (those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond), however, it also includes spatial inequalities – those characteristics of communities and the built environment, such as level of urbanization, growth rates and economic vitality, that contribute to the social vulnerability of places. Those who are most vulnerable socially are generally expected to be most vulnerable in disastrous events.

Vulnerability is thus intimately related to social processes in disaster-prone areas and is usually related to the fragility, susceptibility or lack of resilience of the population when faced with different hazards. People or communities are resilient or vulnerable in the context of particular situations, especially their risk environments. For example, quality of housing will be an important determinant to a community's vulnerability to a flood but is less likely to influence its vulnerability to drought. People with very different backgrounds/occupations may be equally resilient in totally different situations. For example, a person may be vulnerable to a particular loss such as flooding of their home, but they may have resilience in terms of being insured, having skills to repair damage or personal networks to provide them with emotional support. In this case their resilience is independent of the potential for loss or vulnerability.

Morrow (1999) refers to the social construction of disaster vulnerability and to the social exclusion of some groups in disaster response. According to the literature on social vulnerability, it might be expected that specific social groups within communities, e.g. households with young children, older residents, long term ill or disabled, unemployed, and those on lower incomes or with lower social status, would be particularly vulnerable during hazardous events. These groups are outlined in more detail in section 6 below on Indicators/parameters of socio-economic vulnerability.

However, vulnerability is not static; if someone is deemed 'vulnerable' at the present time, this does not imply this person will remain so (Tapsell *et al.*, 2005). The same applies to the non-vulnerable; people may become vulnerable due to forces or processes such as aging, illness or redundancy, which are independent of adverse events such as floods. In addition, people may become vulnerable as a direct consequence of an adverse event. An example of this would be increased insurance premiums following a flood, which may make the insurance prohibitively expensive, or it may be affordable but only at the expense of some other resource, thus compromising the individual's or family's quality of life.

A number of social science based research studies have been conducted on *volcanoes* that investigate aspects of social vulnerability and these are certainly increasing at the greatest rate in the young history of volcanology. These studies are often conducted by interdisciplinary teams representing fields of sociology, geology, geography, public health, medical science, public policy and planning. Research questions are often broad but occasionally narrowly defined. Examples of major research topics described in the literature are outlined in Appendix IV (Table IV.a for non-health related topics and in Table IV.b for health related topics).

Major challenges in reducing social vulnerability lie in the need to develop a society that has the knowledge, skills, and resources (material and intellectual) to implement protective actions for health and property, such as occurs when people shelter in place or evacuate. A second major challenge lies in the need to develop an effective volcano early warning system that remains robust in communities faced with a variety of volcanic unrests ranging from slight or background unrest to high intensity eruptions over durations of hours, days, to months, even decades.

Much of the literature related to warnings is not specific to volcanoes and there are two models widely accepted in the USA. First, is the *Protective Action Decision Model* (PADM) of

Lindell, Perry and colleagues (Houts, Lindell *et al*., 1984; Lindell and Prater, 2002; Lindell and Perry, 2004), which draws heavily from emergent norm theory (Turner and Killian, 1987) and behavioral decision theory. Second is the *Warning Response Model* (WRM) of Mileti and colleagues (Mileti and Sorensen, 1990; Mileti and Fitzpatrick, 1992; Mileti and O'Brien, 1992). These models are based on several decades of warning, evacuation, and disaster research literature (Mileti and Peek, 2000; Lindell and Perry, 2004), but they differ in some specific details such as their delineation of *cognitive processes* (a focus of the PADM) and warning *message characteristics* (a focus of the WRM). However, the fact that they are derived from the same basic literature leads them to make similar predictions about disaster response. Since the concept of 'warning' means that the time available to respond is restricted, often to tens of minutes to hours or days (sometimes longer periods of weeks to months at most), effective public response to warning messages requires that actions be taken in the time frame necessitated by the hazard activity. This requires that warnings and responses be engrained in the social and cultural fabric of a population at hazard. This in turn is strongly influenced by characteristics such as age, ethnicity, education, etc.

It is worth noting that social-psychological factors also influence social vulnerability through their influences on decisions to seek information, prepare or respond with adaptive behaviour. Variables in this category include risk perception, self-efficacy (the notion that an individual has the ability to mitigate a hazard or its effects), outcome expectancy (the idea that a hazard or its effects can be mitigated by anyone), trust (e.g. in emergency management authorities), sense of community (feelings of belonging) and attachment to place.

In *earthquake* research, Cole (1994, 1995) applied Social Accounting Matrices in order to estimate the impact of disasters on groups in society.

Finally, a conceptualisation of vulnerability, which has gained in significance in the scientific community in recent years, is that of Cutter *et al*. (2000) and Cutter (2003). The authors use a conceptual model of vulnerability that incorporates both biophysical and social indicators to provide an 'all-hazards' assessment of vulnerability at the local level. These may be particularly relevant for comparing results from diverse locations and contexts as they incorporate the notion of 'place' which may also correlate with territory.

In Appendix V, we present a general overview of definitions of social vulnerability including some sources of references.

2.5 Inter-relationships between socio-economic vulnerability and territorial and systemic vulnerability

Socio-economic vulnerability is intimately related to territorial vulnerability because of the particular historical-cultural evolution of the social and political characteristics of territories which may be identified (e.g. functional urban areas, sub-regions, regions). Hewitt (1997) suggested the uniqueness of territorial vulnerability when he referred to the "geographicalness" of risks (i.e. hazards) and argued the importance of taking into account the interrelationships and distinctive mix of conditions that define human settlements and regions.

Two case studies from the literature demonstrate the importance of the 'territorial experience'; although there are many other similar case studies in the literature (*cf.* Mitchell, 1999).

Firstly, Parker and Tapsell (1997) demonstrate how, through longevity, London – the oldest of contemporary megacities – has developed a unique perspective on urban hazards with low recurrence intervals because there have been correspondingly more opportunities for

social learning about ways of adjusting exposures and vulnerabilities to such hazards through adoption of particular institutional and policy responses.

Secondly, in the context of a dynamic newly-industrializing economy, Chan (1995) reveals how the socio-economic vulnerability of Peninsular Malaysian society is heavily differentiated by the variegated ethnic mix. In this society, where economic vulnerability may be measured by income level, the low income, predominantly rural Bumiputeras (i.e. the indigenous Malays) might be expected to display the highest levels of vulnerability to floods. However, their vernacular 'kampung' house architecture is well adjusted to flooding, and their territorial social capital which includes their strong kinship bonds, make them less vulnerable to flooding than more mobile, higher income Chinese and Indian groups living in less well adapted flood prone urban settings.

Systemic vulnerability refers to physical, economic and social systems which are functionally connected, including at different levels of functioning such as the local/urban and regional systems. Connections may work laterally (i.e. between neighbouring regions) as well as vertically (i.e. between sub-regions and the region, or between regions and the nation). The initial effects of flooding, whether they be physical, social or economic can propagate from one system to another and from one level or region to another so that the initial impact is spread, and increased or magnified.

The impacts of hurricane Katrina on New Orleans in 2005 are a powerful illustration of the systemic vulnerabilities propagated by physical and economic vulnerabilities and the differential fragilities of businesses. The economic impacts on New Orleans, including the collapse of municipal tax revenues, business bankruptcies, the disruption of utilities, the delay of exports due to the closure of the port, and the property damage, spread to the State and on to the federal level temporarily increasing energy prices, reducing annual economic growth by up to 1%, and seriously affecting the global insurance/re-insurance industry.

Against this, construction materials markets and businesses saw gains in the reconstruction phase. Some companies and public agencies with business continuity plans in place faired much better than those who did not, but generally small and medium enterprises may often be particularly susceptible to loss and bankruptcy. Large companies who had made contingency plans to transfer staff to pre-planned accommodation in another state avoided much loss and disruption. The loss of over 1,800 lives, long-term evacuations of families, loss of communities, business bankruptcies, the problems people encountered in dealings with insurance companies and ill-health caused by the event and its aftermath, are just some of the surface indicators of human suffering and social impacts (Birch *et al.*, 2006).

Similar systemic vulnerabilities are identified in detail in case studies of other floods in the USA, including the Mississippi floods of 1993 (Changnon, 1996) and 1927 (Barry, 1997). Barry's account demonstrates the far-reaching systemic economic, social and political vulnerabilities which a major flood disaster can reveal.

At the national level economic parameters have been used to formulate macro-economic indices for identifying particularly vulnerable territories (Lewis, 1999; Cherveriat, 2000). The UN Development Policy and Analysis Division utilises an Economic Vulnerability Index (EVI) which includes seven parameters including remoteness (i.e. peripherality), merchandise export concentration, instability of agricultural production, and homelessness due to natural disasters (UN Department of Economic and Social Affairs, 2009).

2.6 Exploration of various interrelationships

2.6.1 Socio-economic vulnerability and exposure

Exposure is mainly concerned with the population (i.e. number of people) and the value of 'assets' (i.e. homes, businesses, infrastructure), which combine to form an economic system, located in a risk zone (Parker, 1999a). On the other hand, vulnerability relates to the loss of potential values present in this risk zone when resilience (or the capacity to cope with the loss) is taken into account (Parker, 1999b). Both exposure and vulnerability values can be expected to be potentially spatially variable.

Exposure values can be very high, for example, in the centre of cities or in the most economically advanced nations, and such concentrations of assets and wealth can be associated with high economic vulnerability values (for example, where redundancy, robustness and adaptability are poorly-developed) or conversely low economic vulnerability values (for example, where business continuity planning is well-developed leading to well-developed redundancy, robustness and adaptability).

In social terms, spaces with concentrations of high asset values are often associated with high personal wealth leading to low social vulnerability, although in inner cities wealthy neighbourhoods are often closely juxtaposed with poor and disadvantaged ones leading to pockets of significant social vulnerability.

2.6.2 Socio-economic vulnerability and hazard

A hazard may be regarded as the pre-disaster situation in which some risk of a disaster event exists, principally because a human population has placed itself and its socio-economic system in an exposed situation with overlaid differential vulnerabilities (Alexander, 1993). In this sense, vulnerability stems from the pre-disaster situation, and human vulnerability is a function of the costs and benefits of inhabiting and using risk areas for economic and social gain, although in many developing countries the poor have little choice. When the risk (e.g. a flood) becomes tangible and impending, there is a distinct threat of disaster and disaster can follow. The impact of the disaster is then a function of the magnitude and other characteristics of the hazard, exposure, vulnerability and measures taken to mitigate each of the hazard and its impact.

2.6.3 Socio-economic vulnerability and damage assessment

The relationship between socio-economic vulnerability and assessed damages is far from straight-forward. Assessed damage potential can be a poor indicator of economic and social vulnerability to disasters. This will be illustrated in what follows for the case of flooding damage.

Flood damage potential is likely to be high in wealthy communities which may well have large houses filled with consumer goods. Members of such communities may well suffer from a flood, but they are usually well-insured against flood loss, as well as being well-connected and articulate (and thereby able to secure compensation, maximise insurance claims and payouts and generally insulate themselves against crises). Such communities are likely to be much more robust than communities which are poor or less well-off (see Appendix VI). See also Cole (1995) in his application of a social accounting matrix approach to calamity preparedness.

These poorer communities, on the other hand, will generate much lower values for flood damage potential and on the surface this would suggest that their vulnerability is low whereas the opposite may be the case. Unless assessed flood damage potential is adjusted

or weighted by social group or socio-economic class, it is likely to provide a misleading measure of socio-economic vulnerability and then there is the risk that investment in flood mitigation measures will flow to the more wealthy areas where the flood damage potential provides high benefits to match high costs.

There are additional reasons why assessed flood damages may initially mislead concerning socio-economic vulnerability. The flood damages which are easiest to assess are usually those which can be readily converted into monetary values, such as the damage to the structure of a building or to its contents. However, research has revealed that the intangible effects of flooding, including health effects, social-psychological and emotional impacts, which are usually not measured in monetary terms may be overlooked or under-estimated.

In the UK and the USA research has shown that the most vulnerable and those in disadvantaged sectors of society are significantly more likely to experience these impacts (Tapsell *et al.*, 1999, 2003; Tapsell and Tunstall, 2001; Tunstall *et al.*, 2006; Green *et al.*, 2007; Rath *et al.*, 2007).

3 Vulnerability and resilience

In Appendix III, some further working definitions and concepts related to economic systems vulnerability are given, including resilience. The third definition of resilience in the Appendix III almost suggests that resilience is simply the opposite of vulnerability, and that the two concepts exist in some kind of binary (on/off) relationship. However, according to Buckle *et al.* (2001) it is not possible to divorce vulnerability and resilience from each other – they are linked in a double helix and are not necessarily opposite ends of a continuum. Obviously a resilient system is less vulnerable than a non-resilient one, but this relation does not necessarily imply symmetry. Resilience is clearly related to the capacity of response component of vulnerability, and thus it would be less than the flip side of vulnerability (Gallopín, 2006).

The term 'vulnerability' has been said to have negative connotations and according to some authors should be turned around and approached positively as 'resilience', or as the capacity to cope with or adapt to change. This is broadly similar to the concept of adaptive capacity which has been used and developed by climate change researchers (Adger *et al.*, 2004). Some writers prefer to use the term resilience in place of vulnerability because of these more positive connotations; e.g. the United Nations International Strategy for Disaster Reduction which defines 'capacities' as the opposite of 'vulnerability'.

In a bibliometric analysis of the terms 'resilience', 'vulnerability' and 'adaptation' Janssen (2006b) concludes that the number of publications on these three terms (knowledge domains) has increased steadily over the last decade. Particularly, the 'resilience' knowledge domain seems to be only weakly connected with the other two domains in terms of co-authorships and citations. The resilience knowledge domain has a clear background in ecology and mathematics with a focus on theoretical models, while the vulnerability and adaptation knowledge domains have a stronger background in geography and natural hazards research with a focus on case studies and climate change research. The increasing number of cross citations and papers classified in multiple knowledge domains seems to indicate an increasing integration of the three different knowledge domains.

Also Adger (2006) comments on this division in knowledge domains and provides another overview of the evolution of approaches to vulnerability, arguing that the two major research traditions that acted as seedbeds for ideas, which eventually translated into current research on vulnerability of social and physical systems, are the analysis of vulnerability as lack of entitlements and the analysis of vulnerability to natural hazards.

Figure 2 draws clouds around the development of different concepts taking place within the realm of climate change research, contributing to the development of vulnerability analysis of social-ecological systems.

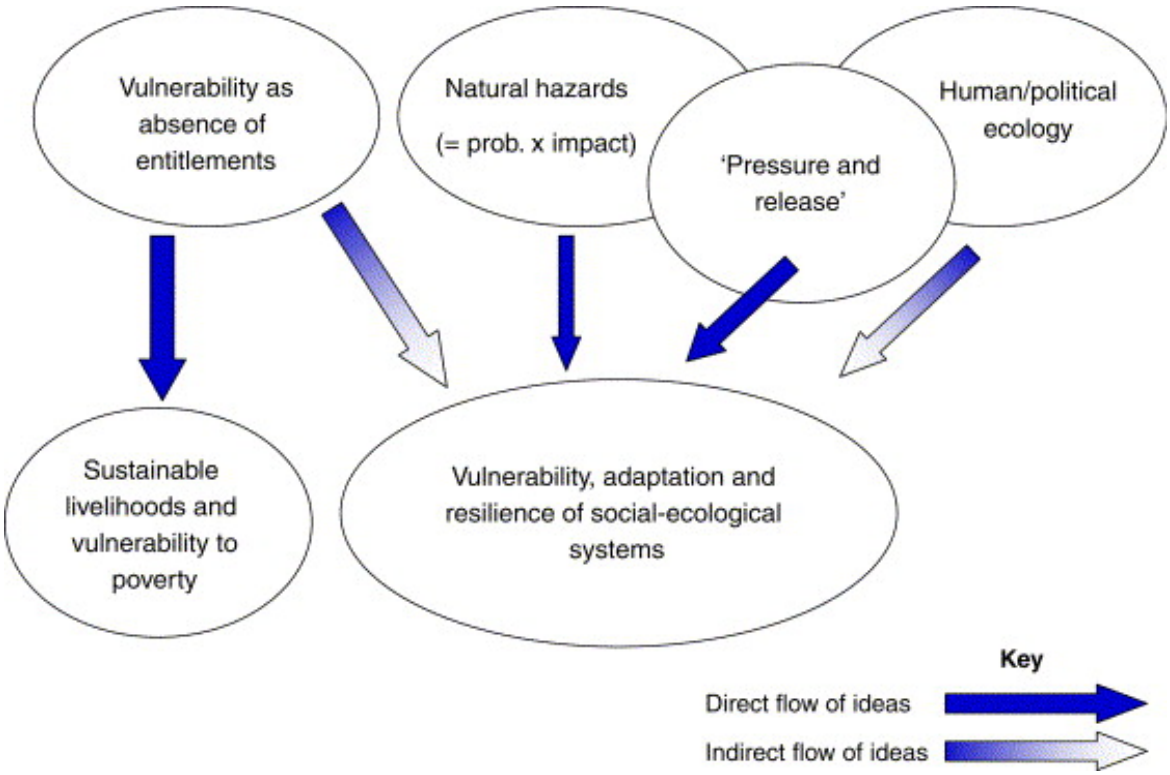


Figure 2: Traditions of vulnerability research and their evolution (Adger, 2006)

A novel connection between vulnerability and resiliency is established by Folke (2006). He concludes that resilience is not only about being persistent or robust to disturbance. It is also about the opportunities that disturbance opens up in terms of recombination of evolved structures and processes, renewal of the system and emergence of new trajectories. Consequently, resilience provides adaptive capacity that allows for continuous development, like a dynamic adaptive interplay between sustaining and developing with change. Therefore, resilience of socio-ecological systems incorporates the idea of adaptation, learning and self-organization in addition to the general ability to persist disturbance.

The resilience perspective is increasingly used as an approach for understanding the dynamics of social–ecological systems. Folke (2006) discusses the origin of the resilience perspective and provides an overview of its development to date. With roots in one branch of ecology and the discovery of multiple basins of attraction in ecosystems in the 1960–1970s, it inspired social and environmental scientists to challenge the dominant stable equilibrium view.

The resilience approach emphasizes non-linear dynamics, thresholds, uncertainty and surprise, how periods of gradual change interplay with periods of rapid change and how such dynamics interact across temporal and spatial scales. Recent advances include understanding of social processes like social learning and social memory, mental models and knowledge–system integration, visioning and scenario-building, leadership, agents and actor groups, social networks, institutional and organizational inertia and change, adaptive capacity, transformability and systems of adaptive governance that allow for management of essential ecosystem services.

Gallopín (2006) explores further the concepts of vulnerability, resilience, and adaptive capacity by identifying the conceptual linkages between them and through the use of a generic systems approach that can be specified for different concrete system types (social, ecological, but particularly socio-ecological).

4 Strategies, approaches and practices to decrease socio-economic vulnerability and to increase resilience

The literature contains numerous strategy prescriptions mainly targeted at less developed countries. These can, if necessary, be broken down into the four phases of the disaster cycle (mitigation, preparedness, emergency, rehabilitation). Many of the prescribed measures which follow are adaptive in character and the emphasis tends to be on developing strategies at the local, community level to complement those at the national level. What is important is that risk reduction measures for one hazard should be compatible with measures for other hazards. This eliminates the possible substitution of one risk for another e.g. relocating people from a floodplain to higher ground which is then at risk from landslides. Detailed knowledge is required of vulnerability of locations on a wide range of natural hazards.

Early strategies and measures were largely aimed at developing countries, although some of these measures are also relevant in more developed economies. Blaikie *et al*. (1994) provide a general prescription for managing a reduction of socio-economic vulnerability comprising 12 principles (Appendix VII). Parker (2000) identifies nine 'non-conventional and radical approaches' to reducing flood hazard and disaster vulnerability (Appendix VIII).

Regarding vulnerability reduction, Yodmani (2001) draws a distinction between the 'disaster paradigm' and the 'poverty paradigm', and argues that the disaster management community has been moving towards the latter. In his view the disaster paradigm treated disasters as one-off events, emphasised relief delivery and technocractic/engineering solutions, developed vulnerability analysis and evolved an approach comprising hazard assessment, vulnerability analysis, and enhancement of management capacity.

On the other hand, the ascendant poverty paradigm views reducing poverty as a matter of social spending and social welfare; emphasised external donors, saw poverty as more than income deficit, sought to link poverty reduction to national development programs through targeting inequalities and the empowerment of the poor, and measured human poverty indicators such as lack of access to resources. This has led to the kind of approaches to socio-economic vulnerability reduction set out in Appendix IX (Yodmani, 2001). Further strategies to address socio-economic vulnerability are identified by Moss (2005), Matin (2002) and Lebel (2006), while Osbahr (2007) focuses upon resilience-building strategies based upon adaptation mechanisms in Africa.

With some exceptions (e.g. Parker and Penning-Rowsell, 2005), flood strategies for industrialised nations pay relatively scant attention to socio-economic vulnerability reduction strategies, and focus more on resilience-building, often linking this to the quest for sustainability (e.g. Hunt, 2005). In the context of post-industrialised nations, resilience strategies include designing flood resistant buildings, employing a wide range of spatial-planning measures, introducing sustainable urban drainage systems, improving awareness-raising, preparedness/emergency planning, business continuity planning, and integrated hazard and disaster management (Bosher, 2008; Friesecke, 2004).

More recent approaches are also focusing on identifying more vulnerable groups within communities (e.g. the very elderly, those with disabilities, those on low income and with few social networks) for more effective targeting of flood warnings and evacuation measures, as well as helping to build social capital, coping capacity and future resilience (e.g. Beaudoin, 2007; Green *et al.*, 2007; Steinführer *et al.*, 2007a; De Marchi *et al.*, 2007).

Disaster resilience is often viewed as the intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its non-essential attributes and rebuilding itself. However, some people (e.g. Manyena, 2006) see problems with this view. Although social vulnerability reduction strategies are often oriented towards creating a coping environment, people want more than simply to cope. Moreover, interventions are more likely to be successful when the emphasis is on building local knowledge and augmenting existing capacity. This entails the identification of the essential and non-essential elements of communities and building on affirmative action, rather than endless risk assessments and reactions to negatives.

Suggestions could be to consider the choices open to funding agencies to channel their resilience building support, or vulnerability reduction, into education, capacity building, psychosocial programmes and people-centred strategies, or more towards predetermined institutions and infrastructures. Responses to flood risk management following the Carlisle floods of 2005 in England have focused on building such community resilience and integrating this with urban regeneration strategies (Watson *et al.*, 2008). Similar approaches are being used in New Orleans following Hurricane Katrina (Green *et al.,* 2007).

Working with local communities, building up trust and fostering two-way communication regarding the management of flood risk is now being introduced as an approach and was successfully used in the town of Shaldon, UK. Here, a strategy of Engage Deliberate Decide (EDD) was used to involve the local community in decision-making rather than the old Decide Announce Defend (DAD) approach. This has resulted in increased community support for resulting flood risk management measures (C. Brookes, personal comm. Environment Agency, 2007).

5 Psychology, awareness and perception

From a purely social standpoint, a disaster can involve the psychological, socio-demographic, socio-economic and socio-political sphere of a population due to particular factors of vulnerability linked with the level of literacy and education, psychological attitudes, social equity, positive traditional value, knowledge structure, customs and ideological beliefs and overall organizational systems (*ECB project*[2]). Some of these aspects are related to a 'collective' dimension whereas others can have both an individual and a collective dimension according to the Four-quadrants system approach (Wilber, 2001).

5.1 Psychological impact

Before the impact, risk perception is the most interesting aspect having potential consequences on vulnerability reduction, through the implementation of disaster awareness and preparedness education programs and activation of mitigation measures. Activities aimed at investigating this field are spread where the occurrence of the event is frequent or the memory is strong.

Change in risk perception and hazard intrusiveness (frequency of thought, discussion and information about a hazard) are long-term adaptive consequences of the occurrence of a disaster, able to mobilize communities to engage in hazard mitigation and emergency preparedness measures to reduce vulnerability (Prater and Lyndell, 2000). However, a survey carried out in Turkey by Fişek (2002), aimed at preparing guidelines for local disaster preparedness, response and recovery plans after the 1999 Marmara earthquake, has focused also on reasons for not engaging in any kind of mitigation/preparedness. Answers include educational reasons, economic reasons, psychological and behavioural reasons, religious reasons, and others related to time.

It is worth comparing the vulnerability concept for scientific community experts in physical risk assessment and in psychosocial discipline. According to the former, vulnerability is related to the propensity of people or buildings to be damaged in case of hazardous events and represents a degree of system fragility. In other words, it measures the incapability of people, buildings and infrastructures to resist the adverse impacts of an hazardous event whereas following the psycho-social approach, vulnerability is related to the coping capacity of the system. If coping capacity is able to satisfy needs arising from emergency, normalcy is coming soon but if this does not happen, a part of needs is left not satisfied and the system shows its vulnerability (Lavanco, 2007). With respect to this meaning, there is a better understanding of reasons for which, after a disaster, panic reaction is not so common as it could be thought. In fact, panic is recognized as a non-adaptive reaction, dangerous for survival and so it is rarely manifested, only when all way out are prevented to victims. On the opposite, generally, safety pursuit prevails through actions and decisions based on resources and information available at time.

At 'impact time', reactions considered 'normal' to an abnormal situation (the disaster) can have different nature (Nolen-Hoeksma, 2003 as reported by Antoniou *et al.,* 2005):

a) emotional (e.g. shock, grief, helplessness, anger, terror, difficulty feeling happy or loved)

[2]Emergency Capacity Building Project

b) cognitive (e.g. impaired concentration and decision-making ability, memory impairment, disbelief, confusion, nightmares, decreased self-efficacy, intrusive thoughts, dissociation)
c) physical (e.g. fatigue, exhaustion, insomnia, cardiovascular strain, hyper arousal, increased physical pain, reduced immune response, headaches, gastrointestinal upset, decreased appetite and libido, vulnerability to illness)
d) interpersonal (e.g. increased relation conflict, social withdrawal, reduced relational intimacy, alienation, impaired work performance, decreased satisfaction, distrust, externalization of blame and vulnerability, feeling abandoned, rejected, over protectiveness).

According to Beck (1976), the factors involved in the occurrence of more severe and persistent anxiety following natural disasters such as floods can be divided into two categories:

- factors that lead people to experience relatively greater levels of anxiety (in this case the experience of being flooded);
- factors involved in the maintenance of high levels of anxiety (e.g. for flooding this can relate to subsequent heavy rainfall and anxiety about future flooding, and lack of trust or confidence in the responsible authorities to provide protection from flooding or a flood warning).

In psychology, cognitive theory proposes that people experiencing anxiety believe that they are threatened with either physical or social harm. Whether or not the harm they fear is objectively present is irrelevant to the experience of anxiety (Salkovskis, 1996). One of the hallmark symptoms of Post Traumatic Stress Disorder is physiological reactivity to traumatic reminders, which in the event of flooding might be heavy rainfall (evidenced in the posttraumatic stress symptoms scores). Beck, Emery and Greenberg (1985) describe a useful conceptualization of the cognitive component of anxiety which appears relevant to flooding (see Tapsell and Tunstall (2006) for a discussion of this in relation to flood hazard, including the perceived probability of threat, the perceived cost and awfulness of the danger, the perceived ability to cope with danger and the perceived "rescue factors").

Norris *et al.* (2001) reviewed the empirical literature on psychosocial resources in the aftermath of natural and human-caused disasters. Protection afforded by psychological resources included: ways of coping (which can be positive but not always helpful e.g. avoidance coping, blame assignment); beliefs about coping (often more important than actual coping, perceptions about capabilities to cope); self-efficacy, mastery, perceived control, self-esteem, hope and optimism. Protection afforded by social resources included: social 'embeddedness', as well as received and perceived social support. In the latter case those who believe that they are cared for by others, and that help will be available if needed, fare better psychologically than those who believe they are unloved and alone. Smith (1996) reports active coping as being associated with less psychological distress among flood victims when tested at six weeks and five months after the 1993 Midwest flooding in the US, while avoiding coping was associated with greater psychological distress.

As stated by Gist and Lubin (1989), a disaster is an event at community scale for its traumatic impact and collective reactions, so even coping strategies have to be investigated at a community level. Lazarus (1966) argues about two typologies of coping resources:

1. material and social resources;
2. personal resources.

The former refers to resources related to context availability: economic resources, provided services, network and social support. The latter refer to personal cognitive skills in appraising and solving a problem, to health status and personal self-trust and self-efficacy

(Amerio, 2000). Usually, people who have a low level of control on life events are likely to experience the worst impacts after a disaster (Peterson and Seligman, 1984).

Moreover, as argued by Lavanco (2007), people who have scarce access to economic resources or scarce cognitively and in organizational skills and show a larger vulnerability. The author also focuses on the concept of community, recently modified by globalization effects. In fact, in rural communities, the interactions relate to a well-defined geographic space; whereas in modern society, due to the development of transport systems, higher efficiency (technological data) and mobility requirements (social data), the edges of daily life are subjected to dilatation, which makes the reference to a territorial unit as an essential requirement of a sense of belonging futile. In a scenario of a 'global community', characterized by the absence of boundaries, homogenization of cultural and interpersonal models and the sharing of decoding categories for the events, new forms of collective fears gain ground. Media information plays an important role in this process. Emotional reactions to a catastrophic event are strongly influenced by the typology of information provided, their accuracy and by the moment and style of their dissemination. By doing so, information bears on perception and event appraisal.

These factors, together with self-perception, self-appraisal and relational aspects linked to personal and social spheres, represent the main elements to shape psychological coping reactions to the negative experience of disaster and to fill that discrepancy between event and coping capacities identified as vulnerability.

5.2 Identity and the sense of 'self' and 'place'

Damage to people's homes from disasters can have a significant psychological impact. Flooding of homes is said to undermine people's individual sense of self- and place-identity (Tapsell and Tunstall, 2007; Sime, 1997; Fullilove, 1996). People have a strong emotional attachment to their homes and can experience severe distress if their homes are damaged or destroyed. Homes are often conceived as emotional sanctuaries providing refuge from the outside world. Possessions within the home can also assume considerable significance to people as attachment objects, helping to mark important events and experiences in people's lives, define who they are, and who they care most about (Csikszenmihalyi and Rochberg-Halton, 1981). Green (1993) as well as Tapsell and Tunstall (2001) reported that anxiety about future risk of flooding leads to changes in the way the individual uses their home, and in their lifestyle. Following flooding there may also be a community-wide tendency for people to feel less positive about their surroundings, less enthusiastic, energetic and less able to enjoy life. Evidence from the north of England suggests that flooding may impair the quality of community life for quite some time due to the disruption of community activities and a sense of community breakdown (Tapsell and Tunsall, 2001).

5.3 Prior experience, values and awareness of risk

In disasters of smaller magnitude, there is evidence that prior experience with the specific type of event may reduce anxiety. People who have previous experience show higher levels of hazard preparedness and are more likely to evacuate when authorities suggest so. In a study of flood victims in Kentucky, Norris and Murrell (1988) found that, while controlling for pre-flood symptoms, there were modest flood effects on both trait anxiety and weather-specific distress in older adults without prior flood experience, but no flood effects in older adults who had been in floods before. The study provides support for the 'innoculation hypothesis' and other conceptualisations that emphasise the advantage of being familiar to

or experienced with a stressor that is at hand. An implication is that 'experienced' victims could be a valuable resource in prevention efforts. However, Tunstall and Bossman-Aggrey (1988) reported that previous experience of flooding did not leave residents with knowledge about how to cope with a future flood, but with a feeling that there is little they can do. This 'loss of control' may be a stressor in its own right and can explain the high levels of continuing anxiety and worry expressed by residents.

Findings from research conducted over a number of years in England and Wales (and re-analysed for the FLOODsight project by Tunstall *et al.,* 2007) show that awareness prior to actually experiencing flooding or on moving to the current address was low but this varied between the three studies in question, and different questions were asked in each. Prior flood experience, tenure and length of residence were the significant factors affecting awareness in two of the data sets. In all three studies there were significant and marked variations in prior awareness according to the specific location where the interviews took place. This suggests that the nature of the events, local flood history and possibly institutional factors such as awareness raising campaigns, social networks and community preparedness are more significant factors in flood risk awareness than individual characteristics. It appears that while residents acknowledge a level of risk, for most of those without flood experience, the level was not associated with an immediate risk to their homes.

In the Lower Thames Survey there were significant differences in flood risk according to whether or not respondents lived on the river bank. River bank residents tended to judge their property to be less at risk in general terms than non-residents. However, the opposite was the case when respondents were asked about the likelihood of flooding over specific future time periods. In this instance, river bank residents were more likely to view the risk of their property being flooded in the future as certain or very likely compared with non-river bank residents. Another finding from this study is that a very high percentage of people in such a high-risk area (where there has not been frequent flooding) will be willing to live with the risk in exchange for other benefits associated with living in the area, such as amenities, environment, and social networks. This illustrates the strong attraction of living in the area balanced against the limited knowledge of the risk of flooding and also limited experience and possibly poor understanding of the impacts of flooding.

Results from the FLOODsite research in England, Germany and Italy showed that being aware of flood risk does not necessarily result in people being prepared. In one of the English studies preparedness actions taken by respondents varied from keeping alert for flood warnings during high risk months, avoiding keeping irreplaceable items on ground floors and acquiring sand bags, while in another study they involved moving valuables, personal property and cars to safety and saving property from damage. Another important behavioural response in the latter study was the attempt to keep the flood waters out of the property. Few people took the more effective action of putting up flood boards or gates, probably because they did not have them. Those with prior experience of flooding inside their home were more active in taking certain measures and significantly more of those who had been flooded three or more times had taken more drastic preventative measures such as building walls around their property and buying flood boards. This indicates that previous experience is more significant in preparing for flooding rather than simply awareness.

Taking out insurance was a common form of preparedness measure by residents in the flood affected areas, although for many flood insurance may have come automatically as part of their general household cover. The key factor important in insurance take-up was social status, with those in the lowest social groups and those living in 'vulnerable' housing significantly less likely to have insurance cover. Tenure was also important in affecting

insurance take-up, with those not owning or buying their property less likely to have insurance of all kinds.

Another key preparatory action that those in flood risk areas in England and Wales can take is to register with the Environment Agency to receive flood warning messages via the Agency's Floodline Warnings Direct system. Again, those with prior experience of more than one flood event and prior awareness of flood risk were more likely to take this preparedness measure. Thus, flood risk awareness and experience were the only variables considered that accounted for registration before the last/worst flood. Age and receipt of a flood warning were significant factors affecting respondents' ability to take actions. Flood warnings in this instance were a significant driver of behaviour before and during a flood event, although this has not always been found to be the case in other studies.

In the Lower Thames study of mainly 'at risk' residents, for almost all, actions were taken before any recent flooding inside their property but with recent evidence (the 2003 flood) of the potential for flooding in the area. In this survey, it was possible to examine the way risk was constructed by the residents and the actions taken. Only one difference emerged: those who considered flooding in their home likely in the next 50 years were significantly more likely to have undertaken at least one preparatory measure than those who thought flooding unlikely. Thus, viewing the flood risk to the home as more likely had a limited impact on preparatory action, and mainly resulted in residents paying more attention to information about possible flooding.

The data therefore help to illustrate people's experience of flooding and how their perceptions or constructions of flood risk may be influenced by a number of factors, such as flood event characteristics, proximity to river, organisation or institutional responses to the event and the characteristics and resources of the population affected. Very different drivers of human behaviour are observable before a flood at work across forms of preparedness action such as registering onto the flood warning system and taking out insurance. Flood awareness and experience were important for the former and of no significance for the latter. Instead, taking out insurance appears to be related to socio-economic factors and institutional arrangements affecting tenure. Most of the actions reported as taken by respondents required the individual householder to take the initiative before a flood event and there were few institutional pressures on residents to make these preparations.

Results from this research also reflect those from Germany (Steinführer *et al.,* 2007) and Italy (De Marchi *et al*., 2007) in that awareness of flood risk does not necessarily lead to preventative or protective actions by residents in at risk areas.

Morris-Oswald and Sinclair (2005) conducted a study in Canada of two communities which assessed the influence of value orientations (norms and beliefs) of floodplain residents on flood management planning and mitigation decisions. The study used a qualitative methodology of semi-structured interviews with 48 residents in the two communities. A core value expressed in both communities was that of security, however, this was expressed through specific and somewhat different dynamics in each community. In one community the importance of social capital was reflected in ensuring a sense of security. The community had a history of kinship ties and extensive social networks. Volunteerism was also important in the town. In the other town security was more closely tied to the practicalities of a low crime rate and a high quality of protective and support services in the community (e.g. police, fire). This suggests strong faith in local authorities to deal with practical flood issues and a high level of conformity to authorities, particularly within the dyked areas. Cooperation was also a publicly lauded value along with recreational values and again volunteerism. Distinct patterns of leadership in the two towns also impact on flood risk management, with a local economic development committee seeming to make many decisions in one town, indicating low public participation in decision-making. In the

other town no single community group assumes general leadership within the community, although again the general public is rarely involved in decision-making.

Values related to growth and economic development were particularly evident in one town, while in the other residents seem more content with the status quo with regard to community growth. Residents in both communities showed a distinct preference for technological solutions to the problem of flood vulnerability, namely structural mitigation measures. The consequences of value orientations were most profound with regard to public involvement, expectations of government institutions, and structural protection measures. In particular, identified community values such as dependency, conformity and compliance increase the likelihood of residents allowing others to assume responsibility for flood-related issues. Local interest in both vulnerability reduction and sustainable development within the floodplain is thus reduced. Such values that inhibit involvement of residents in flood management decisions also constrain the ability of flood risk managers to anticipate the response, behaviours and needs of residents during a flood, which can result in more risk to residents and overall stress and confusion. The findings highlight that values are deeply relevant to understanding community level response to flood hazard. Some of the values found were deemed to be regional or even national values. Shared values indicate common motivations and can serve as the common ground for conflict resolution and to achieve common goals, e.g. increased resilience.

Overall, it remains clear that psychological elements like risk perception, awareness and personal and collective coping mechanisms are crucial elements to be considered in any vulnerability assessment.

6 Models and methodologies for socio-economic vulnerability assessment

Numerous models and methodologies exist for assessing economic and social vulnerability. One theoretical model, designed by Green *et al*. (1994) as part of the Euroflood project, is aimed at understanding both the social and economic vulnerability of households to flood hazards. This methodology adopted a formula in which household vulnerability is a complex function of many variables, including: socio-economic variables, property and infrastructure variables, flood event characteristics, flood warning and response variables.

However, most approaches in the past have tended to focus on either economic or social vulnerability assessment, as often different approaches and methods are needed for each. Besides different models and approaches have been adopted at different scales, i.e. the micro/project, meso/regional and the macro scale. Therefore, for the purposes of this report the various assessment models and methodologies will be discussed separately.

6.1 From damage loss assessment to economic systems vulnerability assessment

Although damage and loss assessment methodologies are certainly not the same as models and methodologies for socio-economic vulnerability assessment, they are strongly related.

Lessons, conceptual and methodological issues in the field of damage assessment have certainly a bearing on the further development of models and methodologies for assessing economic and social vulnerability.

That's why in what follows reference is made to a number of damage and loss assessment methodologies complemented by assessment frameworks for the vulnerability and resilience of economic systems.

Van der Veen *et al*. (2003b) presented a number of papers that reflect current methodologies in damage estimation. They conclude that the field is now covering a full range of micro, meso, and macroeconomic approaches.

The following topics are relevant:

1. Cochrane (2004) discusses pitfalls in the development of a *methodology* for estimating flood damage. Those pitfalls include double counting of value added and direct damage to buildings, ignoring post-disaster liabilities and questions how indirect losses might be modelled. Cochrane categorises techniques for calculating and estimating indirect damage in one of six categories: linear programming models, surveys, econometric models, input-output models, general equilibrium models, and hybrid models. He is critical on the use of Computable General Equilibrium (CGE) Models: looking at actual events relative price changes are conspicuously absent, which robs CGE of one of its chief advantages. Cochrane discusses new issues in loss estimation asking attention for forms of indirect losses often neglected: non-market losses. Here, he relates to the European research on non-market losses by Flood Hazard Research Center at Middlesex University, UK. Based on the empirical case of the attack on the World Trade Center, he defines a number of critical issues, which are relevant for damage and loss assessment in general: i. Baselines for estimating loss are inconsistent and misleading; ii. Failure to account for the reconstruction stimulus; iii. Failure to distinguish between losses sustained from the disaster versus the cost of adjusting to the disaster; iv. The possible existence of post disaster systemic losses.
2. Green (2004) takes a *macro and a micro* point of view in evaluating vulnerability to flooding. He argues that vulnerability has to be discussed in its entire systems context. Scale issues are central to the assessment of vulnerability. Floods may be a negligible hazard when compared to other hazards that exist. And, at the other hand, a household may be vulnerable to an event when neither the local community nor the country as a whole is vulnerable. Green concludes that a systems' approach in defining vulnerability eventually will have far-reaching implications as vulnerability is path-dependent; vulnerability thus is time-dependent; and vulnerability has to be understood as being constructed rather than being innate.
3. Mechler (in Van der Veen *et al*., 2003b) takes a different stance: he stresses the *macro economic consequences* of a disaster. Especially he and his co-authors calculate the macro-economic effects of diverted funds and foreign funds for relief and reconstruction. Direct stock losses due to a disaster are an input in a macro model that uses a flow-of funds accounting methodology to ensure consistency between the sources and uses of funds in a national accounting framework. He distinguishes between the public sector, the monetary sector, the foreign sector and the private sector. In an empirical study, Mechler applies the model to Honduras, computing the effects of a catastrophe on GDP. He concludes that it is important to understand the probable size of losses compared to resources available to meet reconstruction and relief needs. At the International Institute for Applied Systems Analysis (IIASA), a methodology was developed to integrate direct losses to capital stock as calculated using analysis tools of Swiss Re with macroeconomic planning tools of the World Bank in order to study the macroeconomic effects of natural disasters and be able to plan accordingly so as to reduce the adverse impacts. The authors undertook a series of case studies on Argentina, Honduras, and Nicaragua. The methodology allows estimating the potential aggregate effects of natural disasters

before they occur and take respective coping measures by reducing or sharing risk (Freeman *et al.*, 2004).

4. Rose (2004) puts the discussion on resiliency with respect to its *scope*: micro-economic, meso-economic and macro-economic. According to Rose, resiliency has a behavioral emphasis: individuals and firms do not simply react passively in the face of a disaster. He distinguishes three difficulties: firstly, on the conceptual level, where actions may violate established norms, such as rational behaviour; secondly, the operational level, where it is difficult to model individual and community behavior in one single framework; and thirdly, the empirical level where it is difficult to gather data. He then turns to the resiliency of markets: prices do act as invisible hands that guide resources to their best allocation. Computable General Equilibrium Models are state-of-the-art in regional economic modelling, but he acknowledges the fact that CGE models emphasize equilibrium, whereas after a disaster, disequilibrium ensues. These disequilibria can be researched by analyzing the underlying closure rules. Rose applies this type of disequilibrium model to simulate the impacts of water disruption in a regional economy. Finally, Rose is able to make a distinction between inherent resiliency and adaptive resiliency within a CGE model; inherent resiliency is the ability or capacity of a system to absorb or cushion against damage, and adaptive resiliency is the ability to cope due to ingenuity or extra effort.

   Recently, Rose (2007) further develops operational definitions of economic resilience. He argues that the effectiveness of economic resilience as a major way to reduce losses from disasters would be further enhanced if it could be precisely defined and measured. There, he distinguishes static economic resilience (efficient allocation of existing resources) from dynamic economic resilience (speeding recovery through repair and reconstruction of the capital stock).

5. Bockarjova, Steenge and Van der Veen (2004), Cole (2004) and Okuyama (2004) strive at structuring *resiliency* within an *Input-Output accounting* framework. Cole (2004) extends the IO system with a Social Accounting Matrix in order to capture adaptations of societies to lifeline disruptions. Societies are structured and adapt over time to balance performance and its protection. The question Cole raises is how society deals with the balance between the level of protection and accompanying costs, based on output losses. Moreover, how are these losses divided over all actors in the system? He illustrates his theoretical model with empirical material for a sub-regional economy in the US. The Niagara Power Project is the example for a lifeline disruption of power supply that hits a regional economy. Cole shows in his work how costs of protection vary with the size and frequency of events over time and the relative importance of direct and knock-on effects for the well-being of economic actors.

6. Okuyama (2004) applies an IO framework to model damages due to earthquakes. He illustrates his work with the Great Hanshin Earthquake in Japan. Okuyama bases his model on Miyazawa's Extended Framework of conventional IO models. This extension has the advantage of structuring production generation and income distribution and linking location of production and location of consumption. Temporal impacts of a disaster are captured in a Sequential Interindustry model. Okuyama distinguishes between a just-in-time production mode, an anticipatory production mode and a responsive production mode. Each economic sector is then assigned to one of the three modes. A simulation of the Sequential Interindustry model produces a production chronology that reveals how an economic structure deals with a disaster. Okuyama concludes that recovery and reconstruction activities after a disaster need to be planned and phased so that no significant supply constraints occur; secondly, detection of temporal key sectors are crucial for economy-wide recovery.

7. Bockarjova, Steenge and Van der Veen (2004) formulate a new view on *structural changes* in a regional economy after a disaster. Starting from Input-Output analysis their basic question is 'where to start from'. The reason being that a catastrophe by definition affects the existing networks and connections in a fundamental way. Certain elements in the structure may be lost, some possibly forever, while others may survive. From the literature, they apply the concept of an 'Event Matrix'. It traces the development of the situation at selected intervals after the catastrophe and during reconstruction. The problem with the concept, however, is that it is still in the developing phase. By introducing the notion of a 'Basic Equation' that structures the insight in production capacities that remain active, they make an important step forward.
8. Thissen (2004) investigates the effects of a *lifeline transport infrastructure disruption* on a regional economy. He formulates a Spatial Applied General Equilibrium Model where a transport disruption affects production and labour allocation between regions. The effect on labour markets is seen as a major improvement towards previous models where commuting and migration patterns were omitted. Search behaviour of commuters and migrants is such that in the end utility is equal for labourers among regions taking local price differences such as housing prices into account. Secondly, an important element of the model is that the effect of transport infrastructure takes agglomeration effects in consideration.

For Latin America and the Caribbean, ECLAC (2003) presented an example of an initiative where a uniform and consistent methodology has been developed to assess the social, economic and environmental effects of disasters, breaking them down into direct damages and indirect losses and into overall and macroeconomic effects. Macro-economic effects in this respect include: Gross GDP; sectoral production; current account balance; indebtedness and monetary reserves; public finances and gross investment; and prices and inflation.

Further methodological issues in the methods for the assessment of economic damage and vulnerability, but to a large extent addressed in the economic literature – also in relation to standard cost-benefit analysis approaches, include: the financial (private) versus the economic (public, societal) perspective; scale issues; stack versus flow estimation; estimation of direct and indirect damage; and the valuation of tangible versus intangible losses.

***Because of these development at various scales (macro, meso and micro), for the different continents we see now more or less standardized approaches to measure damages*:**

For Europe a number of different assessment methodologies have been developed to calculate flood losses. Methodologies in England and Wales, especially detailed researched flood damage data, are probably still the most developed (Penning-Rowsell and Chatterton, 1977; Parker *et al*., 1987; Penning-Rowsell *et al*., 2005). Data and methodologies have also now been developed in Germany (Kreibich *et al*., 2005; Merz *et al*., 2004), the Netherlands (van der Veen *et al*., 2003; Vrouwenvelder *et. al*. 2003), the Czech Republic (Sartrapa *et al*., 2005) and France (Water Agency Artois-Picardie, 2006; Water Agency Loire-Bretagne, 1999). Similar damage assessment methodologies have been devised by the US Army Corps of Engineers (Hydrologic Engineering Center in Davis, California (2008), Canada (e.g. Schultz and Kejelland, 2002) and Australia (*cf*. Zerger, undated).

In England, since the 1970s, a system of modelling flood damages at different spatial scales has evolved, including a national high level method, a regional level method, an intermediate level method for Catchment Flood Management Plans and a local level. At almost all levels standard flood damage data developed by the Flood Hazard Research Centre at Middlesex University are used (Penning-Rowsell and Chatterton 1977; Parker *et*

al., 1987, Penning-Rowsell *et al*., 1992; Penning-Rowsell *et al*., 2005). Standard damage data are available, for example, for residential buildings (with a breakdown by type and age of building), and for different types of non-residential property (e.g. offices, manufacturing plants, retail units etc.). Indirect loss values are also available for all building types, for traffic disruption, emergency service costs and agricultural production. Intangible loss values (some quantitative, other qualitative) are available for people, health, environmental impacts, and recreational impacts. Flood damages are also calculated for different depths and durations of flooding.

In Germany slightly different approaches have been developed in different *Bundesländern* or regions. For example, in North Rhine-Westphalia a state level, meso-scale damage and risk analysis has been carried out, and a more detailed level analysis has been used at river basin level. A micro-scale damage evaluation method has also been developed there (Meyer and Messner, 2005).

The Czech Technical University in Prague has developed a system of three methods of flood damage evaluation with different levels of accuracy, and all methods are based on the same approach which is an estimation of the value of assets at risk per metre or cubic metre, mainly based on data from official statistics (Satrapa *et al*., 2005). The three methods relate to three different scales of analysis: national, regional and local.

The flood damage assessment methodologies currently used in European Union member states have been recently reviewed in Meyer and Messner (2005), Messner *et al*., (2006b) and in Parker *et al*. (2008). Meyer and Messner (2005) have compared the flood damage evaluation methods of England, the Netherlands, the Czech Republic and Germany. These countries have different histories of flood protection policy and different institutional settings, but all use sophisticated methods of flood damage evaluation.

In principle these methods all follow the same idea of trying to place economic values to elements of flood risk in order to estimate the benefits of measures designed to prevent flood damage. Although the methods exhibit different approaches, such as the categories of land uses chosen, in the degree of detail, the scale of analysis and the application of principles relating to replacement or depreciated costs, are broadly similar.

6.2 Methods for assessing social vulnerability

Warner (2007) examines the state of research and emerging perspectives on social vulnerability by addressing general frameworks for thinking about social vulnerability to multiple stressors and examining some of the factors that contribute to social vulnerability. The review underscores the importance of examining social vulnerability when designing and implementing policy.

Research on social vulnerability has traditionally focused on characteristics that contribute to specific aspects of social vulnerability in a subgroup of the total population at risk from a hazard rather than an all inconclusive investigation of the relevant factors in the total population. Moreover, the focus of this research has been on how to *assess* characteristics of vulnerability rather than how to *integrate* social vulnerability into the broader context of vulnerability and risk equations. Consequently, the findings are fragmentary and there is no consensus on a) the primary factors that influence social vulnerability, b) the methodology to assess social vulnerability, or c) an equation that incorporates quantitative estimates of social vulnerability into either overall vulnerability assessment or risk. Nevertheless, several methods for assessing social vulnerability have been proposed. We present a few recent ones here, without specifying the type of hazard.

Cutter *et al.*, (2003) used 1990 US Census data from all 3,141 counties in the USA as the unit of analysis. These data were free and available through the internet via the US Census Bureau portal. Using the Census data, variables that represented the broader dimensions and constructs of social vulnerability were identified. Originally some 250 variables were selected and then reduced to 85 raw and computed variables. Factor analysis (principle component analysis) reduced the data to eleven factors, which explained some 76% of the variance in vulnerability among all counties. The methodology used in developing this Social Vulnerability Index (SOVI) model allows for a robust and consistent set of variables that can be monitored through time to assess changes in vulnerability. A major strength of the model is that the data are obtained from standard census studies performed by governments rather than expensive one-off surveys such as those often funded through scientific research. The shortcoming of the model is that it is not linked into a model of risk, but as the authors explained, a logical next step is to integrate the model findings or outputs (GIS maps of vulnerable areas) with physical hazard maps.

In a separate study, Dwyer *et al.* (2004) describe a methodology for measuring aspects of social vulnerability and its role in contributing to risk from natural hazards in Australia. A limitation of this study is that it is specific to individuals in households. In yet other studies, Paton (2002) has developed a social-cognitive model that predicts the factors that influence individuals' decision-making process in the context of preparing for natural hazards. Key variables in this model are self-efficacy and outcome expectancy (Paton *et al.*, 2008). Key strengths of this model are that it has been tested across multiple hazards and in both individualist and collectivist cultures. A limitation of its use in social vulnerability studies is that the model has not been integrated into risk equations. Yet another limit to its application to social vulnerability studies is that the model focuses on understanding the factors that predict why people do or do not undertake preparedness actions rather than how effective specific preparedness actions taken might be in reducing vulnerability. Attention in recent hazard and disaster research studies has focused on describing 'social capital' and 'collective efficacy'. These relate to the collective intellectual and physical strength of individuals in communities who are able to reduce individual and group vulnerability.

With the growing awareness of, and emphasis on, the social aspects of flooding in the last decade, particularly in Europe, more and more research is now focusing on assessing the social vulnerability of individuals, households and communities to flood risk and impacts. Many quantitative surveys have been undertaken focusing on household impacts (including health impacts) and responses to floods (e.g. Tapsell *et al.*, 1999, 2002; 2003; Skertchly and Skertchly, 2000; RPA, FHRC *et al.*, 2004; Steinfuhrer *et al.*, 2007b; De Marchi *et al.*, 2007, Tunstall *et al.*, 2007; Werrity *et al.*, 2007).

Analytical approaches for assessing vulnerability tend to closely follow research paradigms from historical narratives, contextual analyses, case studies, to statistical analyses, GIS and mapping techniques.

Much social research involves qualitative approaches and methods such as in-depth interviews, focus groups, oral histories, etc. (e.g. Thrush, 2002) although quantitative techniques such as structured surveys and collection of statistical data are also frequently employed. Appendix X outlines some methodologies for assessing social vulnerability to flood hazard.

Social impact and response are often measured by threats to lifelines or infrastructure to support basic needs, special needs of populations, poverty or wealth indicators, gender, age etc. The geographical scale poses difficulties in measurement as applications range from local to global scales. For flood risk the most detailed vulnerability assessments are conducted at the local level, often of individuals or households. Methodological decisions

often mean sacrificing localised detailed case study approaches for more broadly based patterns and distributions (Cutter, 1996). Sophisticated tools for health risk assessment exist but these are largely aimed at providing aggregate measures or focus on description of impacts and response capacities. Techniques such as the General Health Questionnaire (Goldberg and Hillier, 1979) and the Post Traumatic Stress Scale (Scott and Dua, 1999) have been used in England and Wales to assess health impacts following flooding (RPA *et al.,* 2004).

There is a growing range of literature on the health impacts of flooding (Hobbs, 1995; Ohl and Tapsell, 2000; Hajat *et al*., 2005; Few and Matties, 2006; Ahern and Kovats, 2006), much of which has been used to suggest the parameters and indicators of vulnerability outlined in Section 7 below.

Much of the literature focuses on post-disaster responses and on how to determine physical and psychological impacts on health and well-being. In developed countries floods may potentially impact upon human health in a number of ways, the most serious being by death from drowning or serious injury (HR Wallingford, 2003; Ahern and Kovats, 2006; Tunstall *et al*., 2006). The risk to life from flood hazards has been modelled by various authors (Brown and Graham, 1988; Waarts, 1992; Vrounwemvelder and Steenhuis, 1997; Graham, 1999; Wallingford, 2003, 2005; Jonkman, 2007; Zhai *et al*., 2006; Priest *et al.,* 2007). These models differ in the types of flood risk being assessed, from river flooding to dyke breaches and dam failures, and include a range of different variables. Many focus on the key variables influencing risk to life e.g. area characteristics (topography, nature of housing and propensity to collapse, institutional responses such as flood warnings), flood characteristics (depth, velocity, etc.) and population characteristics (age, health, etc.). Some models are based on the analysis of just one flood event (e.g. Waarts, 1999 on the 1953 flood), while others focus on analysing data from a number of flood events (HR Wallingford, 2003, 2005; Jonkman, 2007; Priest *et al*., 2007). The models also vary in whether they attempt to predict actual numbers of fatalities or merely indicate levels of risk e.g. low to extreme. Some models (e.g. Priest *et al*., 2007) have also developed simple GIS mapping of the risk to life to provide vulnerability maps of study areas.

More frequently than deaths, common health effects in developed countries from flooding result from minor injuries (Schmidt *et al*., 1993; Manuel, 2006), diarrhoeal episodes, (Wade *et al*., 2004; Reacher *et al*., 2004), respiratory disease (Franklin *et al*., 2000) and psychological impacts (Bennet, 1970; Phifer and Norris, 1989; WHO, 2003). The risk to public health from communicable diseases is still a problem in many developing countries but is relatively infrequent in developed countries due to good sanitation and water supplies and lack of overcrowding (Malilay, 1997; Meusel and Kirch, 2005; Ahern and Kovats, 2006), although the risk could increase in the future with global warming. Toxicants in sediment and air may also pose a problem as evidenced following Hurricane Katrina (Manuel, 2006).

Most studies agree that the psychological impacts are by far the most significant (Tunstall *et al*., 2006). Beck and Franke (1996) report that 15-20% of people studied following natural disasters are reported to have symptoms of Post Traumatic Stress Disorder (PTSD). Moreover, there is growing evidence that disaster victims may continue to experience psychological health symptoms long after the event (Steinglass and Gerrity, 1990; Tunstall *et al.,* 2006). Thirty-eight percent of those interviewed following the 1993 Midwest floods in the US met criteria for post-flood psychiatric disorder (McMillen *et al*., 2002). Moreover, those who are diagnosed with PTSD or psychiatric problems are more likely to have a greater number of physical health problems than those who are not diagnosed (Stoudemire, 1995). Chronic problems identified by Norris *et al*., (2001) in their review of 177 articles comprising over 50,000 individuals who experienced 80 different types of disasters (62% of which were natural disasters, mostly in the US), include: troubled family and interpersonal

relationships, social disruption, occupational and financial stress, concerns about general living conditions and the wider community, and obligations to provide support to others.

Health Impact Assessment (HIA) is a relatively new multidisciplinary process and its potential as a tool for assessing disaster risk or vulnerability has not yet been fully explored. HIA views a range of evidence within a structured framework through a variety of procedures and methods, often integrated with Environmental Impact Assessment (EIA) and Social Impact Assessment early in the planning cycle. It uses checklists of determinants as indicators of changes in health risks. Health inequality is a central issue and identification of the most vulnerable groups is very important.

In order to deepen understanding of the processes that shape how vulnerability to health impacts varies, an intermediary research tool has been suggested by Few (2007) that narrows analysis to specific hazards (in this case floods) and health outcomes and disentangles the points at which aspects of vulnerability and response actions come into play. This 'health impact pathway' model for flooding depicts the potential progression of impacts of flood hazard events and possible response mechanisms (Appendix XI).

There have been few studies comparing social vulnerability in differing cultural contexts. One example is that conducted as part of the EC FLOODsite project which analysed social vulnerability of flooded and at risk populations in Germany, Italy, England and Wales (see Steinführer *et al.*, 2007a). Many similarities were found across the four countries regarding social vulnerability, however, local culture and context was a key influencing factor. Institutional arrangements, previous flood-experience, frequency of floods, location, community size etc. all matter and can be summarised under the umbrella-term *'risk cultur"*, which differs between and among regions. Several additional aspects also need to be considered when assessing social vulnerability, these include people's behaviour, assumptions, knowledge and ignorance (Gross 2007; Kuhlicke 2007) as well as processes of sense-making.

7 Indicators/parameters of socio-economic vulnerability

Many initiatives have been undertaken to develop indicators to measure vulnerability in its different dimensions. The United Nations Universities Institute for Environment and Human Security (UNU-EHS) has been active over the last decade to look into state-of-the-art vulnerability assessment, particularly in the field of hazards (e.g Brikmann and Wisner, 2006; Birkman, 2006). The Tyndall project reviewed work on vulnerability indicators and developed more formal approaches to develop indicators of vulnerability and adaptive capacity in the field of climate change policy processes (Adger *et al.*, 2004)

Indicators are qualitative or quantitative parameters that describe features of a certain, often complex and ill-defined, phenomenon and communicate an assessment of the phenomenon involved (Dopheide and Martinez, 2000). The latter implies that, although indicators can be either descriptive or normative, they always have implicitly or explicitly a reference to a norm. This makes indicators clearly different from simple measurements.

The rationale behind measuring vulnerability and the use of vulnerability indicators has been summarized in Birkmann (2006). Vulnerability indicators can have the following functions: i. identification and visualisation of vulnerability; ii. evaluation of political strategies; and iii. monitoring implementation of strategies and actions.

More practical motives for the development and use of vulnerability indicators include: vulnerability indicators help to set priorities (among groups and/or areas); they provide

background information for action; they help to raise awareness (among policy makers and in civil society); they assist to monitor and analyse trends; and they enhance the empowerment of local groups and communities if developed and used as part of community-based disaster management and self-assessment (Wisner *et al.*, 2004) – see workshop UNU-EHS.

The numerous initiatives to measure, qualify and/or assess vulnerability are well summarised and documented (Adger, 2000; Adger *et al.,* 2004; Birkmann, 2006). However, many of the initiatives to measuring vulnerability often lack a systematic and transparent approach (Birkmann, 2006). As Downing (2004) emphasizes *"the indiscriminate use of indicators—pick any that seem relevant and are available—must be avoided*". Rather it is important to develop and have a conceptual model as a basis for any indicator development. At the same time it can be argued that the "indiscriminate" search for indicators and the many indicator initiatives have contributed to an improved understanding of what is actually meant with vulnerability and how vulnerability is perceived, including its related factors.

In this sense, any initiative or procedure to develop indicators follow either a more deductive, theory-based approach or a more inductive approach, based on statistical relationships. In the first case the indicators are developed and selected based on a good understanding and a strong conceptual framework of the phenomenon under study (vulnerability). In the second case indicators are selected based on data and observed empirical relationships that best assesses the phenomenon under study.

However, in both cases, even in the more inductive approach, eventually a good conceptual understanding of the concept being measured, i.e. vulnerability remains crucial.

In literature and in a number of indicator initiatives a sequence of phases and steps have been proposed to develop indicators. Many of these procedures for indicator development will include as an early phase, i.e. before developing and identifying the actual indicators and collecting the data, the development of an appropriate conceptual framework. An example is given in Birkmann (2006), where nine steps are proposed: 1. defining goals; 2. scoping; 3. choosing indicator framework; 4. defining selection criteria; identifying potential indicators; 6. choosing a final set of indicators; 7. analysing indicator results; 8. reporting; and 9. assessing indicator performance.

Many vulnerability indicator studies neither belong to the pure deductive or the pure inductive approach. Many studies eventually work with a set of multiple indicators that were partly based on a basic definition and concept of vulnerability, but to a large extent also determined by the data availability. Indicator programmes that effectively attempt to enhance the understanding of the concept will have to be iterative in nature; combining elements of the deductive as well as the inductive approach and including sufficient feedback loops with the main users and stakeholders involved. A complex and debated concept as vulnerability will, however, require a minimum of consensus on the adopted definitions and framework.

Adger (2004) discusses three characteristics of vulnerability and vulnerability research that present particular problems when devising vulnerability indicators; which are complexity and limited understanding of the concept or phenomenon (i.e. the paradox as put forward by Birkmann (2006) *"We aim to measure vulnerability yet we cannot define it precisely*"); the issue of different scales; and the dynamism. The first point refers to the earlier reported seemingly unending debate on what vulnerability is, making the operationalisation of vulnerability through indicators an even more difficult task.

Within the last few years, three major global projects have been carried out to measure risk and/or vulnerability with the help of indicators and indices at the national scale, for international and global comparisons, namely:

1. the Disaster Risk Indexing project (DRI) of the UNDP in partnership with the UN Environment Programme-Global Resource Information Database (UNEP-GRID);
2. the Hotspots indexing project implemented by Columbia University, the ProVention Consortium (under the umbrella of the World Bank); and
3. the Americas programme of IDEA in partnership with the Inter-American Development Bank (IADB).

These projects can be considered as important initiatives which represent the first comprehensive global and regional assessments of disaster risk; for a summary and review of these initiatives, see Pelling (2005) and Birkmann (2007). Whereas Pelling (2005) focuses primarily on the methodologies used, Birkmann (2007) places more emphasis on aspects of applicability and policy implications and outlines challenges and limitations of the different approaches.

The analysis and discussion of the approaches and indicators for risk and vulnerability at different levels by (Birkmann, 2007) showed that these approaches can fulfil relevant functions like identifying and highlighting areas most at risk and pointing to where risk and vulnerability reduction is needed.

However, major shortcomings that were identified included: the challenges and limitations regarding the data; the issues of up- and downscaling, and the contextualisation.

Research has clearly indicated that vulnerability is spatially and socially differentiated, and the scale of analysis is most important. National level assessments can result in loss of information and capturing local variability and pockets or hotspots of vulnerability are important.

There is a distinct body of literature on economic vulnerability indices. This literature and related research which is part of the development framework seeks to identify the vulnerability of national economies to exogenous shocks. This work often focuses upon less developed economies, small states and small island states (Briguglio *et al.*, 2004). There is a separate group of vulnerability studies with a long history which seek to identify those population groups which are most likely to experience the adverse impacts of natural hazards including flood hazards, in order to target preventative measures and disaster relief (Mbithi and Wisner, 1973; Kamau *et al.*, 1989; Reardon and Matlon, 1989; Cutter 1996; FIVIMS 2000; FEWSNET, 2000). Most of this research has focused upon developing countries at the local to regional spatial scales. However, social and environmental indicators research is currently experiencing a renaissance, especially in the area of sustainability science. There are now many examples of the use of indicators to assess human vulnerability to various hazards and threats in developed countries (e.g. Cutter *et al.*, 2003; Granger *et al.*, 1999 and Dwyer *et al.*, 2004). Many sets of indicators have been developed to examine highly context-specific processes. For example, the United Nations Development Program's Human Development Index (UNDP, 2000) provides a composite indicator of human wellbeing, as well as indicators of gender disparity and poverty among nations. The World Bank similarly provides annual data and indicators in its World Development Indicators Reports (e.g. World Bank, 2003).

With the growth in the recognition of climate change and its linked natural hazards, such as floods, as a global threat many assessments have been made of the potential impacts in different world regions (Jallow *et al.*, 1996; Nicholls *et al.*, 1999; Schiller *et al.*, 2001). Many of these studies use a vulnerability framework, and recently progress has been made towards more formal assessments of vulnerability (Adger *et al.*, 2004). Research has clearly indicated that vulnerability is spatially and socially differentiated, and the scale of analysis is

most important. National level assessments can result in loss of information and capturing local variability and pockets or hotspots of vulnerability are important.

Phases and criteria of indicator development

Vulnerability and resilience may thus be examined at a variety of levels or scales e.g. the individual, family group, household, community, local, national, regional or even global levels (Adger *et al.,* 2004). The development of indicators of social vulnerability to natural hazards is a relatively small area of research, particularly within applications to industrialised nations. There is still no consistent set of metrics used to assess vulnerability to environmental hazards, although there have been calls for just such an index, and Cutter *et al.* (2003) talk of the need for redirecting social indicators research. It is possible, however, to identify certain criteria to aid indicator selection. It must be remembered that indicators only provide an 'indication' of much broader and complex social concepts, and therefore good indicators must have a clear conceptual basis in order to measure what is intended. The following criteria can be used as a guide for the selection of indicators (Cutter *et al.,* 2003; Adger *et al.,* 2004; Dwyer *et al.,* 2004). Indicators should be:

- Reliable and verifiable
- Sensitive to change over time
- Simple and easily understood while reflecting complexity of concept
- Quantitative – measurable via readily understood model
- Recognisable by others
- Objective
- And, ideally, comparable within and between communities.

The work by Adger *et al.* (2004) is particularly comprehensive in identifying indicators and parameters of social and economic vulnerability to climate change hazards, and is almost directly applicable to all natural hazards. Indicators tend to focus on processes that shape variations of vulnerability in time and space, and these processes operate at different spatial scales. For example, while decreasing labour availability is a process that may manifest itself on a community level, a national level indicator may aim to capture the processes that shape the local level decrease, such as urbanisation and de-agrarianisation. Adger *et al.* (2004) distinguish between 1) output-based and 2) predictive indicators of socio-economic vulnerability which explain more about underlying causes. The number of people killed by a hazard over a time period is an example of 1), whereas parameters measuring adaptive capacity are an example of 2).

Criteria for peer review of vulnerability assessments (Downing, 2004)

- Does the assessment combine a qualitative narrative of the conditions of vulnerability with quantitative assessment and modelling?
- Has vulnerability been defined, taking account of common definitions among stakeholders to the assessment and with respect to the exposure unit, threat and consequences?
- Does the choice of indicators reflect the conceptual understanding of vulnerability, in particular the sequence of driving forces, exposures and consequences?
- Does the depiction of aggregate vulnerability reflect multiple attributes and has been validated by stakeholders to the assessment?
- Is the assessment of vulnerability linked to selection of adaptation options and strategies?

The EU Floods Directive (European Commission, 2007) requires an assessment of flood risks aiming at reducing the adverse consequences for economic activities and human health, as well as cultural and environmental values. Quantitative flood risk indicators and flood risk maps are identified as the means of responding to this Directive and each country is seeking to produce such indicators (e.g. Office of Public Works (Ireland), 2008). The Directive specifies that the maps should show the number of inhabitants affected and the type of economic activity potentially affected. Research undertaken for Ireland (Office of Public Works, 2008) assesses the flood risk indicators currently in use in the EU and recommends adoption of certain indicators in Ireland. Indicators are being developed as part of the National Flood Risk Assessment methodology, Catchment Flood Management Plan methodology and the Thames Estuary 2100 strategy in England and Wales. Some of the key indicators relating to economic and social vulnerability are listed in Appendix XII. Comparisons of economic (direct and indirect loss) and intangible (e.g. health damage) indicators used in England and Wales, Holland, the Czech Republic and different parts of Germany are tabulated by the Office of Public Works (2004). Appendix XII also includes some parameters and indicators which might be used in assessing institutional vulnerability. There are also a growing number of post-flood reviews of the functioning, or in some case the under-performance, of flood emergency response organisations.

Any flood vulnerability analysis needs information about the elements at risk, which can be specified in terms of element-at-risk indicators, exposure indicators and susceptibility indicators (Meyer and Messner, 2005 - see Figure 2), reflecting different conceptual models. In this regard natural *and* social science indicators are both of importance. From considering data from the literature, Tapsell *et al*. (2005) suggest a number of common indicators for assessing social vulnerability to flooding which could be applied across European states (Appendix XIII). These include indicators of elements at risk, exposure indicators and susceptibility and resilience indicators. The symbols indicate whether the variable may be an indicator of increased or decreased social vulnerability (+ = increases vulnerability, - = decreases vulnerability). While not fully explaining all the underlying causes of social vulnerability these variables provide an initial metric for operationalising the concept. However, evidence from recent research in Europe indicates that noone is *per se* highly vulnerable to flooding (Steinführer *et al*., 2007). There is some evidence for the vulnerability of certain social groups which were identified as vulnerable at different points in time and during different phases of a flood event.

7.1 Problems with the use of indicators

The use of taxonomies of 'vulnerable groups' such as those outlined in Appendix XII (e.g. women, children, the elderly), is not without problems (Wisner, 2005). Although there is truth that these groups may often have 'special needs' and that there is empirical support for the use of such 'check lists', the taxonomic approach fails in that it produces too many 'false positives', e.g. not *all* women are equally vulnerable. Buckle *et al*. (2000) and Brown and Damery (2002) see the use of taxonomies such as these to be a very limited view of vulnerability in that these categories have not been adequately explored and may give rise to a stereotyped and unenlightened view of risk and capacity for hazard response.

Other research has revealed that the identification of vulnerability must be balanced by that of capacity (Anderson and Woodrow, 1998). For example, although acknowledging women's tendency to vulnerability, Fothergill's reviews of the literature on gender and disaster (1996; 1998) found a number of examples (within warning communication and response) of women being generally more risk-aware, more likely to believe and act upon warnings, and more likely to relay them to others. Additionally, to have access to local community or family networks (social capital) can also counterbalance the negative effects of a lack of financial

and other resources (Fordham, 1999; Tapsell *et al.*, 1999; Cannon, 2000). Moreover, the same property type may indicate different levels of vulnerability according to the ownership status of the occupant.

Another problem is that although researchers are beginning to recognize the differential vulnerabilities of social groups, these analyses are often one-dimensional, i.e. they focus on gender *or* race/ethnicity *or* age etc. but not on the *interactions* within and between several social groups. Although indicators may not in isolation make a person vulnerable, a combination of these indicators, or the relationship between indicators, may render an individual highly vulnerable (Dwyer *et al.*, 2004). Therefore, we need to know how vulnerabilities are compounded to create the most vulnerable (Wisner, 1993). Many of the indices apply additive models to produce their vulnerability scores. However, relationships of indicators can take many interactive forms, not all of which are additive and need to be considered. Cutter *et al.* (2003) also conclude that not all indicators are necessarily equal, and the need to develop a defensible weighting scheme is important.

7.2 Sources of data

Sources of data for vulnerability indicators may be primary or secondary. Primary data, usually obtained via social surveys, can be tailored to the specific research question to be addressed. However, this approach is time-consuming and expensive in terms of organisation and analysis. Secondary source data such as the census are more cost-effective than primary data but the research is then constrained by the need to fit the conceptualisation of vulnerability around the available data (Pelling, 2006). Not all social data is nationally available in some EU member states to which vulnerability and/or resilience indices might be attached, however, member states are now requested to supply statistical data on their populations. Some countries do not hold national censuses (Germany, Sweden, Iceland). For countries where there is no census data other alternative data sources are needed. Data is normally available on 'core' topics but some data is on 'non-core' topics which include optional variables that vary depending on national priorities (University of Thessaly, 2004). Moreover, the last date of collection of national data varies. Some countries also hold additional types of registers (e.g. Denmark for income, education, social security etc.). In the case of some Eastern European states, which historically developed under different socio-economic and political systems and administrative boundaries, comparative data is not always available. It is also unclear at what level data is available. For example, in the UK data is available at the very local level of Output Areas (average population per unit of 296 – divided by 2.4 for number of households). However, this does not appear to be the case for many countries and it may not be possible to distinguish regional variations (Tapsell *et al.*, 2005).

8 Case studies

Cases of various applications of models, methodologies and indicators are tabulated in Appendix XIV. Two of these studies are outlined in more detail below. The first is an example from a developing country using a quantitative methodology, while the second is a contrasting qualitative study from a developed country.

8.1 Impacts of floods in Urban Bangladesh

This case study is the outcome of doctoral research (Islam, 1997, 2006). There are two components: (i) the development of appropriate flood damage evaluation methods for Bangladesh based upon testing the applicability of English methods, and (ii) the

conceptualisation, categorisation and measurement of the magnitude of urban impacts of different types of floods (flash flood, river flood and tidal flood) in Bangladesh. When the research was undertaken most of the flood damage appraisal methods developed and used in Bangladesh (e.g. within the Flood Action Plan) were geared to assessing crop losses. The research also sought to discover (a) how important urban flood impacts are in Bangladesh, a country which was only 23% urbanised when the study was undertaken, (b) which sectors of the economy are critically vulnerable to floods, including the impacts of agricultural flooding on the urban-industrial economy, and (c) evidence of the differential impacts of floods amongst the socio-economic occupants of Bangladesh.

The research methodology involved three reference floods (i) the 1988 river flood in Tangail town, (ii) the 1993 flash flood in Bahubal, and (iii) the 1991 tidal surge (which killed about 150,000 people) in Khatunganji (also known as Chittagong). According to construction materials, five types of housing were identified (depending upon the susceptibility of construction materials to flood damage), together with seven groups of business and five groups of industrial enterprises. Each group was sampled using post-flood inspection and interview techniques to discover the flood damages experienced, supported by data from informed and secondary sources. Sampling was arranged to cover flooding of different depths in properties so that data could be synthesised into depth-damage relationships. Depth-damage curves were constructed for the different house types for the different flood types, and the results also provide a measure of variance in damageability. The relationships between flood warning, flood perception, social variables and flood damages were also analysed, revealing that these variables are important in explaining flood damage magnitudes. The incidence of diarrhoeal disease was found to be closely correlated to flooding. Mean damage values were also derived for commercial and industrial enterprises, and the study analysed the reasons for variability: the flash flood and tidal floods were found to be much more damaging than the river flood. English flood damage evaluation principles proved generally transferable to Bangladesh but detailed methods required considerable development for the Bangladesh case.

The research gauged the 'ripple effect' (i.e. systemic vulnerability) of flooding owing to linkages in the economy. Industry and business enterprises suffered output loss equivalent to 1.6 times their monthly output, with the extent of this loss being highest in the engineering enterprises which were found to be most vulnerable (the food and agro-business enterprises were found to be least vulnerable). The impacts of flooding faded considerably with geographic and economic distance from the flood events: declining from town to region, and then to nation. The national losses were, however, permanent losses. The country as a whole was found to be capable of making up 48% of the total production loss suffered by sampled firms (but this reduced to 35% for the region and 20% for the town). National losses were found to be highest in the cotton and textile and lowest in the food and agro-business sectors. Generally the research reveals that the urban-industrial sector of the Bangladesh economy is more vulnerable to floods than the rural-agricultural sector.

This micro-level analysis is complemented by a macro-level analysis in this case study. The macro analysis is based upon national level time series data collected from secondary sources, and is undertaken for broad sectors of the economy, agriculture and industry. In this analysis flows and stocks in economic variables, such as employment and income, input and output, comprise a category of economic linkages, and spatial linkages are the ones between the enclave region (i.e. the urban area) and the hinterland (i.e. rural area) in a national economy. Initial linkage effects of floods cause a decrease of products a) due to flood damage to physical facilities (e.g. buildings or machinery) and b) due to damage to stock (e.g. finished goods). A second round of linkages relates to recovery which increases expenditures and purchases, which have positive multiplier effects. All of these linkages are

modelled in a complex inter-sectoral model of economic linkages and flood impacts. The analysis reveals that, although floods severely affect crops such as rice, the adverse impact of flooding on total crop production in Bangladesh is not as severe as often pronounced. For industries the analysis demonstrates that, at least in the short run, flooding does not have a great influence on production (just a 5% drop), and this is related to industrial under-capacity characteristics (this dampens flood impacts). However, the poorer and smaller business units appear to be more vulnerable to flooding, as are the poorer occupants of the residential sector.

8.2 A study of the health impacts of flooding in England

Research was carried out by the Flood Hazard Research Centre (FHRC) at Middlesex University between 1998 and 2002 (Tapsell *et al.*, 1999; Tapsell and Tunstall, 2001; Tapsell *et al.*, 2003). The research, which was a small qualitative study, examined the health impacts of flooding in the Cherwell catchment in Banbury and Kidlington, Oxfordshire, on Easter 1998. In these floods there was no flood warning and significant damage to houses and their contents. Research took the form of a series of focus groups with flooded residents, the first being six months after the flood, followed by successive groups one year and four years later. The same people took part in the focus groups in all three studies. The research was aimed primarily at improving understanding of the health effects of flooding and thus people's vulnerability to these impacts. The objective of the initial research was to investigate the extent and types of health impacts of flooding resulting from the floods, and to determine, where possible, changes in health as a result of being flooded. Those chosen for focus groups were drawn from groups in the community considered to be potentially the most vulnerable to flooding, including the elderly and women from an Asian ethnic minority. Some quantitative data was also collected from participants in the 2002 study through the use of a self-report Health Checklist Questionnaire designed by FHRC, and the General Health Questionnaire (GHQ-12), a commonly used survey instrument.

The initial study identified pre-existing physical health problems experienced by the respondents, and the additional perceived health effects resulting from flooding. The research also highlighted the disruption households experience following flooding which creates stress and anxiety which appears to underlie additional health problems. Significant anxiety was reported owing to a reported loss of confidence in authorities, and an underlying loss of self-identity and security in the home. Women were found to shoulder extra responsibilities for their family's health care, for dealing with insurers and builders and were generally found to be impacted heavily by the flooding aftermath. Members of the ethnic minority group appeared to be particularly vulnerable to flood disruption due to a combination of factors related to low incomes, less insurance, and feelings of isolation due to lacking language abilities and differing cultural practices.

The second study in 1999 revealed that most of the perceived physical health effects of flooding had disappeared for all but a few people. However, stress and anxiety attributed to the flood continued in many people. Respondents reported no change in their feelings of lack of confidence in the authorities, even though they were aware of various positive actions being taken. In 2002, for the majority of respondents the perceived physical effects of flooding were no longer significant. However, results from the use of the GHQ-12 re-affirmed the psychological health effects reported in the 1998 and 1999 studies, with all but four respondents reporting psychological after-effects of flooding (increased anxiety, stress and sleeping problems were the most commonly reported). These effects were more prevalent in Banbury than Kidlington, and the Asian community in Banbury experienced more effects than others. The factors perceived to be partly responsible for changed health status include anxiety during heavy or prolonged rainfall, the fear of future flooding, anxiety

associated with increased frequency of flood warnings since 1998, concerns over recent surface water flooding, and concerns of flood insurance and the saleability of properties.

This study is particularly useful in enhancing understanding of the health effects of floods and in uncovering perceived mental and physical health effects, impacts that have been largely unrecognised in any detail and under-estimated in the past. The study is unique (at least in the UK) in assessing the extent to which health impacts of floods persist. The research results help to draw out the full costs of flooding which can be entered into decisions about investment in flood risk management projects.

9 Integrated vulnerability and resiliency assessment methodologies

The inclusion of socio-economic vulnerability analyses within integrated flood vulnerability analyses is becoming more central, yet to date few such analyses appear to have been carried out. Although flood vulnerability is still often associated with biophysical parameters there is growing recognition of the importance of social and economic understandings of vulnerability and the parameters and indicators which can provide quantitative and qualitative descriptors. Moreover, as we concluded in Section 3, the move from vulnerability to resiliency is novel but becoming more and more accepted. However, empirical case studies of resilience studies are rare.

Some examples of vulnerability studies are given:

The EC-funded FLOODsite project aims to deliver an integrated European methodology for flood risk analysis and management for rivers, estuaries and the coast (www.floodsite.net). Many individual methodologies and models have been developed within the project, including those on assessing risk to life, social, economic and environmental vulnerability.

The UNCHS (Habitat) Disaster Management Programme (2001) sets out an integrated methodology for assessing vulnerability to floods for utilisation countries such as China, Bangladesh and Vietnam. The methodology includes assessment of social, economic and environmental vulnerability to floods.

The Environment Agency (UK) is currently developing the Thames Estuary 2100 strategy which is likely to be the most comprehensive and integrated flood management strategy ever developed in the UK. The Thames estuary includes the Thames floodplain through London. This strategy involves many studies and analyses including ones which seek to integrate a wide range of very detailed data on flood exposure, and social and economic vulnerability throughout the Thames estuary area (e.g. Environment Agency, 2007).

10 Conclusions

A review of publications on **definitions and approaches to analyse vulnerability and vulnerability of socio-economic systems** in particular, reveals once again that one can speak of a "Babylonian confusion" (Thywissen, 2006). Definitions vary between disciplines, hazard types and analytical contexts as illustrated by the outcome of earlier reviews some of which are included in the appendices of this paper. Neither multidisciplinary literature on disaster nor risk management has developed a widely accepted definition of vulnerability. As an alternative, often taxonomies of vulnerability are proposed, which are, however, less useful to arrive at a comprehensive and integrated understanding of vulnerability.

The lack of consensus makes it almost impossible and even undesirable to conclude with one final vulnerability definition. On the other hand the adoption of a relativistic approach in the definition of vulnerability would not be very constructive for the further development of methodologies to assess vulnerability. In addition, a kind of evolution of the concept could be sketched and links with other related concepts be identified.

- A differentiation can be made between biophysical and social vulnerability, where the first is directly related to the exposure to a hazard, whereas the latter focuses more on the internal state of a system.
- The stage of exclusive focus on the physical environment and ignorance or over-simplification of the socio-economic environment has largely come to an end.
- In this paper we arrive at a definition that largely follows the majority of definitions in the social, economic and institutional literature that conceive vulnerability as "*a function of susceptibility to loss and the capacity to recover*".
- The term vulnerability has evolved from a rather negative concept to a concept that relates directly to more positive notions like resilience and adaptive capacity.
- The traditional interpretation of vulnerability as the reciprocal of resilience is more and more challenged and replaced by notions seeing resilience as an integral component of vulnerability or considering vulnerability as the static and resilience as the dynamic propensity of a system.
- Psychological elements like risk perception, awareness and personal and collective coping mechanisms are crucial elements to be considered in any vulnerability assessment.
- The intrinsic relationship of vulnerability with terms such as resilience and adaptive capacity has emphasized more and more the need for the consideration of dynamic elements, including elements of learning, in the application of the vulnerability concept.

Regarding the **assessment of the vulnerability of socio-economic systems** a clear distinction should be made between economic vulnerability and social vulnerability assessment as two related but distinct fields of analysis.

The methods of **economic vulnerability assessment** are closely linked with damage assessment methodologies and therefore experiences in the field of the latter are relevant for vulnerability assessment. Methodological issues that are relevant for economic assessment are: the private versus the public and societal perspective; the scale and level of analysis; stock versus flow estimation; estimation of direct and indirect damage; and the valuation of tangible and intangible losses. Although economic assessment methodologies still differ in specific elements between thematic (hazard-wise) and geographical areas, one

could observe presently more or less standardized approaches to measure damages. Finally one could observe a transition from economic and purely financial damage loss assessment to the assessment of the vulnerability of economic systems.

Social vulnerability assessment related to hazards often focuses on the understanding of the social environment that transforms a natural hazard into a disaster, where the cause is often seen as mainly social and the consequences differ between social groups.

Methodologies to assess social vulnerability are not necessarily specific for vulnerability assessment and include typical social science approaches, like qualitative and participatory methodologies. Key in these approaches is the recognition of the specific contexts in which the vulnerability is being assessed. Risk perception and local coping mechanisms are some examples of specific elements that are addressed as part of social vulnerability assessment. Integrating the outputs of social vulnerability assessment with the outcome of more physical assessment remains difficult.

In addition, a number of relevant indicator initiatives have been identified that intend to measure vulnerability in its different dimensions. Approaches vary from deductive to more inductive approaches. Whatever the approach, crucial remains the application of a systematic and transparent approach in the development of indicators, including a good conceptual understanding of vulnerability in the specific context.

Finally, the availability of up-to-date data remains crucial for any relevant assessment of vulnerability.

Despite the absence of an unequivocal definition of vulnerability, we can conclude that a number of perspectives and methodological approaches from the social and economic sciences provide indispensable contributions to vulnerability assessment in an integrated manner.

Dilemmas that remain to be addressed to possibly arrive at a successful integrated assessment of vulnerability include:

- Should a more conceptual deductive approach or a more pragmatic inductive approach be followed?
- To which extent a more mechanistic way of thinking or a more cognitive approach should be adopted in vulnerability assessment?
- Should the output of any vulnerability assessment become an integral part of the risk equation or could less formalised approached be tolerated?

References

Adger, N.W. (2000), *Social and ecological resilience: are they related?,* Progress in Human Geography, 24 (3): 347-364.

Adger, N. W., Kelly, P. M., Ninh, N. H., (eds.) (2001), *Living with Environmental Change: Social Resilience, Adaptation and Vulnerability in Vietnam*, London: Routledge.

Adger, N. W. (1999), *Social Vulnerability to Climate Change and Extremes in Coastal Vietnam,* World Development, 27(2): 249-269.

Adger, N. W. (2006), *Vulnerability,* Global Environmental Change, 16(3): 268-281.

Adger, N. W., Brooks, N., Bentham, G., Agnew, M., Eriksen, S. (2004), *New indicators of vulnerability and adaptive capacity,* Technical Report. Tyndall Centre for Climate Change Research, Norwich.

Adger, N., Kelly, M., Bentham, G. (2001), *New Indicators of Vulnerability and Adaptive Capacity*. Paper presented at the International Workshop on Vulnerability and Global Environmental Change, Lila Nyagatan. Stockholm, 17-19 May 2001.

ADRC (2005), Total disaster risk management - Good practices. <http://www.adrc.or.jp/publications/TDRM2005/TDRM_Good_Practices/PDF/Chapter1_1.2.pdf>, last accessed 24/01/2006.

Ahern, M., Kovats, S. (2006), *The Health Impacts of Floods*, In: Few, R., Matties, F. (Eds), "Flood Hazards and Health: Responding to Present and Future Risks" (28-53), London: Earthscan.

Ahmed, A. K. (2006), *Concepts and Practices of "Resilience": A Compilation from Various Secondary Sources*, A Working Paper prepared for Coastal Community Resilience (CCR) Program, Bangkok: US Indian Ocean Tsunami Warning System Program.

Alexander, D. (1993), *Natural Disasters*, London: UCL Press.

Alexander, D. (2000), *Confronting Catastrophe - New Perspectives on Natural Disasters*. Oxford: Oxford University Press.

Alkire, S. (2003), *A Conceptual Framework for Human Security*, Centre for Research on Inequality, Human Security and Ethnicity (CRISE), Working Paper No. 2, Oxford: University of Oxford.

Allen, A.G., Baxter, P.J., Ottley, C.J. (2000), *Gas and particle emissions from Soufrière Hills Volcano, Montserrat, West Indies: characterization and health hazard assessment*, Bulletin of Volcanology, 62(1): 8-19.

Alwang, J., Siegel, P.B., Jorgensen, S. L. (2001), *Vulnerability: a view from different disciplines*. Social Protection Discussion Paper Series, No. 0115, World Bank. <http//:www.worldbank.org/sp>, last accessed 24/01/2006.

Anderson, M.B., Woodrow, P.J. (1998), *Rising from the ashes: development strategies in times of disaster*, Boulder, CO: Westview Press

Antoniou, A.A., Harkiolakis, N., Halkias, D., Christopoulus, A. (2005), *The need for psychological assessment of it personnel involved with organizational disaster recovery and business continuity plans*. Available at http://www.aueb.gr/pympe/hercma/proceedings2005/H05-FULL-PAPERS-1/ANTONIOU-HALKIOLAKIS-HALKIAS-CHRISTOPOULOS-1.pdf. Amerio, Psicologia di comunità, Il Mulino, Bologna.

Atkins, J., Mazzi, S., Easter, C. (2000), *A Commonwealth Vulnerability Index for Developing Countries: The Position of Small States*, London: Commonwealth Secretariat.

Bankoff, G. (2001), *Rendering the World Unsafe: 'Vulnerability' as Western Discourse*, Disasters, 25'(1): 19-35.

Bankoff, G., Frerks, G., Hilhorst, D. (2004), *Mapping vulnerability: Disasters, development and people*. London: Earthscan.

Barberi, F., Davis, M. S., Isaia, R., Nave, R., Ricci, T. (2008), *Volcanic risk perception in the Vesuvius population,* Journal of Volcanology and Geothermal Research, 172(3-4): 244-258.

Barry, J.M. (1997), *Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America*, New York: Touchstone Press.

Bar-Ziv, J., Goldberg, G.M. (1974), *Simple siliceous pneumoconiosis in Negev Bedouins*, Archives of Environmental Health, 29(3): 121-126.

Bavarian State Ministry of the Environment River Basin Agenda for Alpine Space (2006), *Model and examples for sustainable development of the Alpine river basins*, Short Report, Munich.

Baxter, P.J. (1999), *Impacts of Eruptions on Human Health*, In: Sigutdson, H. (Ed.), "Encyclopedia of Volcanoes" (1035-1043). San Diego: Academic Press.

Baxter, P.J., Bonadonna, C., Dupree, R., Hards, V.L., Kohn, S.C., Murphy, M.D., Nichols, A., Nicholson, R.A., Norton, G., Searl, A., Sparks, R.S.J., Vickers B.P. (1999), *Cristobalite in volcanic ash of the Soufriere Hills Volcano, Montserrat, British West Indies,* Science, 283(5405): 1142-1145.

Baxter, P.J., Ing, R., Falk, H., Plikaytis, B. (1983), *Mount St-Helens Eruptions - the Acute Respiratory Effects of Volcanic Ash in a North-American Community*, Archives of Environmental Health, 38(3): 138-143.

Beaudoin, C.E. (2007), *New Social Capital and Health in the Context of Katrina*, Journal of Health Care for the Poor and Underserved, 18: 418-430.

Beck, A.T. (1976), *Cognitive therapy and the emotional disorders*, New York: International Universities Press.

Beck, A.T., Emergy, G., Greenberg, R.L. (1985), *Anxiety disorders and phobias*, New York: Basic Books.

Beck, R.J., Franke, D.I. (1996), *Rehabilitation of victims of natural disasters*, Journal of Rehabilitation, 62(4): 28-32.

Bennett, G. (1970), *Bristol floods 1968: controlled survey of effects of health of local community disaster*, British Medical Journal; August 21: 454-458.

Benson, C., Clay, E.J. (2004), *Understanding the Economic and Financial Impacts of Natural Disasters*, Washington DC: World Bank.

Birch, E.L., Wachter, S.M. (Eds.) (2006), *Rebuilding Urban Places After Disasters: Lesson from Hurricane Katrina*, Pennsylvania: University of Pennsylvania Press.

Birkmann, J. (2006), *Measuring vulnerability to natural hazards - Towards disaster resilient societies*, United Nations University Press.

Birkmann, J. (2007), *Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications*, Environmental Hazards, 7(1): 20-31.

Birkmann, J., Wisner, B. (2006), *Measuring the un-measurable, The challenge of vulnerability*, Bonn: UNU-EHS. Bonn

Blaikie, P., Cannon, T., Davis, I., Wisner, B. (1994), *At Risk: Natural Hazards, People's Vulnerability, and Disasters*, New York: Routledge.

Bolin, R., Stanford, L. (1998), *The Northridge Earthquake: Vulnerability and Disaster*, London: Routledge.

Bočkarjova, M. (2007), *Major disasters in modern economies: An input-output based approach at modelling embalances and disproportions*, Enschede: Gildeprint BV.

Bočkarjova, M., Steenge, A.E., van der Veen, A. (2004), *On Direct Estimation of Inital Damage In the Case of a Major Catarstrophe: Derivation of the "Basic Equation",* Disaster Prevention and Management: An International Journal, 13(4): 330-337.

Bočkarjova, M., Steenge, A.E., van der Veen, A. (2007), *Flooding and consequent structural economic effect, A methodology,* In: Begum, S., Stive, M.J.F., Hall, J.W. (Eds.), *"Flood Risk Management in Europe Innovation in Policy and Practice"* (131-154), New York: Springer.

Bosher L. (2008), *Hazards and the Built Environment: Attaining built-in resilience*, London: Routledge.

Briguglio L., Galea, W. (undated) *Updating and Augmenting the Economic Vulnerability Index*, Occasional Paper, Malta: Islands and Small States Institute, University of Malta (www. home.um.edu.mt/islands/eviar_briguglio_galea_ver4.pdf)

Briguglio, L. (1995), *Small island developing states and their economic vulnerabilities*, World Development, 23(9): 1615-1632.

Briguglio, L., Cordina, G., Farrugia, N., Vella, S. (2004), *Economic vulnerability and resilience concepts and measurements*, International Workshop on Vulnerability of Small States, University of Malta

Briguglio, L., Cordina, G., Farrugia, N, Vella, S. (2008), *Economic Vulnerability and Resilience. Concepts and Measurements*, UNU-WIDER

Brown, C., Graham, W. (1988), *Assessing the threat to life from dam failure,* Water Resources Bulletin, 24(6): 1303–1309.

Brown, J.D., Damery, S.L. (2002), *Managing flood risk in the UK: towards an integration of social and technical perspectives,* Transactions of the Institute of British Geographers, 27(4): 412-426.

Buckle, P. (1998), *Re-defining community and vulnerability in the context of emergency management*, Australian Journal of Emergency Management.

Buckle, P., Marsh, G., Smale, S. (2000), *New approaches to assessing vulnerability and resilience*, Australian Journal of Emergency Management, Winter: 8-14.

Buckle, P., Marsh, G., Smale, S. (2001), *Assessing Resilience and Vulnerability, Principles, Strategies and Actions: Guidelines,* Emergency Management Australia Project.

Burton I., Kates, R.W., White, G.F. (1978). *The Environment as Hazard*, New York: Oxford University Press.

Cannon, T. (2000). *Vulnerability analysis and disasters,* In: Parker, D.J. (Ed.), "Floods" (45-55), London: Routledge.

Cannon, T., Twigg, J., Rowell, J. (2002), *Social vulnerability, sustainable livelihoods and disasters*.

<http://www.benfieldhrc.org/SiteRoot/disaster_studies/projects/soc_vuln_sust_live.pdf>, last accessed 24/01/2006.

Cardona, O.D. (2003), *Indicators for Disaster Risk Management*. First Expert Meeting on Disaster Risk Conceptualization and Indicator Modelling, Manizales, March 2003. < http://tinyurl.com/of79h this link re-direct to a PDF file>, last accessed 24/01/2006.

Carlino, S., Somma, R., Mayberry, G.C. (2008), *Volcanic risk perception of young people in the urban areas of Vesuvius: Comparisons with other volcanic areas and implications for emergency management*, Journal of Volcanology and Geothermal Research, 172(3-4): 229-243.

Carpenter, S., Walker, B., Anderies, J.M., Abel, N. (2001*), From metaphor to measurement: Resilience of what to what?*, Ecosystems, 4(8): 765-781.

Chambers, R. (1983), *Rural Development: Putting the Last First,* London: Longman.

Chambers, R. (1989), *Editorial Introduction: Vulnerability, Coping, and Policy*, IDS Bulletin, 20(2): 1-7.

Chan, N.W. (1995), *A Contextual Analysis of Flood Hazard Management in Peninsular Malaysia*, Unpublished PhD thesis, Middlesex University, London

Changnon, S.A. (Ed.) (1996), *The Great Flood of 1993: Causes, Impacts and Responses*, Boulder, CO: Westview Press.

Cherveriat, C. (2000), *Natural disasters in Latin America and the Caribbean: An overview of risk*, Inter-American Development Bank, Research Department, Working Paper No 434

Chester, D. K., Duncan, A.M., Dibber, C.J.L. (2008), *The importance of religion in shaping volcanic risk perception in Italy, with special reference to Vesuvius and Etna*, Journal of Volcanology and Geothermal Research, 172(3-4): 216-228.

Climate changes Spatial Planning Programme (2008) www.klimaatvoorruimte.nl - http://climatechangesspatialplanning.climateresearchnetherlands.nl/nl/25222734-Home.html last accessed 24/08/2009

Cochrane, H. (2004), *Economic loss: myth and measurement*, Disaster Prevention and Management: An International Journal, 13: 290-296.

Cole, S. (1994), *A Community Accounting Matrix for Buffalo's Eastside Neighborhood*, Economic Development Quarterly, 8(2): 107-126.

Cole, S. (1995), *Lifelines and Livelihood: A Social Accounting Matrix Approach to Calamity Preparedness*, Journal of Contingencies and Crisis Management, 3(4): 228-246.

Cole, S. (2004), *Performance and protection in an adaptive transaction model*, Disaster Prevention and Management: An International Journal, 13: 280-289.

Correira,F., M. Santos, R. Rodrigues (1987), *Engineering risk in regional drought studies*, In: Duckstein & Plate (Eds.), "Engineering Reliability and Risk in Water Resources". Dordrecht: Martinus Nijhoff Publishers: 61-86

Cronin, S.J. and Sharp, D.S. (2002) *Environmental impacts on health from continuous volcanic activity at Yasur (Tanna) and Ambrym, Vanuatu*, International Journal of Environmental Health Research 12(2): 109-123

Cronin, S.J., Neall, V.E., Lecointre J.A., Hedley M.J., Loganathan P. (2003), *Environmental hazards of fluoride in volcanic ash: a case study from Ruapehu volcano, New Zealand*, Journal of Volcanology and Geothermal Research, 121(3-4): 271-291.

Csikszentmihalyi, M., Rochberg-Halton, E. (1981), *The Meaning of Things: Domestic symbols and the self*, Cambridge: Cambridge University Press.

Cutter, S.L. (1993), *Living With Risk*, Edward Arnold: London.

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

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*, Annals of the Association of American Geographers, 90(4): 713 – 737.

Cutter, S.L., Boruff, B. et al. (2001), *Indicators of Social Vulnerability to Hazards*, Unpublished paper. Columbia, S.C.: University of South Carolina, Hazards Research Lab.

Cutter, S.L. (2003), *The vulnerability of science and the science of vulnerability*, Annals of the Association of American Geographers, 93(1): 1-12.

Cutter, S.L., Boruff, B., Shirley, W.L. (2003), *Social Vulnerability to Environmental Hazards*, Social Science Quarterly, 84(2): 242-261.

De Marchi, B., Scolobig A., Delli Zotti G., Del Zotto M. (2007), *Risk construction and social vulnerability in an Italian Alpine Region*, FLOODsite Report No. T11-2006-08, ISIG, Gorizia

Defra/Welsh Assembly/Environment Agency, Catchment Flood Management Plans, Defra: London, 2004.

Department for Communities and Local Government (2007), Improving the flood performance of new buildings, *Flood resilient construction*, London: DCLG.

Department for the Environment Food and Rural Affairs/Environment Agency (DEFRA/EA) (2007), *Flood resistance and resilience solutions: and R&D scoping study*, R&D Technical Report, by Bowker, P, London: DEFRA/EA.

Department of Human Services (2000), Assessing resilience and vulnerability in the context of emergencies: Guidelines. Victorian Government Publishing Service

Dopheide, E., Martinzez, J. (2004), *Indicators - Planning and Management Tools*. Enschede: Special Lecture Notes Series, ITC. unpublished.

Dominey-Howes, D., Minos-Minopoulos, D. (2004), *Perceptions of hazard and risk on Santorini*, Journal of Volcanology and Geothermal Research, 137(4): 285-310.

Downing, T. (2004), *What have we learned regarding Vulnerability Science?*, Proceedings Science in Support of Climate Change Adaptation, a side event held on 7 December 2004 at the 10th Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, pp. 18-21; http://www.aiaccproject.org/whats_new/Science_and_Adaptation.pdf.

Dwyer, A., Zoppou, C., Nielsen, O., Day, S., Roberts, S. (2004), *Quantifying Social Vulnerability: A methodology for identifying those at risk to natural hazards,* Canberra: Australian Government/Geoscience Australia.

ECLAC, Economic Commission for Latin America and the Caribbean (2003), *Handbook for Estimating the Socio-economic and Environmental Effects of Disasters,* Santiago, Chile: ECLAC and International Bank for Reconstruction and Development (The World Bank).

Emergency Capacity Building Project
http://www.ecbproject.org/publications/ECB3/Leaving_Disasters_Behind_Chapter_2_Key_Concepts.pdf last accessed 24/08/2009

Environment Agency Thames Estuary (2007), *Flood Vulnerability Baseline Assessment, Phase 3 Studies* – Work Element 6.1, TE2100, London: Environment Agency.

European Commission (2007), *Assessment and management of flood* risks – the Floods Directive, Directive 2007/60/EC, Brussels: European Parliament and Council.

Federal Emergency Management Agency (2009), www.training.fema.gov/EMIWeb/EMICourses/E464CM/01 Unit 1.pdf last accessed 24/08/2009

Feldbrügge, T., von Braun, J. (2002), *Is the World becoming a more risky place? – Trends in disasters and vulnerability to them*. ZEF – Discussion Papers On Development Policy No. 46, Center for Development Research, Bonn, May 2002.

Few, R. (2007), *Health and climate hazards: Framing social research on vulnerability, response and adaptation*, Global Environmental Change, 17: 281-295.

Few, R., Matties, F. (Eds.) (2006), *Flood Hazards and Health: Responding to the Risks of Climate Change*, London: Earthscan.

FEWSNET (2000), *Annual Performance and Monitoring Report for the Year 2000, Famine Early Warning System Network FEWS NET*, Washington DC: Chemonics International Inc..

Fişek, G.O. Yeniçeri, N. Müderrisoglu, S., Özkarar, G. (2007), *Risk perception and attitudes towards mitigation*, IIASA-DPRI Meeting. Integrated Disaster Risk management: Megacity Vulnerability and Resilience. Laxenburg, Austria, 2002. Available at http://www.iiasa.ac.at/Research/RMS/dpri2002/Papers/fisek.pdf.

FIVIMS (2000*), Report on the Geneva meeting on Vulnerability: Fifth meeting of the sub-group on indicators, assessment and mapping,* Geneva 10-11 July 2000. Food and Insecurity and Vulnerability Information and Mapping Systems FIVIMS, Rome, 2000.

FLOODsite (2007), *Integrated Flood Risk Analysis and Management Methodologies*, from http://www.floodsite.net/default.htm.

Folke, C. (2006), *Resilience: The emergence of a perspective for social-ecological systems analyses*, Global Environmental Change, 16(3): 253-267.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Hollign, C.S., Walker, B. (2002), *Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations*, Scientific Background Paper on Resilience for the process of The World Summit on Sustainable Development on behalf of The Environmental Advisory Council to the Swedish Government.

Fordham, M. (1999), *The intersection of gender and social class in disaster: balancing resilience and vulnerability*, International Journal of Mass Emergencies and Disasters, 17(1): 15-37.

Fothergill, A. (1996), *Gender, Risk and Disaster*, International Journal of Mass Emergencies and Disasters, 14(1): 33-56.

Fothergill, A. (1998), *The neglect of gender in disaster work,* In: Enarson, E., Morrow, B.H. (Eds.), "Through Women's Eyes: The Gendered Terrain of Disaster", Westport, CT: Praeger: 11-26.

Franklin, J., Wiese, W., Meredith, J., Lalikos, J., Dolezal, J., Brigham, D., Wooden, W., Ohl, C. (2000), *Hurricane Floyd: Response of the Pitt County medical community*, North Carolina Medical Journal, 61: 384-389.

Freeman, P., Martin, L., Mechler, R., Warner, K. (2004), *A methodology for incorporating natural catastrophes into macroeconomic projections*, Disaster Prevention and Management: An International Journal, 13(4): 337-342.

Friesecke F. (2004), *Precautionary and Sustainable Flood Protection in Germany – Strategies and Instruments of Spatial Planning*, Paper presented at 3rd FIG Regional Conference, Jakarta, Indonesia, October 3-7, 2004.

Fullilove, M.T. (1996), *Psychiatric implications of displacement: Contributions from the psychology of place*, American Journal of Psychiatry, 153(12): 1516-1523.

Gallopín, G.C. (2006), *Linkages between vulnerability, resilience, and adaptive capacity*, Global Environmental Change, 16(3): 293-303.

Garatwa, W., Bollin, C. (2002), *Disaster Risk Managment - A working concept*. Eschborn: Deutsche Gesellschaft fürTechnische Zusammenarbeit (GTZ), <http://www2.gtz.de/dokumente/bib/02-5001.pdf>, last accessed 24/01/2006.

Gist, R., Lubin, B. (1989), *Psychological Aspects of Disasters*, New York: Wiley.

Goldberg, D.P., Hillier, V.F. (1979), *A scaled version of the General Health Questionnaire*, Psychological Medicine, 9: 139-145.

Graham, W.J. (1999), *A procedure for estimating loss of life caused by dam failure,* Dam safety office report DSO-99-6.

Granger, K., Jones, T., Leiba, M., Scott, G. (1999), *Community Risk in Cairns: a Provisional Multi-Hazard Risk Assessment*, AGSO Cities Project Report Number 1, Canberra: Australian Geological Survey Organisation.

Green, C.H. (1993), *The Human Aspects of Flooding,* Enfield*:* Flood Hazard Research Centre, Middlesex University.

Green, C. (2004), *The evaluation of vulnerability to flooding*, Disaster Prevention and Management: An International Journal, 13(4): 323 – 329.

Green C.H., Van der Veen, A., Wiersta, E., Penning-Rowsell, E.C. (1994), *Vulnerability Refined: Analysing Full Flood Impacts*, In: Penning-Rowsell E.C., M. Fordham (Eds.) "Floods Across Europe", London: Middlesex University Press: 32-68.

Green, R., Bates, L.K., Smyth, A. (2007) *Impediments to recovery in New Orleans' upper and Lower Ninth Ward: one year after Hurricane Katrina,* Disasters, 31(4): 311-335.

Greene, M., Perry, R.W., Lindell, M. (1981) *The March 1980 eruptions of Mount St Helens: Citizen perceptions of volcano hazard*, Disasters, 5: 49-66.

Gregg, C.E., Houghton, B.F., Johnston, D. M., Paton, D., Swanson, D. A. (2004a), *The perception of volcanic risk in Kona communities from Mauna Loa and Hualalai volcanoes, Hawaii*, Journal of Volcanology and Geothermal Research, 130: 179-196.

Gregg, C.E., Houghton, B.F., Paton, D., Swanson, D.A:, Johnston, D.M. (2004b), *Community preparedness for lava flows from Mauna Loa and Hualalai volcanoes, Kona, Hawaii*, Bulletin of Volcanology, 66: 531-540.

Gregg, C.E., Houghton, B.F., Paton, D., Swanson, D. A., Lachman, R., Bonk, W. J. (2008), *Hawaiian cultural influences on support for lava flow hazard mitigation measures*

during the January 1960 eruption of Kīlauea volcano, Kapoho, Hawai'I, Journal of Volcanology and Geothermal Research, 172: 300-307.

Gross, M. (2007), *The Unknown in Process: Dynamic Connections of Ignorance, Non-Knowledge and Related Concepts,* Current Sociology, 55: 742-759.

Hajat, S., Ebi, K.L., Kovats, S., Menne, B., Edwards, S., Haines, A. (2005), *The Human Health Consequences of Flooding in Europe: a Review*. In: Kirch, W., Menne, B., Bertollini, R. (Eds.), "Extreme Weather Events and Public Health Responses." Published on behalf of World Health Organization Regional Office for Europe. Berlin: Springer-Verlag: 185-196.

Handmer, J., Wisner, B. (1999), *Conference Report: Hazards, Globalization and Sustainability*, Development in Practice9(3): pp. 342-346.

Handmer, J. (2002), *We are all vulnerable*, <http://online.northumbria.ac.uk/geography_research/radix/resources/vulmeeting-pbmelbourne11.doc>, last accessed 24/01/2006.

Hansell, A.L., Horwell, C.J., Oppenheimer, C. (2006), *The health hazards of volcanoes and geothermal areas*, Occupational and Environmental Medicine, 63(2): 149-156.

Haynes, K., Barclay, J., Pidgeon, N. (2007), *Volcanic hazard communication using maps: an evaluation of their effectiveness*, Bulletin of Volcanology, 70(2): 123-138.

Haynes, K., Barclay, J., Pidgeon, N. (2008), *Whose reality counts? Factors affecting the perception of volcanic risk*, Journal of Volcanology and Geothermal Research, 172: 259-272.

Heliker, C. (1990), *Volcanic and Seismic Hazards on the Island of Hawaii*, U.S. Geological Survey General Interest Publication 48.

Hewitt, K. (1997), *Regions of Risk: A Geographical Introduction to Disasters*, London: Longman.

Hilhorst, D. (2004), *Complexity and Diversity: Unlocking Social Domains of Disaster Response*, In: Bankoff, G., Frerks, G., Hillhorst, D. (Eds.), "Mapping Vulnerability – Disasters, Development and People", London: Earthscan.

Hobbs, M. (1995), *A district framework for managing psychosocial aspects of disaster*, Advances in Psychiatric Treatment, 1: 176-183.

Holling, C.S. (1973), *Resilience and stability of ecological systems*, Annual Review of Ecology and Systematics, 4: 1-23.

Horwell, C.J. (2007), *Grain-size analysis of volcanic ash for the rapid assessment of respiratory health hazard*, Journal of Environmental Monitoring, 9(10): 1107-1115.

Horwell, C.J., Baxter, P.J. (2006), *The respiratory health hazards of volcanic ash: a review for volcanic risk mitigation*, Bulletin of Volcanology, 69(1): 1-24.

Horwell, C.J., Fenoglio, I., Ragnarsdottira, K.V., Steve, R., Sparksa J., Fubini, B. (2003), *Surface reactivity of volcanic ash from the eruption of Soufriere Hills volcano, Montserrat, West Indies with implications for health hazards*, Environmental Research, 93(2): 202-215.

Houts, P.S., Lindell, M.K., Hu T.W., Cleary, P.D., Tokuhata, G., Flynn, C.B. (1984), *The protective action decision model applied to evacuation during the Three Mile Island crisis*, International Journal of Mass Emergencies and Disasters, 2: 27-39.

HR Wallingford (2003) *Flood Risks to People Phase 1.* Final Report Prepared for Defra/Environment Agency Flood and Coastal Defence R&D Programme.

HR Wallingford (2005) *The Flood Risk to People Methodology. Flood Risks to People*, Phase 2 R&D Output FD2321/TR1. Defra/ Environment Agency Flood and Coastal Defence R&D Programme.

Hunt, J. (Ed.) (2005), *London's Environment: Prospects for a Sustainable World City*, London: Imperial College Press.

IFRC (International Federation of Red Cross and Red Crescent Societies) (1999), *Vulnerability and capacity assessment*. An International Federation Guide. Switzerland: IFRC.

International Association for Impact Assessment (2003), *Social Impact Assessment: International Principles,* Special Publication Series No. 2, May 2003. Fargo, ND: IAIA.

IPCC (International Pannel on Climate Change) (2001), *Climate Change 2001*. Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Integovernmental Panel on Climate Change (R.T. Watson and the Core Writing Team, Eds.). Cambridge: Cambridge University Press.

Integrated Regional Information Networks (IRIN) (2006), *Disaster Reduction and the human cost of disaster* - IRIN Web Special. <http://www.irinnews.org/webspecials/DR/Definitions.asp>, last accessed 24/01/2006

Islam, K.M.N. (1997), *The Impacts of Flooding and Methods of Assessment in Urban Areas of Bangladesh*, Unpublished PhD thesis, Flood Hazard Research Centre, London: Middlesex University.

Islam, K.M.N. (2005), *Flood Loss Potentials in Non-agricultural Sectors: Assessment Methods and Standard Loss Database for Bangladesh*, Dhaka: Palok Publishers.

Islam, K.M.N. (2006), *Impacts of Flood in Bangladesh: Micro and Macro Level Analysis*, Dhaka: AH Development Publishing House & Community Development Library.

Jallow, B.P., Barrow, M.K.A., Leatherman, S.P. (1996), *Vulnerability of the coastal zone of The Gambia to sea level rise and development of response strategies and adaptation options*, Climate Research, 6: 165-177.

Janssen, M. A., Ostrom, E. (2006a), *Resilience, vulnerability, and adaptation: A cross-cutting theme of the International Human Dimensions Programme on Global Environmental Change*, Global Environmental Change, 16(3): 237-239.

Janssen, M. A., Schoon, M.L., Ke, W., Borner, K. (2006b), *Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change*, Global Environmental Change ,16(3): 240-252.

Johnson, C.L, Penning-Rowsell, E.C., Parker, D.J. (2007), *Natural and imposed injustices: The challenges in implementing 'fair' flood risk management policy in England*, Geographical Journal, 173 (4): 374-390.

Johnston, D.M., Houghton, B.F., Neall, V.E., Ronan, K.R., Paton, D. (2000), *Impacts of the 1945 and 1995-1996 Ruapehu eruptions, New Zealand: An example of increasing societal vulnerability*, Geological Society of America Bulletin, 112(5): 720-726.

Jonkman, S.N., Bočkarjova, M., Kok, M., Bernardini, P. (2008), *Integrated hydrodynamic and economic modelling of flood damage in the Netherlands*, Ecological Economics, 66: 77-90.

Jonkman, S.N. (2007), *Loss of life estimation in flood risk assessment: theory and applications,* PhD dissertation, Delft: Delft Cluster.

Journal of Prehospital and Disaster Medicine (2004): Glossary of Terms. <http://pdm.medicine.wisc.edu/vocab.htm >, last accessed 24/08/2009

Kamau, C.M., Anyango, G.J., Gitahi, M., Wainaina, M., Downing, T.E. (1989), *Case Studies of Drought Impacts and Responses in Central and Eastern Kenya*, In: Downing, T.E., Gitua, K.W. Kamau, C.M. (Eds.), "Coping with Drought in Kenya: National and Local Strategies", Boulder and London: Lynne Reinner Publishers.

Kates, R.W. (1962), *Hazard and Choice Perception in Flood Plain Management*, Research Paper No. 98, Chicago: University of Chicago, Department of Geography.

Kelman, I. (2007), *Understanding Vulnerability to Understand Disasters, Panel contribution to the Population-Environment Research Network Cyberseminar on Population and Natural Hazards* (http://www.populationenvironmentresearch.org/seminars.jsp).

Klein, R. (2003), *Environmental Vulnerability Assessment*. <http://www.pik-potsdam.de/~richardk/eva/>, last accessed 24/01/2006.

Klein, R.J.T., Nicholls, R.J., Thomalla, F. (2003), *Resilience to natural hazards: How useful is this concept?*, Global Environmental Change Part B: Environmental Hazards, 5(1-2): 35-45.

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

Kuhlicke, C. (2007), *(Non-)Knowledge in Hazard and Vulnerability Research: A Heuristic Typology for Empirical Case Studies,* In: Warner, K. (Ed.), "Perspectives on Social Vulnerability". Bonn: UNU.

Lavigne, F., De Coster, B., Juvin, N.Flohic, F. Gaillard, J.-C. Texier, P. Morin, J. Sartohadi, J. (2008), *People's behaviour in the face of volcanic hazards: Perspectives from Javanese communities, Indonesia*, Journal of Volcanology and Geothermal Research, 172(3-4): 273-287.

Lazarus, R.S. (1966). *Psychological Stress and the Coping Process*. New York: McGraw-Hill.

Lebel, L. (2006) *Flood disaster management: assessing institutionalised capacities and practices*, at www.mpowernet.org/mweb.php?pg=138.

Lebel, L., Manuta, J., Khrutmuang, S., Huaisai, D. (2005), *Risk reduction or risk reproduction and redistribution?: the politics of flood disaster management in Thailand,* USER Working Paper WP-2004-16, Chang Mai: Unit for Social and Environmental Research, Chang Mai University.

Lewis, J. (1999), *Development in Disaster-prone Places: Studies of Vulnerability*, London: Intermediate Technology Publications.

Lindell, M. K., Perry, R.W. (2004), *Communicating Environmental Risk in Multiethnic Communities*, Thousand Oaks, CA: Sage

Lindell, M. K., Prater C.S. (2002), *Risk area residents' perceptions and adoption of seismic hazard adjustments*, Journal of Applied Social Psychology, 32: 2377-2392.

Longo, B. M., Grunder, A., Chuan, L., Rossignol, A. (2005), *SO2 and fine aerosol dispersion from the Kilauea plume, Kau district, Hawaii, USA*, Geological Society of America, 33(3): 217-220.

Malilay, J. (1997), *Floods*, In: Noji, E. (ed.), "The Public Health Consequences of Disasters", New York: Oxford University Press: 287-301.

Manning, M. (2004), *Inherent conditions leading to economic vulnerability of small states of the Pacific Region and appropriate policy measures to strengthen their economic resilience for sustainable development, with particular emphasis on Papua New Guinea*, Paper presented at the International Workshop on Vulnerability of Small States, University of Malta, March

Manuel, J. (2006), *In Katrina's Wake*, Environ Health Perspect, 114 (1): A32-A39.

Manyena, S.B. (2006), *The Concept of Resilience Revisited*, Disasters, 30(4): 434.

Matin, N. (2002), *Corporate Social Responsibility and Natural Disaster Reduction: Insights from Bangladesh*, Research paper, DFID ESCOR Award No. R7893, London: Benfield Greig Hazard Research Centre.

Mbithi P.M., Wisner, B. (1973), *Drought and famine in Kenya: magnitude and attempted solutions*, Journal of East African Research and Development, 3: 113-143.

McMillen, C., North, C., Mosley, M., Smith, E. (2002), *Untangling the psychiatric comorbidity of posttraumatic stress disorder in a sample of flood survivors*, Comprehensive Psychiatry, 43: 478-485.

Merz, B., Kreibich, H., Thieken, A., Schmidtke, R. (2004), *Estimation of uncertainty of direct monetary flood damage to buildings*, Natural Hazards and Earth System Sciences, 4: 153-163.

Messner, F. (2007), *Evaluating flood damages: guidance and recommendations on principles and methods, Integrated Flood Risk Analysis and Management Methodologies*, FLOODsite, Centre of Environmental Research, a member of Dresden Flood Research Center.

Messner, F. and Meyer, V. (2006a) *Flood damage, vulnerability and risk perception - challenges for flood damage research,* Flood Risk Management - Hazards, Vulnerability and Mitigation Measures, J. Schanze, E. Zeman and J. Marsalek, Springer Publisher

Messner, F., Penning-Rowsell, E.C., Green, C., Meyer, V., Tunstall, S., Van der Veen, A. (2006b) *Guidelines for Socio-economic Flood Damage Evaluation*, Report No. T9-0601, FLOODsite, Oxford, Coordinator: HR Wallingford, UK.

Meusel, D., Kirch, W. (2005), *Lessons to be Learned from the 2002 Floods in Dresden, Germany*, In: Kirch, W., Menne, B., Bertollini, R. (Eds.), "Extreme Weather Events and Public Health Responses", Published on behalf of World Health Organization Regional Office for Europe. Berlin: Springer-Verlag: 175-183.

Meyer, V., Messner, F. (2005), *National Flood Damage Evaluation Methods: A review of applied methods in England, the Netherlands, the Czech Republic and Germany*, UFZ discussion paper 21/2005, Department of Economics, UFZ, Leipzig (www.ufz.de/data/dp21200553680.pdf).

Michaud, J.D., Michaud, J.P., Krupitsky, D. (2007), *Temporal variability in SO2 exposures at Hawaii Volcanoes National Park, USA*, Environmental Geology 52(1): 81-92.

Michaud, J.P., Grove, J.S., Krupitsky, D. (2004), *Emergency department visits and "vog"-related air quailty in Hilo, Hawaii*, Environmental Research, 95: 11-19.

Michaud, J.P., Krupitsky, D., Grove, J.S., Anderson, B.S. (2005) *Volcano related atmospheric toxicants in Hilo and Hawaii Volcanoes National Park: Implications for human health,* NeuroToxicology, 26(4): 555-563.

Mileti, D.S., Fitzpatrick, S. (1992), *The casual sequence of risk communication in the Parkfield earthquake prediction experiment*, Risk Analysis, 9: 20-28.

Mileti, D.S., O'Brien, P.W. (1992), *Warnings During Disaster: Normalizing Communicated Risk*, Social Problems, 39(1): 40-57.

Mileti, D.S. (1999a), *Designing Future Disasters: An Assessment and Bolder Course for the Nation,* Washington: Joseph Henry Press.

Mileti, D.S. (1999b), *Disasters By Design. A Reassessment of Natural Hazards in the United States.* Brookfield: Rothstein Associates Inc.

Mileti, D.S., Peek, L. (2000), *The social psychology of public response to warnings of a nuclear power plant accident*, Journal of Hazardous Materials, 75(2-3): 181-194.

Mileti, D.S., Sorensen, J.H. (1990), *Communication of Emergency Public Warnings: A Social Science Perspective and State-of-the-Art Assessment*, Oak Ridge: Oak Ridge National Laboratory,

Mitchell, J.K. (Ed.) (1999), *Crucibles of Hazard: Mega-Cities and Disasters in Transition*, New York: United Nations Press.

Morris-Oswald, T., Sinclair, J. (2005), *Values and floodplain management: Case studies from the Red River Basin, Canada*, Environmental Hazards, 6: 9-22.

Morrow, B.H. (1999), *Identifying and Mapping Community Vulnerability*, Disasters, 23(1): 1-18.

Moss S. (undated) *In Harm's way: How international finance institutions' policies can increase poor people's vulnerability to disaster*, Johannesburg: Action Aid and London: Christian Aid, www.actionaid.org.

Musser, L. (2002), Vulnerability bibliography. <http://sciencepolicy.colorado.edu/events/security_symposium_2002/vulnerability_bibliography.pdf>, last accessed 24/08/2009

Mustafa, D. (1998), *Structural Causes of Vulnerability to Flood Hazard in Pakistan*, Economic Geography. 74 (3): 289-305.

Nicholls, R.J., Hoozemans, F.M.J., Marchand, M. (1999), *Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses*, Global Environmental Change, 9(1): S69-S87.

Nolen-Hoeksma, S. (2003), *Abnormal Psychology*. New York: McGraw Hill – Higher Education.

Norris, F.H., Murrell, S.A. (1988), *Prior experience as a moderator of disaster impact on anxiety symptoms in older adults*, American Journal of Community Psychology, 16: 665-683.

Norris, F.H., Byrne, C.M., Diaz, E., Kaniasty, K. (2001), *The Range, Magnitude, and Duration of Effects of Natural and Human-Caused Disasters: A Review of the Empirical Literature,* National Centre for Post-Traumatic Stress Disorder, White River junction, Vermont: Department of Veterans Affairs.

Office of Public Works (2008), *Flood Risk Assessment, Indicators, Methods and Datasets – Scoping Study*, Draft Final Report, May, Flood Hazard Research Centre, London and Halcrow, Swindon.

Office of Science and Technology (2004), *Foresight: Future Flooding,* London, OST.

Ohl, C.A., Tapsell, S.M. (2000), *Flooding and human health: the dangers posed are not always obvious*, British Medical Journal, 321: 1167-8.

Okuyama, Y. (2004), *Modeling spatial economic impacts of an earthquakeinput-output approaches*, Disaster prevention and management : an international journal, 13(4): 297.

Osbahr, H. (2007) *Building resilience: Adaptation mechanisms and mainstreaming for the poor*, Human Development Report 2007/2008, UNDP Human Development Report Office Occasional Paper, Oxford: Centre for the Environment, University of Oxford.

Overseas Development Institute (2005), *Aftershocks: Natural Disaster Risk and Economic Development Policy*, Briefing Paper, London, ODA. www.odi.org.uk/publications/briefing/bp_disasters_nov05.pdf, 2005.

Parker D.J., Thompson, P.M., Green, C.H. (1987), *Urban flood protection benefits: a project appraisal guide*, Aldershot UK: Gower Technical Press.

Parker, D.J. (2000), *Introduction to Floods and Flood Management*, In: Parker, D.J. (Ed.) "Floods", London: Routledge: 3-39.

Parker, D.J., Tapsell, S.M. (1997), *Hazard and Disaster Management Learning and Failure in the London Megacity*, Geography and Environmental Management Paper No. 29, London: Middlesex University.

Parker, D.J. (1999a) *Disaster response in London: A case of learning constrained by history and experience*, In: Mitchell, J.K. (Ed.), "Crucibles of Hazard: Mega-Cities and Disasters in Transition", Tokyo: United Nations University Press: 186-247.

Parker, D.J. (1999b), *Criteria for Evaluating the Condition of a Tropical Cyclone Warning System*, Disasters, 23(3): 193-216.

Parker, D.J., Penning-Rowsell, E.C. (2005), *Dealing with disasters*, In: Hunt, J. (Ed.) "London's Environment: Prospects for a Sustainable World City", London: Imperial College Press: 175-202.

Parker, D.J., Priest, S., Tapsell, S.M. (2008). *Modelling the damage reducing effects of flood warnings*, FLOODsite Final Report, Report No. T10-07-02, Flood Hazard Research Centre, Middlesex University, London.

Paton, D. (2002), *Modelling community empowerment and resilience to manage community change and development*, Research Report, Auckland: Auckland City Council.

Paton, D., Smith, L., Daly, M., Johnston, D. (2008), *Risk perception and volcanic hazard mitigation: Individual and social perspectives*, Journal of Volcanology and Geothermal Research, 172(3-4): 179-188.

Pelling, M. (1998), *Participation, social capital and vulnerability to urban flooding in Guyana*, Journal of International Development, 10(4): 469-486.

Pelling, M. (2003a), *The Vulnerability of Cities – Natural Disasters and Social Resilience*, London: Earthscan Publications.

Pelling, M. (2003b): *Social capital, hazards and adaptation strategies for the vulnerable*. Draft. Justice in Adaptation to Climate Change. Seminar for Connective Environmental Research, University of East Anglia, 7-9 September.

Pelling, M. (2005), *Visions of Risk: A Review of International Indicators of Disaster Risk and its Management*, Geneva, UNDP-Bureau for Crisis Prevention and Recovery (BRCP).

Pelling, M. (2006), *Measuring urban vulnerability to natural disaster risk: Benchmarks for sustainability*, Open House International, 31(1): 125-132.

Pelling, M., Uitto, J.I. (2001), *Small Island Developing States: Natural Disaster Vulnerability and Global Change*, Environmental Hazards, 3(2): 49–62.

Penning-Rowsell, E.C., Green, C.H., Thompson, P.M., Coker, A.M., Tunstall, S.M., Richards, C., Parker, D.J. (1992), *The Economics and Coastal Management: A Manual of Benefit Assessment Techniques*, London: Belhaven Press.

Penning-Rowsell, E.C., Johnson, C., Tunstall, S., Tapsell, S., Morris, J., Chatterton, J., Green, C. (2005), *The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques*, London: Middlesex University Press.

Penning-Rowsell, E.C., Chatterton, J.B. (1977), *The benefits of flood alleviation: a manual of assessment techniques*, Aldershot: Saxon House.

Peterson, C., Seligman, M.E.P. (1984), *Casual Explanation as a Risk Factor for Depression: Theory and Evidence*, Psychological Review, 91: 347-374.

Phifer, J.F., Norris, F.H. (1989), *Psychological symptoms in older adults following natural disaster: Nature, timing, duration, and course*, Journal of Gerontology: Social Sciences, 44: S206-S217.

Population Division of the UNDESA, World Population Prospects database (http://esa.un.org/unpp/ last accessed 24/08/2009

Prater, C.S. Lindell, M.K. (2000), *The politics of hazard mitigation,* Natural hazards Review, 1: 73-82.

Priest, S.J., Wilson, T., Tapsell, S., Penning-Rowsell, E., Viavattene, C. and Fernandez-Bilbao, A. (2007), *Building a model to estimate Risk to Life for European flood events*, Milestone report T10-07-10 for the Integrated Project FLOODsite.

ProVention Consortium (2007), *Social Impact Assessment,* Tools for Maintaining Disaster Risk Reduction Guidance Note 11, Geneva: ProVention Consortium.

Puente, S. (1999) *Social vulnerability to disasters in Mexico City: An assessment method*, In: Mitchell J.K. (Ed.) "Crucibles of Hazard: Mega-Cities and Disasters in Transition", New York: United Nations University Press: 295-334.

Putnam, R.D. (2000), *Bowling Alone: Collapse and Revival of the American Community*, New York: Simon and Schuster.

Rashed, T., Weeks, J. (2002), *Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas*, Int. J. Geographical Information Science, 17(6): 547-576.

Rath, B., Donato, J., Duggan, A., Perrin, K., Bronfin, D.R., Ratard, R., Van Dyke, R., Magnus, M. (2007), *Adverse Health Outcomes after Hurricane Katrina among Children and Adolescents with Chronic Conditions*, Journal of Health Care for the Poor and Underserved, 18: 405-417.

Reacher, M., McKenzie, K., Lane, C., Nichols, T., Iversen, A., Hepple, P., Walter, T., Laxton, C., Simpson, J. (2004), *Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other illness and mental health in flooded and non-flooded households,* Communicable Disease and Public Health, 7(1): 1-8.

Reardon T., Matlon P. (1989), *Seasonal Food Insecurity and Vulnerability in Drought-Affected Regions of Burkino-Faso*, In: Sahn E.D. (Ed.), "Seasonal Variability in Third World Agriculture: The Consequences for Food Security", Baltimore: International Food Policy Research Institute/John Hopkins Press: 118-136

Reveau, P. (2004), *Intérêts et limites des études de vulnérabilité,* Risques Naturelles, 36.

Risk and Policy Analysis, Flood Hazard Research Centre, EFTEC, and CASPAR University of Newcastle (2004), *The Appraisal of Human-Related Intangible Impacts of Flooding,* Report to Defra/Environment Agency. R&D Technical Report FD2005/TR, London: Defra.

Rojas-Ramos, M., Catalan-Vazquez, M., Pozzo A.L.M-D., Garcia-Ojeda E., Villalba-Caloca J., Perez-Neria, J. (2001), *A seven months prospective study of the respiratory effects of exposure to ash from Popocatepetl volcano, Mexico*, Environmental Geochemistry and Health, 23(4): 383-396.

Rose, A. (2004), *Defining and measuring economic resilience to disasters*, Disaster Prevention and Management: An International Journal, 13: 307-314.

Rose, A. (2007), *Economic resilience to natural and man-made disasters: Multidisciplinary origins and contextual dimensions*, Environmental Hazards, 7(4): 383-398.

Salkovskis, P.M. (1996), *The Cognitive Approach to Anxiety: Threat Beliefs, Safety-Seeking Behavior, and the Special Case of Health Anxiety and Obsessions*, In: Salkovskis, P.M. (ed.), "Frontiers of Cognitive Therapy", New York: Guilford Press: 48-74.

Sartrapa, L., Fosumpaur, P., Horsky, M. (2005), *Methods of flood damage evaluation*, MS Powerpoint presentation, Prague, Czech Republic.

Schiller, A., de Sherbinin, A., Hirsch, W-H., Pusipher, A. (2001), *The Vulnerability of Global Cities to Climate Hazards*, IDHP Open Meeting 2001, Rio de Janeiro. (www.Sedac.ciesin.org/openmeeting/downloads/1008002293_presentation_aschiller_riopaper1220.pdf).

Schmidt, W., Skala, M., Donelon, I., Donnell, H. (1993), *Morbidity surveillance following the Midwest flood – Missouri*, Morbidity and Mortality Weekly Report, 42: 797-798.

Schneiderbauer, S., Ehrlich, D. (2004), *Risk, hazard and people's vulnerability to natural hazards. A review of definitions, concepts and data*. European Commission Joint Research Centre. EUR 21410 EN.

Schultz, S.D., Kjelland, M.E. (2002) *Estimating Watershed Level Flood Damage in the Red River Valley of the North*, Natural Hazards Review, 3 (1): 4-11.

Scott, W., Dua, J. (1999), *Development of a Scale to Assess Posttraumatic Stress Disorder*, International Journal of Stress Management, 6(3): 149-165.

Searl, A., Nicholl, A., Baxter, P. (2002) *Assessment of the exposure of islanders to ash from the Soufriere Hills volcano, Montserrat, British West Indies*, Occupational and Environmental Medicine, 59(8): 523-531.

Sime, J.D. (1997), *Informative flood warnings: occupant response to risk, threat and loss of place*, In: Handmer, J. (Ed.), "Flood Warning: Issues and practice in total system design", Enfield: Flood Hazard Research Centre, Middlesex University: 155-175.

Sims, R., Medd, W., Mort, M., Watson, N., Walker, G., Twigger-Ross, V. (2008), *Perspectives on resilience from households in Hull*, report study "Flood, vulnerability and urban

resilience: a real-time study of local recovery following the floods of June 2007 in Hull" www.lec.lancs.ac.uk/cswm/hfp.

Skelton, T. (2006), *Representations of the 'Asian Tsunami' in the British Media*, Asian MetaCentre Research Paper Series No. 21, Asian Metacentre for Population and Sustainable Development Analysis, Singapore: Asia Research Institute, National University of Singapore.

Skertchly, A., Skertchly, K. (2000), *Human aspects of the Katherine-Daly flood disaster,* Australian Journal of Emergency Management, Autumn: 47-52.

Smith, B.W. (1996), *Coping as a predictor of outcomes following the 1993 Midwest flood*, Journal of Social Behaviour and Personality, 11(2): 225-239.

Sorensen, J.H., Gersmehl, P.J. (1980), *Volcanic hazard warning system: Persistence and transferability*, Environmental Management, 4: 125-136.

Spence, R.J.S., Baxter, P.J., Zuccaro, G. (2004), *Building vulnerability and human casualty estimation for a pyroclastic flow: a model and its application to Vesuvius*, Journal of Volcanology and Geothermal Research, 133(1-4): 321-343.

Spence, R.J.S., Kelman, I., Baxter, P., Zuccaro, G., Petrazzuoli, S. (2005) *Residential building and occupant vulnerability to tephra fall*, Natural Hazards and Earth System Sciences, 5(4): 477-494.

Steinführer, A., De Marchi, B., Kuhlicke, C., Scolobig, A., Tapsell, S., Tunstall, S. (2007a), *Vulnerability, resilience and social constructions of flood risk in exposed communities, A cross-country comparison of case studies in Germany, Italy and the U.K,* FLOODsite report T11-07-13 (available at: www.floodsite.net).

Steinführer, A., Kuhlicke, C. (2007b) *Social vulnerability and the 2002 flood*, Country Report Germany (Mulde River), FLOODsite, Report No. T11-07-08, UFZ, Leipzig.

Steinglass, P., Gerrity, E. (1990), *Natural disaster and post-traumatic stress disorder: Short-term versus long-term recovery in two disaster-affected communities*, Journal of Applied Social Psychology, 20: 1746-1765.

Sterlacchini, S., Frigerio, S., Giacomelli, P., Brambilla, M. (2007) *Landslide risk analysis: A multi-disciplinary methodological approach*, Natural Hazards and Earth System Science, 7(6): 657-675.

Stoudemire, A. (1995), *Psychological Factors Affecting Medical Conditions,* Washington DC: American Psychiatric Press.

Suarez, P. (2002), *Urbanization, Climate Change and Flood Risk: Addressing the fractal nature of differential vulnerability*. Second Annual IIASA-DPRI Meeting INTEGRATED DISASTER RISK MANAGEMENT Megacity Vulnerability and Resilience. 29-31 July, 2002, Laxenburg, Austria. <http://www.iiasa.ac.at/Research/RMS/dpri2002/>, last accessed 24/08/2009

Susman, P., O'Keefe, P., Wisner, B. (1983), *Global disasters, a radical interpretation*. In: Hewitt, K. (Ed.), "Interpretations of Calamity", Boston: Allen and Undwin, Inc.: 263-283.

Tapsell, S.M. (2000), *Follow-up Study of the Health Effects of the 1998 Easter Flooding in Banbury and Kidlington*, Report to the Environment Agency, Thames Region, Enfield: Flood Hazard Research Centre, Middlesex University.

Tapsell, S.M., Tunstall, S.M. (2001), *The Health and Social Effects of the June 2000 Flooding in the North East Region*, Report to the Environment Agency. Enfield: Flood Hazard Research Centre Middlesex University.

Tapsell, S.M., Tunstall, S.M., Green, C., Fernandez, A. (2005), *Social Vulnerability Indicators,* Report T11-07-01 of FLOODsite Integrated Project, Enfield: Flood Hazard Research Centre.

Tapsell, S.M., Tunstall, S.M. (2006), *The mental health aspects of floods: evidence from England and Wales*, In: Few, R., Matties, F. (Eds.), "Flood Hazards and Health: Responding to Present and Future Risks", London: Earthscan: 89-110.

Tapsell, S.M., Tunstall, S.M. (2007), *"I wish I'd never heard of Banbury": the relationship between 'place' and the health impacts of flooding*, Health & Place, 14(2): 133-154.

Tapsell, S.M., Tunstall, S.M., Penning-Rowsell, E.C., Handmer J.W. (1999). *The Health Effects of the 1998 Easter Flooding in Banbury and Kidlington*, Report to the Environment Agency, Thames Region, Enfield: Flood Hazard Research Centre, Middlesex University.

Tapsell, S.M., Tunstall, S.M., Wilson, T. (2003,) *Banbury and Kidlington - Four Years After the Flood: An Examination of the Long-Term Health Effects of Flooding*, Report to the Environment Agency, Thames Region, Enfield: Flood Hazard Research Centre, Middlesex University.

Tapsell, S.M., Penning-Rowsell, E.C., Tunstall, S.M., Wilson, T. (2002). *Vulnerability to flooding: health and social dimensions*, Phil. Trans. R. Soc. Lond., 360: 1511-1525.

Tayag, J., Insauriga, S. Ringor, A., Belo, M. (1996), *People's Response to Eruption Warning: The Pinatubo Experience, 1991-92,* In: Newhall, C.G., Punongbayan, R.S. (Eds.), "Fire and Mud Eruptions and Lahars of Mount Pinatubo, Philippines", Seattle: University of Washington Press: 87-106.

The Resilience Alliance (www.resalliance.org) and London Resilience (www.londonprepared.gov.uk) last accessed 24/08/2009

Tierney, K.J., Lindell, M.K. Perry, R.W. (1999) *Facing the Unexpected. Disaster Preparedness and Response in the United States*, Washington DC: Joseph Henry Press.

Thierry, P., Stieltjes, L., Koukame, E., Nhueya, P., Salley, P.M. (2008), *Multi-hazard risk mapping and assessment on an active volcano: the GRINP project at Mount Cameroon*, Natural Hazards, 45(3): 429-456.

Thissen, M. (2004), *The indirect economic effects of a terrorist attack on transport infrastructure: a proposal for a SAGE*, Disaster Prevention and Management: An International Journal, 13: 280-289.

Thrush, D. (2002), *Flood Warning for Vulnerable Groups: Collection and Analysis of Primary data on Vulnerable Groups in Emergency Situations. Site Selection and Key Informant Interviews,* Interim Report for the Environment Agency, Guildford: Dept. of Sociology and Centre for Environmental Strategy, University of Surrey.

Thywissen, K. (2006), *Core terminology of disaster reduction: A comparative glossary*, In: Birkmann, J.E. (Ed.), "Measuring vulnerability to natural hazards: towards disaster resilient societies", Tokyo: United Nations University Press: 448-496.

Thywissen, K. (2007), *Components of Risk, A Comparative Glossary*, Bonn: UNU-EHS, SOURCE No. 2/2006.

Tunstall, S.M., Bossman-Aggrey, P. (1988), *Waltham Abbey and Thornwood, Essex: An Assessment of the Effects of the Flood of 29th July, 1987 and the Benefits of Flood Alleviation*, Enfield: Flood Hazard Research Centre, Middlesex Polytechnic.

Tunstall S., Tapsell, S., Green, C., Floyd, P., George, C. (2006), *The health effects of flooding: social research results from England and Wales*, Journal of Water and Health, 4 (3), 365-380.

Tunstall, S., Tapsell S., Fernandez-Bibao A. (2007), *Vulnerability and flooding: a re-analysis of FHRC data*, Country Report England and Wales, FLOODsite, Report No. T11-07-11, London: Flood Hazard Research Centre, Middlesex University.

Tunstall, S.M., Parker, D.J., Twomey, G., Doizy, A., Sangster, E. (1991), *The Severn Floods of January and February 1990*, Report to the National Rivers Authority, London: Flood Hazard Research Centre, Middlesex University.

Turner, R.H., Killian, L.M. (1987), *Collective Behavior*, Englewood Cliffs, NJ: Prentice Hall.

Turner, B.L. *et al.* (2003), *A framework for vulnerability analysis in sustainability science*, Proceedings of the National Academy of Sciences of the United States of America (PNAS100(14): 8074-8079.

UN Department of Economic and Social Affairs (2009) www.un.org/esa/policy/devplan/profile/definitions.html

UNDP (2000), *Human Development Report: Human Rights and Human Development*, New York: United Nations Development Program.

UNDP (United Nations Development Programme) Bureau for Crisis Prevention and Recovery (2004), Re*ducing Disaster Risk: a challenge for development. A global report* (M. Pelling, A. Maskrey, P. Ruiz, L. Hall, eds.). John S. Swift Co., USA

UNDRO (Office of the United Nations Disaster Relief Co-Ordinator) (1991): Mitigating Natural Disasters. Phenomena, Effects and Options. A Manual for Policy Makers and Planners. UNDRO/MND/1990 Manual, Genf.

UNEP (2002), *Global Environment Outlook 3 – Past, Present and Future Perspectives,* London: Earthscan Publications Ltd.

UN/ISDR (2004a), *Terminology: Basic terms of disaster risk reduction*, (Online: http://www.unisdr.org/eng/library/)

UN/ISDR (2004b), *Living with Risk, A global review of disaster reduction initiatives*, Geneva, United Nations

UNCHS (Habitat) (2001) *Assessment of vulnerability to flood impacts and damages*, Disaster Management Programme: Nairobi: UNCHS

University of Thessaly (2004), *Documentation of the 2000 Round of Population and Housing Censures in the EU, EFTA and Candidate Countries*, Part I + II, Luxembourg: European Commission.

US Army Corps of Engineers Hydrologic Engineering Center, Flood Damage Analysis (HEC-FDA) (2008), *Computer Program U. S. Army Corps of Engineers Hydrologic Engineering Cente*, http://www.hec.usace.army.mil/software/hec-fda/hecfda-hecfda.html.

USAID (2006) *Concepts and practices of "resilience": a compilation from various secondary sources*, A Working paper prepared for Coastal Community Resilience (CCR) Program

Van der Veen A., Steenge, A.E., Bockarjova, M., Logtmeijer, C.J.J. (2003), *Structural economic effects of large scale inundation: a simulation of the Krimpen dike breakage*,

In: van der Veen A., Veter Arellano, A.L., Nordvik, J-P., (Eds.), Joint NEDIES and University of Twente Workshop: In search of a common methodology on damage estimation, EUR Report 20997 EN, Office for Official Publications of the European Communities, Bruxelles: European Commission.

Van der Veen, A. (2004), *Disasters and economic damage: macro, meso and micro approaches*, Disaster Prevention and Management: An International Journal, 13(4): 274-280.

Van der Veen, A., Logtmeijer, C. (2005), *Economic Hotspots: Visualizing Vulnerability to Flooding*, Natural Hazards, 36(1): 65-80.

Van der Veen A., Veter Arellano, A.L., Nordvik, J-P., (2003) *In search of a common methodology on damage estimation*, NEDIES Workshop, Delft: European Commission.

Villagrán de Léon, J.C. (2007), *Vulnerability. A Conceptual and Methodological Review*, Bonn: UNU-EHS. SOURCE No. 4/2006.

Vrijling, J.K., Van Hengel, W., Houben, R.J. (1995), *A framework for risk evaluation*, Journal of Hazardous Materials, 43: 245-261.

Vrouwenvelder, A.C.W.M., Steenhuis, C.M. (1997) *Tweede waterkeringen Hoeksche Waard,* berekening van het aantal slachtoffers bij verschillende inundatiescenarios, Report TNO 97-CON-R0332.

Waarts, P. (1992), *Methode voor de bepaling van het aantal doden als gevolg van inundatie,* Report TNO B-91-1099.

Wade, T., Sandhu, S., Levy, D., Lee, S., LeChevallier, M., Katz, L., Colford, J. (2004), *Did a severe flood in the Midwest cause an increase in the incidence of gastrointestinal symptoms?,* American Journal of Epidemiology, 159: 398-405.

Waelde, L.C., Koopman, C., Rierdan, J., Spiegel, D. (2001), *Symptoms of acute stress disorder and posttraumatic stress disorder following exposure to disastrous flooding*, Journal of Trauma and Dissocation, 2: 37-52.

Wallingford, H.R. (2003) *Flood Risks to People Phase 1*. Final Report Prepared for Defra/Environment Agency Flood and Coastal Defence R&D Programme.

Wallingford, H.R. (2005) *R&D Outputs: Flood Risks to People, Phase 2*. FD2321/TR1 The Flood Risk to People Methodology. Defra/ Environment Agency Flood and Coastal Defence R&D Programme

Warner, K., (2007) Perspectives on Social Vulnerability, Bonn. UNU-EHS, Source No. 6/2007

Water Agency Artois-Picardie (2006), *Evaluation economique des Dommages lies aux inondations,* Rapport final – E55915. (www.eau-artois-picardie.fr?IMG/pdf?RapportFinal.pdf)

Water Agency Loire-Bretagne (1999), *Synthesis of proposals of an overall strategy to reduce the risk of flooding by significant floods along the Middle Loire,* Orleans: Water Agency Loire

Watts, M.J., Bohle, H.G. (1993), T*he space of vulnerability: the causal structure and of hunger and famine*, Progress in Human Geography, 17(1): 43-67.

Weichselgartner, J. (2001), *Disaster mitigation: the concept of vulnerability revisited*, Disaster Prevention and Management, 10(2): 85-94.

Werrity, A., Houston, D., Ball, T., Tavendale, A., Black, A. (2007), *Exploring the Social Impacts of Flood Risk and Flooding in Scotland*, Edinburgh: Scottish Executive Social Research.

White, I., Howe, J. (2002), *Flooding and the Role of Planning in England and Wales: A Critical Review*, Journal of Environmental Planning and Management, 45(5): 735-745.

Wilber, K. (2001), *A theory of everything*, Boston: Shambala Publications

Wisner, B. (1993), *Disaster vulnerability, geographical scale and existential reality*, In: Bohle, H.G. (Ed.), "Worlds of Pain and Hunger: geographical perspectives on disaster vulnerability and food security", Fort Lauderdale, FL: Freiburg Studies in Development Geography.

Wisner, B. (2000), *From "Acts of God" to "Water Wars"- The urgent analytical and policy role of political ecology in mitigating losses from flood: A view of South Africa from Central America*, In: Parker D.J. (Ed.) "Floods", London: Routlege: 89-99.

Wisner, B. (2005), *Tracking Vulnerability: History, Use, Potential and Limitations of a Concept*, Keynote Address. SIDA & Stockholm University Research Conference on Structures of Vulnerability: Mobilisation and Research, January 12-14.

Wisner, B., Blaikie, P., Cannon, T., Davis, I. (2004), *At Risk: Natural hazards, people's vulnerability and disasters*, 2nd edition, Routledge: London.

World Bank (2003), *World Development Indicators 2003*. Washington: IBRD.

World Health Organization (2003), *Climate Change and Human Health – Risks and Responses*, Geneva, Switzerland: WHO.

World Monuments Fund (2005), *World Monuments Fund Adds New Orleans and the Gulf Coast as the 101st site on the 2006 World Monuments Watch List of 100 most endangered sites*, WMF Press release.

Yodmani, S. (2001) Disaster Risk Management and Vulnerability Reduction: Protecting the Poor, Paper presented at The Asia and Pacific Forum on Poverty Organised by the Asian Development Bank, Bangkok

Zerger (2009) http://www.geom.unimelb.edu.au/zerger/anuflood.html last accessed 24/08/2009

Zhai, G., Fukuzono, T., Ikeda, S. (2006), *An empirical model of fatalities and injuries due to floods in Japan,* Journal of the American Water Resources Association, 42 (4): 863-875.

Zoleta-Nantes, D.B. (2000), *Flood Hazard Vulnerabilities and Coping Strategies of Residents of Urban Poor Settlements in Metro Manila, The Philippines*, In: Parker, D.J. (Ed.), "Floods", London: Routledge: 69-88.

Appendices

Appendix I. Definitions of 'vulnerability', resilience' and 'resiliency'

As one of the first activities of the UNU-EHS (United Nations University — Institute for Environment and Human Security), a project was launched in late 2004 with the aim to summarize the core terminology of disaster preparedness and reduction. One of the outputs available from the UNU-EHS website (www.ehs.unu.edu/moodle/), is a Core Terminology of Disaster Reduction, compiled and edited by Dr. Katharina Thywissen of UNU-EHS. The definitions and sources of the terms 'vulnerability', 'resilience' and 'resiliency' are reprinted in this annex. A slightly modified version of this glossary is also presented as a chapter (Thywissen, 2006) in Birkmann, (2006).

Vulnerability

1. Vulnerability:

"The vulnerability increases with the number of people affected by the impact of a natural hazard, given by the formula:

$$v_{ij} = 10^{-23} \cdot n_j^2 \text{, for } n \geq 10 \text{ casualties.}$$

where v_{ij} is the vulnerability of an individual i at location j."

Source: Vrijling, J.K. Van Hengel, W., & Houben, R.J. (1995): A framework for risk evaluation. Journal of Hazardous Materials, No. 43, pp. 245-261. Quoted in: Risk, Reliability, Uncertainty, and Robustness of Water Resources Systems. UNESCO International Hydrology Series. eds. J.J. Bogardi & Z.W. Kundzewicz. Cambridge: Cambridge University Press. p. 218.

2. Vulnerability:

"[...] 'vulnerability' to the natural phenomenon must be present for an event to constitute a natural disaster. Vulnerability is defined as a condition resulting from physical, social, economic, and environmental factors or processes, which increases the susceptibility of a community to the impact of a hazard."

Source: ADRC (2005): Total disaster risk management - Good practices. <http://www.adrc.or.jp/publications/TDRM2005/TDRM_Good_Practices/PDF/Chapter1_1.2.pdf>, last accessed 24/01/2006.

3. Vulnerability:

"If risk is one side of the coin, its other side is vulnerability, which we may loosely define as potential for losses or other adverse impacts. People, buidlings, ecosystems or human activities threatened with disaster are vulnerable. […] Essentially, vulnerability refers to the potential for casualty, destruction, damage, disruption or other form of loss with respect to a particular element. Risk combines this with the probable size of impact to be expected from a known magnitude of hazard. [...] Many authors [...] have confused vulnerability with exposure: in reality they are two complementary components of risk."

Source: Alexander, D. (2000): Confronting Catastrophe - New Perspectives on Natural Disasters. Oxford: Oxford University Press. pp.282.

4. Vulnerability:

"The insecurity of the well-being of individuals, households or communities in the face of a changing environment". Moser & Holland (1989) quoted in Alwang *et al.* (2001)."

Source: Alwang, J., Siegel, P.B. & Jorgensen, S. L. (2001): Vulnerability: a view from different disciplines. Social Protection Discussion Paper Series, No. 0115, World Bank. 42 pp. <http//:www.worldbank.org/sp>, last accessed 24/01/2006.

5. Vulnerability:

"Is the characteristic of a person or a group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural disaster" (Blakie *et al.* 1994 p.9 quoted in Alwang *et al*. (2001). "The Extent of a disaster cannot be measured without knowledge of the resilience of the affected groups; this resilience plays out over time."

Source: Alwang, J., Siegel, P.B. & Jorgensen, S. L. (2001): Vulnerability: a view from different disciplines. Social Protection Discussion Paper Series, No. 0115, World Bank. 42 pp. <http//:www.worldbank.org/sp>, last accessed 24/01/2006.

6. Vulnerability:

"Summarizing livelihood and environmental literature: vulnerability is the exposure of individuals or groups to livelihood stress as a result of environmental change."

Source: Alwang, J., Siegel, P.B. & Jorgensen, S. L. (2001): Vulnerability: a view from different disciplines. Social Protection Discussion Paper Series, No. 0115, World Bank. 42 pp. <http//:www.worldbank.org/sp>, last accessed 24/01/2006.

7. Vulnerability:

"The characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete or identifiable event in nature or society."

"Vulnerability concept consists of two opposing forces: On one hand, the processes that cause vulnerability that can be observed; on the other hand, the physical exposure to hazards (earthquakes, storms, floods, etc.). Vulnerability develops then from underlying reasons in the economic, demographic and political spheres into insecure conditions (fragile physical environment, instable local economy, vulnerable groups, lack of state or private precautions) through the so-called dynamic processes (e.g. lack of local institutions, under-developed markets, population growth, and urbanization)."

Source: Blaikie, P., Cannon, T., Davis, I. & Wisner, B. (1994): At Risk: Natural Hazards, People's vulnerability, and Disasters. London, Routledge. pp. 275.

8. Vulnerability:

"Vulnerability concerns the complex social, economic, and political considerations in which peoples' everyday lives are embedded and that structure the choices and options they have in the face of environmental hazards. The most vulnerable are typically those with the fewest choices, those whose lives are constrained, for example, by discrimination, political powerlessness, physical disability, lack of education and employment, illness, the absence of legal rights, and other historically grounded practices of domination and marginalization."

Source: author The Northridge Earthquake: Vulnerability and Disaster. Routledge, London. 288 pp.

9. Vulnerability:

"The degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss) or in percent of the new replacement value in the case of damage to property."

Source: Buckle, P., Marsh, G. & Smale, S. (2000): New approaches to assessing vulnerability and resilience.
<http://online.northumbria.ac.uk/geography_research/radix/resources/buckle-marsh.pdf>, last accessed 24/01/2006.

10. Vulnerability:

"Vulnerability (in contrast to poverty which is a measure of current status) should involve a predictive quality: it is supposedly a way of conceptualizing what may happen to an identifiable population under conditions of particular risk and hazards. Is the complex set of characteristics that include a person's: → initial well-being (health, morale, etc.); --> self-protection (asset pattern, income, qualifications, etc.); → social protection (hazard preparedness by society, building codes, shelters, etc.); → social and political networks and institutions (social capital, institutional environment, etc.)."

Source: Cannon, T., Twigg, J. & Rowell, J. (2002): Social vulnerability, sustainable livelihoods and disasters. <http://www.benfieldhrc.org/SiteRoot/disaster_studies/projects/soc_vuln_sust_live.pdf>, last accessed 24/01/2006.

11. Vulnerability:

"Vulnerability: the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss). […]
On the other hand, vulnerability may be understood, in general terms, as an internal risk factor, mathematically expressed in terms of the feasibility that the exposed subject or system will be affected by the phenomenon that characterizes the hazard."

Source: Cardona, O.D. (2003): Indicators for Disaster Risk Management. First Expert Meeting on Disaster Risk Conceptualization and Indicator Modelling, Manizales, March 2003. < http://tinyurl.com/of79h this link re-direct to a PDF file>, last accessed 24/01/2006.

12. Vulnerability:

"Vulnerability, therefore, is a human-induced situation that results from public policy and resource availability/distribution, and it is the root cause of many disaster impacts. Indeed, research demonstrates that marginalized groups invariably suffer most in disasters. Higher levels of vulnerability are correlated with higher levels of poverty, with the politically disenfranchised, and with those excluded from the mainstream of society."

Source: Pelling, M. (2003b): Social capital, hazards and adaptation strategies for the vulnerable. Draft. Justice in Adaptation to Climate Change. Seminar for Connective Environmental Research, University of East Anglia, 7-9 September.

13. Vulnerability:

"Vulnerability expresses the severity of failure in terms of its consequences. The

concern is not how long the failure lasts but how costly it is."

Source: Correira, Santos, Rodrigues (1987): Engineering risk in regional drought studies. pp. 61-86. In: Duckstein & Plate (eds.): Engineering Reliability and Risk in Water Resources. Martinus Nijhoff Publishers, Dordrecht, Boston, Lancaster, pp. 588.

14. Vulnerability:

"Is a broad measure of the susceptibility to suffer loss or damage. The higher the vulnerability, the more exposure there is to loss and damage."

Source: Department of Human Services (2000): Assessing resilience and vulnerability in the context of emergencies: Guidelines. Victorian Government Publishing Service.

15. Vulnerability:

"The degree of loss to a given element at risk (or set of elements) resulting from a given hazard at a given severity level". In contrast to the concept of risk, here the probability of the occurrence of a hazard is not considered." (UNDP/UNDHA, 1994, pp. 38-39; see also UNDHA, 1992). "Vulnerability has process character and is not static."

Source: Feldbrügge, T. & von Braun, J. (2002): Is the World becoming a more risky place? – Trends in disasters and vulnerability to them. ZEF – Discussion Papers On Development Policy No. 46, Center for Development Research, Bonn, May 2002, pp. 42.

16. Vulnerability:

"Vulnerability (V) = Hazard – Coping with : Hazard = H (Probability of the hazard or process; shock value; predictability; prevalence; intensity/strength); and Coping = C (Perception of risk and potential of an activity; possibilities for trade; private trade, open trade)." "Determinants of disaster vulnerability: → demographic factors: population growth, urbanization, settlements near coastal areas, etc., → the state of economic development: poverty, modernization processes, → environmental changes: climate changes, degradation and depletion of resources (straightening the courses of rivers, deforestation, etc.); → political factors, → an increase in tangible assets, which leads to an increase in damages → effects of disaster protection structures and research, and → the interactions of the causes of disasters."

Source: Feldbrügge, T. & von Braun, J. (2002): Is the World becoming a more risky place? – Trends in disasters and vulnerability to them. ZEF – Discussion Papers On Development Policy No. 46, Center for Development Research, Bonn, May pp. 42.

17. Vulnerability:

"Vulnerability denotes the inadequate means or ability to protect oneself against the adverse impacts of natural events and, on the other hand, to recover quickly from their effects."

Source: Garatwa, W. & Bollin, C. (2002): Disaster Risk Managment - A working concept. Eschborn, Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ), <http://www2.gtz.de/dokumente/bib/02-5001.pdf>, last accessed 24/01/2006.

18. Vulnerability:

"The likelihood that some socially defined group in society will suffer disproportionate death, injury, loss or disruption of livelihood in an extreme event, or face greater than normal difficulties in recovering from a disaster."

Source: Handmer, J. & Wisner, B. (1999): Conference Report: Hazards, Globalization and Sustainability. Development in Practice, Vol. 9, No. 3, pp. 342-346.

19. Vulnerability:

"The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard."

Source: IFRC (International Federation of Red Cross and Red Crescent Societies), (1999): Vulnerability and capacity assessment. An International Federation Guide. IFRC, Switzerland, pp. 33.

20. Vulnerability:

"Vulnerability is defined as the extent to which a natural or social system is susceptible to sustaining damage from climate change. Vulnerability is a function of the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and the degree of exposure of the system to climatic hazards."

Source: IPCC (International Pannel on Climate Change) (2001). Climate Change 2001. Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Integovernmental Panel on Climate Change (R.T. Watson and the Core Writing Team, eds.). Cambridge University Press, Cambridge, United Kingdom, and New York, USA, pp. 398.

21. Vulnerability:

"The potential loss in value of an element at risk from the occurrence and consequences of natural and technological hazards. The factors that influence vulnerability include: demographics, the age and resilience of the built environment, technology, social differentiation and diversity, regional and global economies, and political arrangements. Vulnerability is a result of flaws in planning, siting, design, and construction. Vulnerability is the degree of loss to a given element at risk, or set of such elements, resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (=no damage) to 1 (=total loss). -UNDRO."

Source: Journal of Prehospital and Disaster Medicine (2004): Glossary of Terms. <http://pdm.medicine.wisc.edu/vocab.htm >, last accessed 24/01/2006.

22. Vulnerability:

"Vulnerability is a pervasive socio-economic condition; it is the reason why the poor and disadvantaged are the predominant victims of disaster."

Source: Musser, L. (2002): Vulnerability bibliography. <http://sciencepolicy.colorado.edu/events/security_symposium_2002/vulnerability_bibliography.pdf>, last accessed 24/01/2006.

23. Vulnerability:

"Vulnerability defines the inherent weakness in certain aspects of the urban environment which are susceptible to harm due to social, biophysical, or design characteristics."

Source: Rashed, T. & Weeks, J. (2002): Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas. Int. J. Geographical Information Science, 2003, Vol. 17, No. 6, pp. 547-576.

24. Vulnerability:

Is the predisposition of being susceptible to injuries, attacks or to have difficulties to reconstitute a compromised state of health. All depends on the vulnerable components placed at the centre of our system: 1.) vulnerability of human beings to natural hazards of the planet, depending on their systems, behaviours and reactions of individuals. 2.) formally more or less fragile natural environments that have been settled, often in excess, and that have become vulnerable due the increase in human activity. 3.) Nature itself. 4.) vulnerabilities: Man, goods, activities, and the environment.

Source: Translated from Reveau, P. (2004): Intérêts et limites des études de vulnérabilité. Risques Naturelles, No. 36, Préventique Sécurité. Sept./Oct. 2004.

25. Vulnerability:

"We propose the term 'susceptibility' for 'vulnerability' in the pre-event phase and 'resilience' for 'vulnerability' in the post-event phase. ... Susceptibility would be predominantly determined by physical features, 'resilience' by socio-economic characteristics."

Source: Schneiderbauer, S. & Ehrlich, D. (2004): Risk, hazard and people's vulnerability to natural hazards. A review of definitions, concepts and data. European Commission Joint Research Centre. EUR 21410 EN. 40 pp.

26. Vulnerability:

"Vulnerability is usually defined as the capacity of a system to be wounded from a stress or perturbation. It is a function of the probability of occurrence of the perturbation and its magnitude, as well as of the ability of the system to absorb and recover from such perturbation."

Source: Suarez, P., 2002: Urbanization, Climate Change and Flood Risk: Addressing the fractal nature of differential vulnerability. Second Annual IIASA-DPRI Meeting INTEGRATED DISASTER RISK MANAGEMENT Megacity Vulnerability and Resilience. 29-31 July, 2002, Laxenburg, Austria. <http://www.iiasa.ac.at/Research/RMS/dpri2002/>, last accessed 24/01/2006.

27. Vulnerability:

"Vulnerability is the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to hazard, either a perturbation or stress/stressor."

Source: Turner, B.L. *et al.* (2003): A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the United States of America (PNAS), Vol. 100, No. 14. pp. 8074-8079. <http://www.pnas.org/cgi/reprint/100/14/8074.pdf>, last accessed 24/01/2006.

28. Vulnerability:

"The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. For positive factors, which increase the ability of people to cope with hazards, see definition of capacity."

Source: UN/ISDR (United Nations International Strategy for Disaster Reduction) (2004): Living with Risk. A global review of disaster reduction initiatives. 2004 version. United Nations, Geneva, 430 pp.

29. Vulnerability:

"A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard."

Source: UNDP (United Nations Development Programme) Bureau for Crisis Prevention and Recovery (2004): Reducing Disaster Risk: a challenge for development. A global report (M. Pelling, A. Maskrey, P. Ruiz, L. Hall, eds.). John S. Swift Co., USA, 146 pp.

30. Vulnerability:

"Vulnerability is expressed as the degree of expected damage (i.e., the cost of repair divided by the cost of replacement) given on a scale of 0 to 1, as a function of hazard intensity (or magnitude, depending on the convention used)."

Source: UNDRO (Office of the United Nations Disaster Relief Co-Ordinator) (1991): Mitigating Natural Disasters. Phenomena, Effects and Options. A Manual for Policy Makers and Planners. UNDRO/MND/1990 Manual, Genf.

31. Vulnerability:

"Represents the interface between exposure to the physical threats to human well-being and the capacity of people and communities to cope with those threats."

Source: UNEP (2002): Global Environment Outlook 3 – Past, Present and Future Perspectives. Earthscan Publications Ltd, London, United Kingdom, 426 pp.

32. Vulnerability:

"V. is the intrinsic and dynamic feature of an element at risk (community, region, state, infrastructure, environment etc.) that determines the expected damage/harm resulting from a given hazardous event and is often even affected by the harmful event itself. V. changes continuously over time and is driven by physical, social, economic and environmental factors."

Source: UNU-EHS

33. Vulnerability:

"This definition [by Chambers, 1989] suggests three basic co-ordinates:
1.) the risk of exposure to crises, stress and shocks
2.) the risk of inadequate capacities to cope with stress, crises and shocks; and
3.) the risk of severe consequences of, and the attendant risks of slow or limited poverty (resiliency) from, crises, risk and shocks."

Sources:
Watts, M.J. & Bohle, H.G. (1993): The space of vulnerability: the causal structure and of hunger and famine. Progress in Human Geography, Vol. 17, 1, pp. 43-67.
Chambers, R. (1989): Editorial Introduction: Vulnerability, Coping, and Policy. IDS Bulletin, Vol. 20, No. 2. 1-7pp.

34. Vulnerability:

"Vulnerability should be recognized as a key indicator of the seriousness of environmental problems such as global warning."

Source: Adger, N., Kelly, M. & Bentham, G. (2001): New Indicators of Vulnerability and Adaptive Capacity. Paper presented at the International Workshop on Vulnerability and Global Environmental Change, Lila Nyagatan. Stockholm, 17-19 May 2001.

35. Vulnerability:

"Vulnerability is provisionally defined as the degree to which a system is sensitive to and unable to cope with adverse impacts of global change stimuli. Vulnerability is therefore a function of a system's exposure to global change stimuli and its adaptive capacity, that is, its ability to cope with these stimuli."

Source: Klein, R. (2003): Environmental Vulnerability Assessment. <http://www.pik-potsdam.de/~richardk/eva/>, last accessed 24/01/2006.

36. Vulnerability:

"The degree to which different classes in society are differentially at risk, both in terms of the probability of occurrence of an extreme event and the degree to which the community absorbs the effects of extreme physical events and helps different classes to recover."

Source: Susman, P., O'Keefe, P. & Wisner, B. (1983): Global disasters, a radical interpretation. In: Hewitt, K. (ed.): *Interpretations of Calamity*. Allen and Undwin. Inc. Boston, pp 263-283.

37. Vulnerability (Urban):

"Urban vulnerability to natural hazards such as earthquakes is a function of human behaviour. It describes the degree to which socioeconomic systems and physical assets in urban areas are either susceptible or resilient to the impact of natural hazards. Vulnerability is independent from any particular magnitude from a specific natural event but dependent on the context in which it occurs. The characteristic of the urban community that can be assessed through a combination of ecological factors associated with the physical conditions of the population in that place. The physical and social conditions are inextricably bound together in many disaster situations that we can use the former as indicative of the latter. V. is continuously modified by human actions and therefore it varies over space and time. V cannot be assessed in absolute terms; the performance of the urban place should be assessed with reference to specific spatial and temporal scales (Rashed & Weeks, 2002). The adaptive and coping capacities that determine the extent to which a society can tolerate damage from extreme events without significant outside assistance."

Source: Mileti, D.S. (1999b): Disasters By Design. A Reassessment of Natural Hazards in the United States. Rothstein Associates Inc. Brookfield, USA. pp. 376.

Resilience

1. Resilience:

"The ability to resist downward pressures and to recover from a shock. From the ecology literature: property that allows a system to absorb and use (even benefit from) change. Where resilience is high, it requires a major disturbance to overcome the limits to qualitative change in a system and allow it to be transformed rapidly into another condition. From the sociology literature: ability to exploit opportunities, and resist and recover from negative shocks."

Source: Alwang, J., Siegel, P.B. & Jorgensen, S. L. (2001): Vulnerability: a view from different disciplines. Social Protection Discussion Paper Series, No. 0115, World Bank. 42 pp. <http//:www.worldbank.org/sp/>, last accessed 24/01/2006.

2. Resilience:

"The capacity that people or groups may possess to withstand or recover from emergencies and which can stand as a counterbalance to vulnerability."

Source: Buckle, P. (1998): Re-defining community and vulnerability in the context of emergency management. Australian Journal of Emergency Management.

<http://online.northumbria.ac.uk/geography_research/radix/resources/buckle-community-vulnerability.pdf>, last accessed 24/01/2006.

3. Resilience:

"Qualities of people, communities, agencies, infrastructure that reduce vulnerability. Not just the absence of vulnerability rather the capacity to 1) prevent, mitigate losses and then if damage occurs 2) to maintain normal living conditions and to 3) manage recovery from the impact."

Source: Buckle, P., Marsh, G. & Smale, S. (2000): New approaches to assessing vulnerability and resilience.
<http://online.northumbria.ac.uk/geography_research/radix/resources/buckle-marsh.pdf>, last accessed 24/01/2006.

4. Resilience:

"A measure of how quickly a system recovers from failures." (Emergency Mngm. Australia, 1998) quoted in Buckle *et al*. (2000).

Source: Buckle, P., Marsh, G. & Smale, S. (2000): New approaches to assessing vulnerability and resilience.
<http://online.northumbria.ac.uk/geography_research/radix/resources/buckle-marsh.pdf>, last accessed 24/01/2006.

5. Resilience:

"Not just the absence of vulnerability. Rather it is the capacity, in the first place, to prevent or mitigate losses and then, secondly, if damage does occur to maintain normal living conditions as far as possible, and thirdly, to manage recovery from the impact."

Source: Buckle, P., Marsh, G. & Smale, S. (2000): New approaches to assessing vulnerability and resilience.
<http://online.northumbria.ac.uk/geography_research/radix/resources/buckle-marsh.pdf>, last accessed 24/01/2006.

6. Resilience:

"Resilience is a measure of the recovery time of a system."

Source: Correira, Santos, Rodrigues (1987): Engineering risk in regional drought studies. pp. 61-86. In: Duckstein & Plate (eds.): Engineering Reliability and Risk in Water Resources. Martinus Nijhoff Publishers, Dordrecht, Boston, Lancaster, pp. 588.

7. Resilience:

"The capacity of a group or organization to withstand loss or damage or to recover from the impact of an emergency or disaster. The higher the resilience, the less likely damage may be, and the faster and more effective recovery is likely to be."

Source: Department of Human Services (2000): Assessing resilience and vulnerability in the context of emergencies: Guidelines. Victorian Government Publishing Service.

8. Resilience:

"The ability of an organization to absorb the impact of a business interruption, and continue to provide a minimum acceptable level of service."

Source: Disaster Recovery Journal: Business Continuity Glossary.
<http://www.drj.com/glossary/glossleft.htm>, last accessed 24/01/2006.

9. Resilience:

Details of Resilience might be inherently unknowable – especially in the case of complex communities undergoing constant change.

Source: Handmer, J. (2002): We are all vulnerable.
<http://online.northumbria.ac.uk/geography_research/radix/resources/vulmeeting-pbmelbourne11.doc>, last accessed 24/01/2006.

10. Resilience:

"The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters and improving risk-reduction measures."

Source: Integrated Regional Information Networks (IRIN) (2006): Disaster Reduction and the human cost of disaster - IRIN Web Special.
<http://www.irinnews.org/webspecials/DR/Definitions.asp>, last accessed 24/01/2006.

11. Resilience:

"The capacity of a system, community or society potentially exposed to hazards to

adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures."

Source: UN/ISDR (United Nations International Strategy for Disaster Reduction) (2004): Living with Risk. A global review of disaster reduction initiatives. 2004 version. United Nations, Geneva, 430 pp.

12. Resilience:

"The concept [of resilience] has been used to characterize a system' ability to bounce back to a reference state after a disturbance and the capacity of a system to maintain certain structures and functions despite disturbance.[…] resilience of the system is often evaluated in terms of the amount of change a given system can undergo (e.g. how much disturbance or stress it can handle) and still remain within the set of natural or desirable states (i.e., remain within the same 'configuration' of states, rather than maintain a single state)."

Source: Turner, B.L. *et al.* (2003): A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the United States of America (PNAS), Vol. 100, No. 14. pp. 8074-8079. <http://www.pnas.org/cgi/reprint/100/14/8074.pdf>, last accessed 24/01/2006.

13. Resilience:

"Resilience is the flip side of vulnerability […] a resilient system or population is not sensitive to climate variability and change and has the capacity to adapt."

Source: IPCC (International Pannel on Climate Change) (2001). Climate Change 2001. Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Integovernmental Panel on Climate Change (R.T. Watson and the Core Writing Team, eds.). Cambridge University Press, Cambridge, United Kingdom, and New York, USA, pp. 398.

Resiliency

1. Resiliency:

"Pliability, flexibility, or elasticity to absorb the event. Resiliency is offered by types of construction, barriers, composition of the land (geological base), geography, bomb shelters, location of dwelling, etc. As resiliency increases, so does the absorbing capacity of the society and/or the environment. Resiliency is the inverse of vulnerability."

Source: Journal of Prehospital and Disaster Medicine (2004): Glossary of Terms. <http://pdm.medicine.wisc.edu/vocab.htm >, last accessed 24/01/2006.

2. Resiliency:

"Resiliency to disasters means a locale can withstand an extreme natural event with a tolerable level of losses. It takes mitigation actions consistent with achieving that level of protection."

Source: Mileti, D.S. (1999b): Disasters By Design. A Reassessment of Natural Hazards in the United States. Rothstein Associates Inc. Brookfield, USA. pp. 376.

3. Resiliency:

"Resiliency is thought of as a characteristic of systems that offers flexibility and scope for adaptation whilst maintaining certain core functions (for example, access to basic needs and social stability)."

Source: Pelling, M. (2003b): Social capital, hazards and adaptation strategies for the vulnerable. Draft. Justice in Adaptation to Climate Change. Seminar for Connective Environmental Research, University of East Anglia, 7-9 September 2003.

Appendix II. Discourses and frameworks for analysing vulnerability and resilience

Discourse	Brief characterisation	Exemplar reference source(s)
Level 1	**General focus – coarser-level**	
Hazards paradigm/ technocratic discourse	Dominant until the 1980s viewing natural hazards, such as floods, as the result of extreme hazard events to be combated by practical application of geophysical and engineering knowledge. Vulnerability not employed in the explanation of hazards and disasters.	Burton *et al.,* 1978 Kates, 1962
Engineering/ Architectural/ Discourse	Application of both vulnerability and resilience, as well as resistance, to buildings and other physical structures to reduce flood damage	Bavarian State Ministry of the Environment, 2006. Department for the Environment Food and Rural Affairs/Environment Agency (DEFRA/EA), 2007. Bosher, 2008.
Climate scientist's discourse	A view of vulnerability in terms of the likelihood of occurrence and impacts of weather and climate related events	Nicholls *et al.,* 1999
Resilience building through urban planning discourse	Urban areas can be designed to make them more resilient to flooding hazards and planning mechanisms such as building codes, land use zoning, flood resistant layout, safe havens and sustainable drainage systems can be employed to increase resilience	Department for Communities and Local Government, 2006 Friesecke, 2004
Economic activity and infrastructure disruption analysis	Application of vulnerability and related concepts (e.g. dependence, transferability and susceptibility) to the modelling of secondary flood damages	Parker *et al.,* 1987
Economic systems vulnerability analysis	Application of economic vulnerability concepts and indices to country level economies to identify vulnerabilities and counteracting economic resilience building strategies. Applications at State level to rank States according to economic fragility to internal and external 'shocks' which can include natural disasters such as floods	Manning, 2004
Socio-ecological resilience discourse	Originally a term from ecology, resilience is viewed as ability to bounce back or rebound, and has also been applied to social systems (it can also be applied to economic systems). The concept and related discourses (see Ahmed, 2006) pre-suppose disturbance and the magnitude of disturbance which can be absorbed (though when applied to engineering it is the speed by which the disturbance is absorbed)	Holling, 1973
Biophysical vulnerability discourse mediated with social vulnerability. Also described	Interprets vulnerability in terms of the amount of potential flood damage and flood loss, relating this to particular land use units e.g. buildings such as houses or factories, and to biophysical flood characteristics (e.g. flood depth, duration etc.). This research often also distinguishes residential flood damage by social factors such as house type and the socio-economic grouping of occupants.	Penning-Rowsell and Chatterton, 1977

as land use loss discourse		
Social/political economy analysis	Disasters are culturally and socially (i.e. socially, economically and politically) embedded phenomenon. Vulnerability is a state or condition independent of a hazard. Vulnerability is the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from a flood disaster, within the context of social, political and economic relations, conditions, structures and institutions which foster poverty, inequality and disadvantage. Vulnerability is structurally determined by inequality, race, poverty, social protection etc.	Blaikie *et al.,* 1994 Cannon, 2000 Wisner *et al.,* 2004
Level 2	**Focus on 'social/political economy discourses' – finer-level**	
Tropicality discourse	A discourse which emerged between the 17th and early 20th centuries within a colonial/medical context, depicting the 'tropics' as hot, diseased and infected places dangerous to human health and disaster-prone, for which Western medicine could offer certain cures and western interference is necessary. A 'two worlds' view: 'us' and 'them' with the vulnerable being 'them'.	Bankoff, 2001 See also Skelton, 2006
Development discourse	A discourse of the post-1945 era built on 'tropicality', focusing upon a drive to replicate the socio-economic characteristics of the West in 'Third World' countries in order to reduce poverty, vulnerability and disaster proneness. The 'Third World' becomes homogenised in this discourse as a culturally undifferentiated mass of humanity associated with powerlessness, passivity, hunger, illiteracy, neediness, oppression and inertia.	Bankoff, 2001 See also Skelton, 2006
Western vulnerability discourse	Vulnerability is valuable in this discourse in that it engages (i.e. criticises) the technocratic approach but it also problematically reflects a particular understanding of large parts of the world as 'unsafe' containing societies and people who are weak, passive and pathetic (Hewitt, 1997, 167) which is an essentially Western perspective.	Bankoff, 2001 See also Skelton, 2006
Vulnerability caused by globalisation discourse	The global economy places pressures on vulnerability to disasters. This discourse focuses upon debt and debt repayment crises and enforced economic restructuring policies which can deepen people's disaster vulnerability	Blaikie *et al.,* 1994, 39-41
Vulnerability as livelihood stress discourse	Vulnerability is the exposure of individuals or collective groups to livelihood stress as a result of the impacts of climate extremes and climate change. Social vulnerability to climate change is made up of individual and collective aspects which are linked through the political economy of markets and institutions.	Adger *et al.,* 2001
Vulnerability as a social construction	Vulnerability is people oriented and determined through perceptions and knowledge, and people's ideas about the root causes of their vulnerability to disaster tend to determine the strategies which they select to counter vulnerability. Taking a perception perspective vulnerability becomes a social construction.	De Marchi *et al.,* 2007
Vulnerability as a psychological condition	Psychological factors affect individual and social anomie and pathological behaviour, and potentials for increased social interaction, cohesion and organisation.	Puente, 1999
Vulnerability and flawed development discourse	This discourse argues that despite claiming to be in the forefront of disaster management and risk reduction, the World Bank IMF and regional banks are promoting policies which sometimes increase the vulnerability to disaster of poor people, and sometimes projects are supported which place people in harm's way	Moss, Undated

Corporate Social Responsibility (CSR) and disaster reduction discourse	Through the principles and ethics of CSR, the private, corporate sector of the world's economies has a moral responsibility for flood and other disaster mitigation including vulnerability reduction. However, action is often one-off, short-term and fragmented in nature.	Matin, 2002
Institutional analysis and vulnerability discourse	Institutional arrangements are viewed as contributing causes of vulnerability and disaster	Lebel *et al.,* 2005 Lebel, 2006
Security, vulnerability and resilience discourse	An emerging paradigm for understanding global vulnerabilities and resiliences whose proponents challenge the traditional notion of national security by arguing that the most appropriate subject for security should be the individual rather than the state. Emerged in the post-Cold War era as a multi-disciplinary understanding of security in which development studies, international relations and human rights are important. Linked concepts are economic security, food security, environmental security and so on	Alkire, 2003

Appendix III. Definitions and concepts related to economic systems vulnerability

Concept	Working definition(s)	Exemplar reference source
Exposure	A measure of human population, land uses and investments located in flood zones and at risk from flooding	Parker 2000, 28/9
Susceptibility	The probability and extent to which the physical presence of water will affect inputs or outputs of an activity (e.g. economic or social activity)	Parker *et al.,* 1987, 18
Resilience	1. The speed with which a community returns to its former state after it has been disturbed 2. Amount of change a system can undergo without changing state 3. The opposite of vulnerability and refers to the ability of an entity to resist or recover from damage 4. The capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure	1-3 Kelman, 2007, 6 4. Rose, 2007 See also the range of definitions of resilience discussed in by Ahmed, 2006; The Resilience Alliance (www.resalliance.org) and London Resilience (www.londonprepared.gov.uk)
Economic resilience	A country's ability to economically cope with or withstand its inherent vulnerability, as a result of some deliberate policy	Briguglio and Galea, Undated Rose, 2007
Economic vulnerability	Inherent, permanent to quasi-permanent features of a country which render that country exposed to a very high degree to economic forces beyond its control	Briguglio and Galea, Undated
Resistance	The degree to which a community or economy or economic activity is able to withstand the adverse loadings placed upon it by a disaster	None identified
Disaster-resistant economy	An economy designed and constructed to minimise the impacts of disasters upon it	www.training.fema.gov/EMIWeb/EMICourses/E464CM/01 Unit 1.pdf
Fragility	A condition of weakness in economic or social structures leading to a lack or robustness and to vulnerability	None identified
Buffering capacity	The ability of a society to minimise the change in an essential function or functions for a given change in available resources (goods and/or services)	www://pdm.medicine.wisc.edu/Guidelines/Chapter3.pdf
Coping capacity	The means by which people and organisations use available resources and abilities to face adverse consequences that could lead to disaster	www.klimaatvoorruimte.nl
Powerlessness	Inability to influence safety conditions or to acquire	Hewitt 1997, 27

	means of protection and relief	
Economic marginalisation	The economic disenfranchisement of individuals, groups or societies because of exclusion, poverty, destitution	Blaikie *et al.,* 1994
Disadvantage	Lack of resources and attributes to affect risks or to respond to hazards	Hewitt 1997, 27
Dependence	The degree to which an activity requires a particular good as an input to function normally	Parker *et al.,* 1987, 15 Van der Veen and Logtmeijer, 2005
Adaptability	The ability to take practical steps to protect countries, communities or activities from the likely disruption and damage caused by hazards	www.klimaatvoorruimte.nl Government Office for London, 2005
Transferability	The ability of an activity to respond to a disruptive threat by overcoming dependence either by deferring or using substitutes or relocating	Parker et al., 1987, 16 Van der Veen and Logtmeijer, 2005
Deferral	Purchases of production are deferred in time when they are delayed in time	Parker *et al.,* 1987, 15
Substitutability	The degree to which a good or service can be replaced by another good or service when the need arises	Parker *et al*., 1987, 24 Van der Veen and Logtmeijer, 2005
Redundancy	An important means of increasing the resilience of a system to disruption by duplicating or triplicating etc. components or linkages such that back up capacity is available should one component or linkage fail. The concept of 'diversity' is closely linked – diverse ecological regimes are generally believed to be more resilient to disturbances	Van der Veen and Logtmeijer, 2005 [Bočkarjova, 2007 #57]
Robustness	The ability of a system to continue to perform satisfactorily under loading imposed by, for example, natural disasters	www.klimaatvoorruimte.nl
Multiplier	A means of calculating the total impact of an initial impact and its subsequent effects	Parker *et al*., 1987, 17 Rose, 2007 Okuyama, 2004 Van der Veen and Logtmeijer, 2005 Bočkarjova 2007
Economic viability	The ability to sustain economic activities or an economy given the balance which exists between costs of production and market prices	None identified

Appendix IV. Volcano-vulnerability related research topics

Table IV.a. Selected volcano-vulnerability related research topics.

Topic	Reference
risk perception	(Greene, Perry *et al.,* 1981; Dominey-Howes and Minos-Minopoulos, 2004; Gregg, Houghton *et al.*, 2004; Barberi, Davis *et al.*, 2008; Carlino, Somma *et al,.* 2008; Chester, Duncan *et al.*, 2008)
community empowerment	(Paton, 2002; Gregg, Houghton *et al.*, 2008)
direct versus vicarious experience	(Paton, Johnston *et al.*, 2001)
effectiveness of volcanic hazard maps	(Haynes, Barclay *et al.*, 2008)
formal and informal risk communication (warning) networks	(Sorensen and Gersmehl, 1980; Heliker, 1990; Gregg, Houghton *et al.*, 2004; Haynes, Barclay *et al.*, 2007)
human behavior	(Lavigne, De Coster *et al.*, 2008)
Preparedness	(Johnston, Houghton *et al.*, 2000; Paton and Johnston, 2001; Gregg, Houghton *et al.*, 2004)
Religion	(Chester, Duncan *et al.,* 2008)
Trust	(Paton, Smith *et al.*, 2008; Haynes, Barclay *et al.*, in press)
Vulnerability	(Thierry, Stieltjes *et al.*, 2008)
warning response and systems	(Sorensen and Gersmehl, 1980; Tayag, Insauriga *et al.*, 1996; Gregg, Houghton *et al.*, 2004)

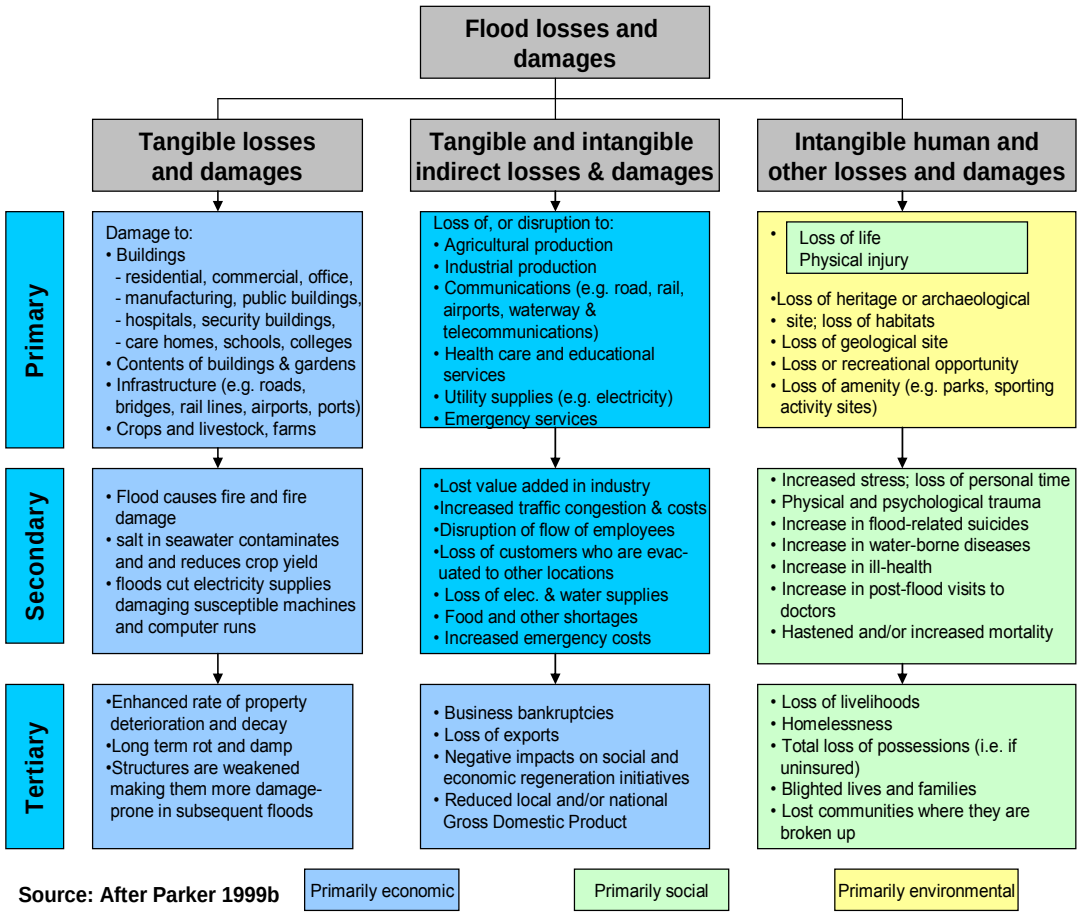
Table IV.b. Selected volcano-vulnerability related research topics related to health.

Topic	Reference
Health effects and mortality/death:	(Baxter, Ing *et al.*, 1983; Baxter, Bernstein *et al.*, 1982; Blong 1984; Baxter and Gresham, 1997; Tanguy, Ribiere *et al.,* 1998; Baxter, 1999)
of volcanic ash inhalation	(Baxter, Ing *et al.*, 1983; Baxter, Bonadonna *et al.*, 1999; Rojas-Ramos, Catalan-Vazquez *et al.*, 2001; Searl, Nicholl *et al.*, 2002; Forbes, Jarvis *et al.*, 2003; Horwell, Fenoglio *et al.*, 2003; Horwell and Baxter, 2006; Horwell, 2007)
of volcanic gas exposure	(Baxter, 1999)
of volcanic aerosol exposure	(Allen, Baxter *et al.*, 2000; Michaud, Grove *et al.*, 2004; Longo, Grunder *et al.*, 2005; Michaud, Krupitsky *et al.*, 2005; Michaud, Michaud *et al.*, 2007)
of pyroclastic surge exposure	(Spence, Baxter *et al.*, 2004; Spence, Kelman *et al.*, 2005)
Health hazards of geothermal areas	(Hansell, Horwell *et al.,* 2006)
Health effects of fluoride	(Cronin and Sharp, 2002; Cronin, Neall *et al.*, 2003)

Appendix V. Definitions of social vulnerability

Definition/concept	Working definition(s)	Exemplar reference source
Social vulnerability	A term used to define the susceptibility of social groups to potential losses from hazard events or society's resistance and resilience to hazard.	Blaikie *et al*., 1994 Hewitt, 1997
Social vulnerability	The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recovery from the impact of a natural hazard … It involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discrete and identifiable event … in nature and in society.	Wisner *et al*., 2004
Social vulnerability	Social vulnerability derives from the activities and circumstances of everyday life or its transformations.	Hewitt, 1997
Social vulnerability	A condition rooted in historical, cultural social and economic processes that impinge on the individual's of society's ability to cope with disasters and adequately respond to them.	Weichselgartner, 2001
Resilience	The capacity for renewal, reorganisation and development	Folke, 2006
Resilience	The ability of a system, community, society, defence to react to and recover from the damaging effect of realised hazards.	Floodsite, 2005
Social resilience	The capacity of a community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.	Floodsite, 2005
Adaptive capacity	The ability or capacity of a system to modify or change its characteristics or behaviour so as to cope better with existing or anticipated external stresses. Adaptive capacity represents potential rather than actual adaptation.	Adger *et al.,* 2004
Social capital	The potential and actual personal relationships of an individual or a group of individuals and the resources which can be mobilized via such networks.	Adger, 2000

Appendix VI. Categorisation of flood damages



Source: After Parker 1999b

Appendix VII. Strategies for managing a reduction in socio-economic vulnerability to disasters

Principle No.	Principle
1	Vigorously manage mitigation
2	Integrate elements of mitigation
3	Capitalise on a disaster to initiate or to develop mitigation
4	Monitor and modify to suit new conditions
5	Focus attention on protection of the most vulnerable
6	Focus on the protection of lives and livelihoods of the vulnerable
7	Focus on active rather than passive approaches
8	Focus on protecting priority sectors
9	Measures must be sustainable over time
10	Assimilate mitigation into normal practices
11	Incorporate mitigation into specific development projects
12	Maintain political commitment

Blakie *et al.* 1994

Appendix VIII. Examples of non-conventional and radical approaches to reducing vulnerability to flood hazards and disasters

Decentralise decision-making and employ and integrate flood knowledge and coping mechanisms of local people and agencies; seek also to prevent the erosion of local knowledge and coping mechanisms
Increase the access of those who are economically marginal and those occupying 'marginalised' hazardous zones to policy-makers and others with power, and seek to empower members of these groups
Reduce social exclusion by introducing inclusionary policies aimed at enhancing the opportunities of low-income groups and those disadvantaged through ethnicity, religion, gender, nutritional and health status, or lack of legal rights
Seek to diversity and strengthen fragile local economies which occupy flood-prone areas such as coastal zones, and prevent policies which jeopardise livelihoods and increase insecurity
Seek to build institutions (e.g. laws, organisational arrangements and public attitudes) which specifically address flood hazard and disaster issues (e.g. a flood protection agency, flood preparedness planning)
Assimilate flood-resistant building designs and other mitigation measures into normal practices
Build flood mitigation into development projects to ensure that new projects do not increase flood hazards and are protected from flood damage and destruction
Train vulnerable communities to prepare for flood hazards and to spread a preventive culture
Seek to avoid culturally and environmentally inappropriate solutions that may be recommended by national and international commercial firms

Parker, 2000, p. 17

Appendix IX. Measures to reduce disaster vulnerability by protecting the poor

Recognise the vulnerability context of the poor within the development framework Livelihood assets, strategies and outcomes and transforming structures (e.g. government, private sector) and processes (laws, institutions)
Community-based disaster management A bottom-up approach to increase people's capacity to reduce vulnerabilities; the community becomes central and acts as a resource; focus is at household level. Involves self-insurance, seasonally-based actions; long-term investments; construction of community support structures; advocacy campaigns
Risk transfer and finance Use of risk pools and risk management strategies of poor households; use of credit markets to smooth production and consumption shocks; deployment of support-led interventions for vulnerability reduction and mitigation; establishment and use of a mitigation/vulnerability reduction fund; national disaster insurance; group-based insurance

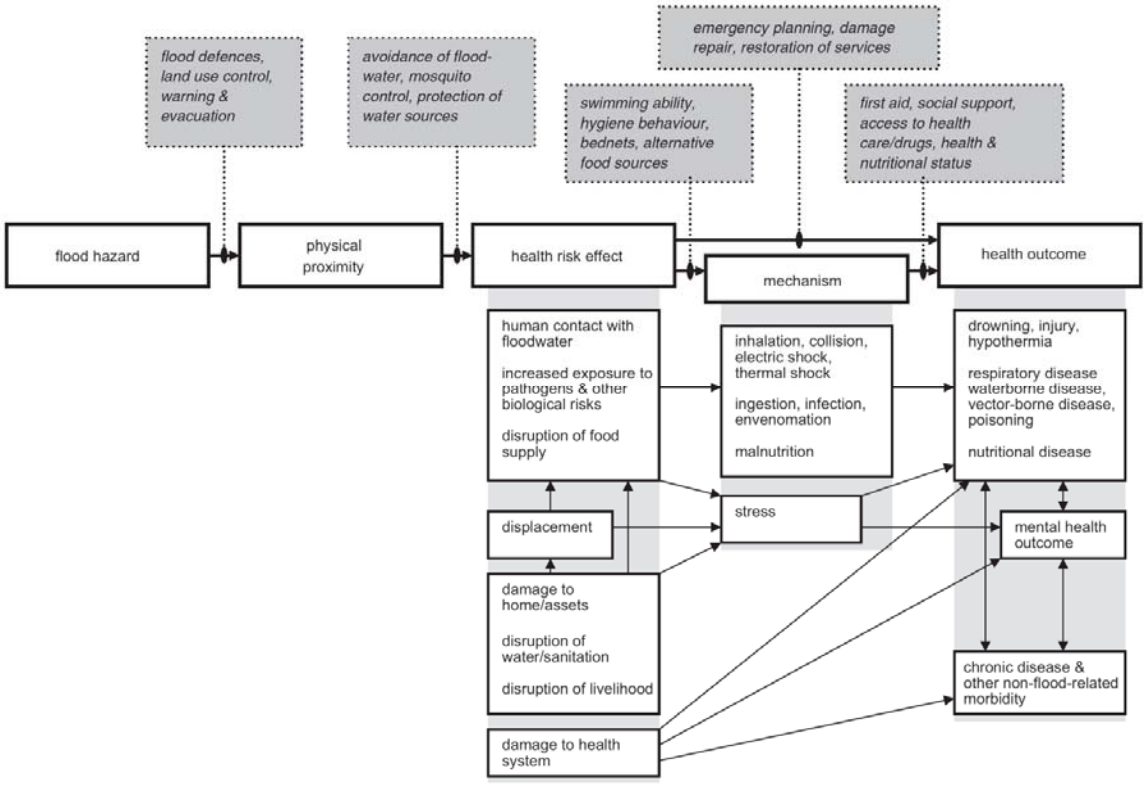
Yodmani, 2001

Appendix X. Methods for assessing social vulnerability

Method or approach	Description	Exemplar reference source
Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) techniques	Largely developed in the context of developing countries for rapid assessment. Uses range of techniques and approaches.	Chambers, 1983
'Pressure and Release model' (PAR) and 'Access model'.	The PAR model aims to show the pressure from both hazard and unsafe conditions that lead to disaster, and then how changes in vulnerability can release people from being at risk. The Access model is an expanded analysis of the principle factors in the PAR model that relate to human vulnerability and exposure to physical hazard, and focuses on the process by which the natural event impacts upon people and their responses. The Access model complements the PAR and unites the two sides of the PAR diagram in a detailed process mode. The two models function in a variety of time scales as root causes, dynamic pressures and unsafe conditions are all subject to change.	Wisner *et al*., 2004
Modified Pressure and Release model	Used in Pakistan to understand the structural causes of vulnerability to flood risk in a case study area. The author concluded that power and the institutional relations that lead to its concentration in a few hands, is the major contributor to vulnerability of all the groups vulnerable to flood hazard. The two key structural causes of vulnerability were identified as: entitlement relations that skew access to productive land and agricultural inputs; a political economy that makes farmers subservient to the needs of the broader cash-driven national and international economic system.	Mustafa, 1998
Social Impact Assessment	SIA is not a single method but a collection of tools and approaches and as such usually requires a team approach. Assessment methods used are diverse and range from large-scale formal studies to participatory research, and may often use RRA and PRA techniques. The selection of relevant tools and methods depends on the context and resources, but normally involves collection of both quantitative and qualitative data. Most of the evidence is primary data from the affected area such as survey research, informant interviews, oral histories, participatory group exercises. Secondary sources that can be used include census data, geographical data (including maps), national and local government statistics, governmental and non-governmental documentation, newspaper reports and previous research. Inclusion of local stakeholders is crucial to the success of SIAs. It has proven difficult, if not impossible, to develop international guidelines for SIA as regulatory, cultural/religious and socio-economic priorities vary greatly. In general SIA can be understood as a framework for evaluation of all impacts on humans and on all the ways in which people and communities interact with their socio-cultural, economic and environmental surroundings. Best suited to country or programme level initiatives where relevant data sets are more likely to be available.	IAIA, 2003 ProVention Consortium, 2007

Social Vulnerability Index (SoVI)	*An index of social vulnerability to environmental hazards. Based on census data available at the county level. Uses a factor analytic approach based on selected indicators.*	Cutter *et* al., 2003
The Social Flood Vulnerability Index (SFVI)	Specifically related to flooding and measures social vulnerability at the local level. Data for the Index is taken from the most recent Census in England and Wales and indicates factors that lead people to be more vulnerable, and therefore less resilient to, exposure to flooding and the impacts from flooding. The choice of data is constrained by the need to (a) use data that is available for the whole of England and Wales and (b) use data that is available for small geographical areas. The SFVI is a composite additive index based on three social groups (the elderly aged 75 and over, single parents, the long-term sick) and four financial deprivation indicators (unemployment, overcrowding in households, non-car ownership, non-home ownership). The Index is categorised into a limited number of bands where category 1 represents low vulnerability to category 5 which represents high vulnerability. Once the data is processed, the mapped results give a clear indication of levels of vulnerability at the local level and between different locations.	Tapsell *et al*., 2002
Health Impact Assessment (HIA)	A relatively new multidisciplinary process. Its potential as a tool for assessing disaster risk or vulnerability has not yet been fully explored. HIA views a range of evidence within a structured framework through a variety of procedures and methods, often integrated with EIA and SIA early in the planning cycle. It uses checklists of determinants as indicators of changes in health risks. Health inequality is a central issue and identification of the most vulnerable groups is very important.	ProVention Consortium, 2007
Health Impact Pathway Model	The model encompasses both quantitative and qualitative research methods and can be used as a tool with which to map out where the different factors that contribute to vulnerability/coping capacity come into effect. The focus of the model is not to derive aggregate measures of risk but to understand how and why the health impacts of hazards vary between individuals and groups in society, and what shapes the ability of people and institutions to cope. The model is meant to be used as an organisational framework for research and analysis and not as a rigid explanatory scheme.	Few, 2007

Appendix XI. Health Impact Pathways Model



Few, 2007: 289

Appendix XII. Examples of indicators and parameters to describe and assess socio-economic and other forms of vulnerability / resilience

Economic systems vulnerability / resilience

Indicator/ parameter	Comments	Reference or source(s)
NATIONAL/GLOBAL REGIONALLEVEL		
Flood losses and time to recover as a relationship between % of GDP and level of development	This is an application of 'Kuznets' Curve' to disaster vulnerability. It describes an inverted U shaped relationship between economic development and disaster vulnerability.	Overseas Development Institute, 2005, p3
Percentage of the population undernourished	Used in the UNDP's Human Assets Index (www.un.org/eas/policy/devplan/profile/definitions.html)	UN Food and Agricultural Organisation (FAO) (www.fao.org/unpp)
Under five mortality rate	Used in the UNDP's Human Assets Index (www.un.org/eas/policy/devplan/profile/definitions.html)	Population Division of the UNDESA, World Population Prospects database (www.eas,un.org/unpp)
Population	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	Population Division of the UNDESA, World Population Prospects database (www.eas,un.org/unpp)
Remoteness (location index)	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	Centre for Study and Research for International Development (CERDI), University of Clermont-Ferrand, France
Merchandise export concentration (Hirschmann indices)	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	UNCTAD, Handbook of International Trade and Development
Share of agriculture, forestry and fisheries in GDP	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	UN Statistics Division, UN National Accounts Main Aggregates Database (www.unstats.un.org/unsd/snaame/selectionbasicfact.asp)
Homelessness due to natural disasters	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	EM-DAT, CRED, University of Louvain, Belgium(www.em-date.net)

Instability of agricultural production	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	UN FAO (www.faostat.fao.org/site/339/default.aspx)
Instability of export of goods and services	Used in the UNDP's Economic Vulnerability Index (EVI) (www.un.org/eas/policy/devplan/profile/definitions.html)	IMF, Balance of Payments Statistics Yearbook
Macro-economic stability	Proposed in the construction of a economic resilience index	Briguglio *et al*., 2004
Micro-economic market efficiency	Proposed in the construction of a economic resilience index	Briguglio *et al.,* 2004
Good governance	Proposed in the construction of a economic resilience index	Briguglio *et al*., 2004
Social development	Proposed in the construction of a economic resilience index	Briguglio *et al.,* 2004
Economic damage generated by floods over a given time period	Output-based indicator. Differentiated by region.	EM-DATA data base, CRED, Catholic University of Louvain (www.cred.be/emdat)
NATIONAL, REGIONAL OR LOCAL LEVEL		
Value of economic assets located in flood risk zones	Predictive indicator Can also be used at regional or local levels	Office of Science and Technology, 2004
Direct economic damage (map Average annual damage/unit area)	Predictive indicator	Office of Science and Technology, 2004 (Irish Catchment Flood Risk Assessment and Management Studies)
Critical infrastructure Point' infrastructure (e.g. hospitals, police stations…)	Predictive indicator	Office of Science and Technology, 2004 (Irish Catchment Flood Risk Assessment and Management Studies)
Transportation routes (e.g. roads, rail routes)	Predictive indicator	Office of Science and Technology, 2004 (Irish Catchment Flood Risk Assessment and Management Studies)
Lengths of transport routes affected	Predictive indicator	Office of Science and Technology, 2004 (quoted as being developed in Thames Estuary 2100 and Catchment Flood Management Plans in England and Wales) Defra/Welsh Assembly/Environment Agency, 2004
Direct economic losses and flood casualty estimates normalised by GDP and population.	Predictive indicator	EU Joint Research Centre quoted in Office of Public Works, 2004

Agricultural impact (potential loss of income from areas of high grade agricultural land)	Predictive indicator	Office of Science and Technology, 2004 (quoted as being developed in Thames Estuary 2100 and Catchment Flood Management Plans in England and Wales) Defra/Welsh Assembly/Environment Agency, 2004

Social systems vulnerability

Indicator/parameter	Comments	Reference source(s)
Number of people killed by floods over a defined time period	Output-based indicator Differentiated by region	EM-DATA data base, CRED, Catholic University of Louvain (www.cred.be/emdat)
Number of people made homeless by floods over a defined time period	Output-based indicator Differentiated by region	EM-DATA data base, CRED, Catholic University of Louvain (www.cred.be/emdat)
Ratio of number killed to affected in floods	Output-based indicator Differentiated by region	EM-DATA data base, CRED, Catholic University of Louvain (www.cred.be/emdat) and Adger *et al.,* 2004
Population estimated to be at risk from flooding as a percentage of total population of spatial territory (e.g. country or catchment or functional urban area)	Predictive indicator Differentiated by a) protected and b) unprotected from flooding by flood defences	Parker, 1996
Vulnerable communities and infrastructure	Predictive indicator identified in pre-event flood incident management planning. Also use of 'Risk Registers' which identify vulnerable households in flood risk zones (these register are compiled by local authorities in England	Office of Public Works, 2008
Density of residential properties	Predictive indicator	Office of Public Works, 2008 (in the Fingal-East Meath study)
High social vulnerability sites (e.g. care homes)	Predictive indicator	Office of Public Works, 2008 (in the Fingal-East Meath study)
Numbers of people affected by deep or fast water or fast onset of flooding.	Predictive indicator	UK Catchment Flood Management Plans
Numbers of people covered by flood warning or emergency /	Predictive indicator	UK Catchment Flood Management Plans

evacuation plans		
Community disruption • Numbers of properties • Social vulnerability • Extent of disruption i.e. few properties to whole community • Duration of disruption community facilities affected e.g. schools, colleges, surgeries / health centres	Predictive indicator	UK Catchment Flood Management Plans
Degree of public flood awareness		
Proportion of at risk population provided with a flood warning system		

Institutional systems vulnerability

Indicator/parameter	Comments	Reference source(s)
Presence or absence of effective policy instruments for addressing social justice issues relating to flood management	The implementation of 'fair' flood risk management policies depends upon institutions possessing effective policy instruments for addressing social justice issues, and where these are absence there will be institutional weakness or vulnerability	Johnson, Penning-Rowsell and Parker, 2007
Disciplinary composition of scientific staff	Where the scientific staff composition of a flood management organisation is narrowly-based for historical reasons and the flood management task has broadened into the socio-economic sphere, the staffing composition may no longer be adequate leading to institutional weakness	
Degree of hegemonic competition between flood emergency response agencies	Where competition for leadership is high, the close cooperation required in responding successfully to a flood emergency is unlikely to be present and communications between agencies is likely to be poor	
Frequency of joint training exercises or rehearsals among key flood emergency response agencies	Where the frequency of joint training exercises is high, the level of performance of the flood emergency response system is likely to be high	
Presence of absence of lead agency designation among flood emergency response organisations	Lack of designation of lead agency status may lead to delayed or lack of decision-making in flood emergencies leading to institutional vulnerability	

Appendix XIII. Indicators for assessing social vulnerability to floods

Indicators for assessing social vulnerability to floods - + = increases vulnerability while - = decreases vulnerability

Indicators for assessing social vulnerability to floods
• Age - very young and elderly (+) • Women - impacts (+) • Men (particularly young) - risk taking behaviour (+) • Long-term-illness or disability (+) • Employed (-), unemployed (+) • Occupation (+/- skilled or unskilled, also linked to income and financial status) • Education level (higher level -, low level +) • Family/household composition (large families +, single parents +, single person households +, home owner -, renter +) • Length of residence (linked to prior experience, short residence +) • Proportion of ethnic minorities and new migrants/visitors (large no. +) • Type of housing (single storey and mobile housing +) • Levels of risk awareness and preparedness (high awareness -, low awareness +) • Serviced by flood warning system (yes -, no +) • Previous flood experience (no experience +) • Access to decision-making (increased access -) • Trust in authorities (no +, yes -) • Social capital/networks (yes -, no +)

Tapsell *et al.,* 2005

Appendix XIV. Cases of application of models, methodologies and indicators

Case description and *level of development of case study territory*	**Application type and *scale***	**Reference source**
The benefits of flood alleviation: sea defence at the coast *Post-industrialised*	Unit-loss methodological approach to urban flood damage modelling Event-tree modelling approach to death from floods *Sub-regional*	Penning-Rowsell *et al.,* 2005 (Ch. 5)
Flood Loss Potentials in Non-Agricultural Sectors, Assessment Methods, Bangladesh *Less-developed*	Flood loss assessment methodologies for use in Bangladesh *Sub-regional case studies*	Islam, 2005
Impacts of Flood in Urban Bangladesh *Less developed*	Inter-sectoral macro and micro level modelling of urban flood loss potential in Bangladesh *Sub-regional case studies but method applicable to national scale*	Islam, 2006
Assessing the economic impacts of large-scale flooding in The Netherlands *Post-industrialised*	Inter-sectoral modelling of the structural economic effects of large-scale flooding *Regional/national*	van der Veen *et al.,* 2003
Identification of the health and social effects of riverine flooding in England *Post-industrialised*	Focus group, self-reporting health questionnaires, interviews and longitudinal comparison methodologies employed to reveal health and social effects *Local case studies*	Tapsell *et al.,* 1999, 2003 Tapsell 2000
Social vulnerability and resilience to torrent and flash flood hazards in the North Italian Alpine region *Industrialised*	Sociological methodology enquiry into social and organisational factors affecting vulnerability and resilience to flooding in a variety of settlements *Local and sub-regional case studies*	De Marchi *et al*., 2007
Social vulnerability to the 2002 flooding in the Elbe catchment (Mulde River) in Germany *Industrialised*	Sociological methodology enquiry into social and organisational factors affecting vulnerability and resilience to flooding in a variety of settlements *Local and sub-regional case study*	Steinführer and Kuhlicke, 2007

Appendix XV. Categories of flood vulnerability indicators