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Del. 1.2:

Comparison of vulnerability concepts used in Natural Hazards to those used in Climate Change analyses

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Short Description:

The aim of the deliverable 1.2 is to compare the vulnerability concepts used in the field of natural hazards and climate change. Key similarities as well as differences will be discussed by comparing vulnerability assessment case study provided by both communities at different spatial scales.

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Partners owning: PIK

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List of Abbreviations

IPCC	Intergovernmental Panel on Climate Change
PAR model	Press and Release Model
NRW	North Rhine-Westphalia

1 Introduction

Scientific approaches to vulnerability evolved considerably in recent years, both stimulated by theoretical and methodological advances and also with the uprising of new issues created by the interweaving of natural, technological and social hazards of contemporary society. As human interventions in physical space produced more complex socio-spatial relations, risks were transformed from localized events into phenomena whose roots are to be found in the very essence of contemporary life, in what sociologists have called risk society (Beck 1992). The multidimensionality of contemporary hazards has made such hybrid hazards (with natural, technological and social causalities) a challenge for today's hazards researchers (Jones 1993).

Nevertheless vulnerability is a weak concept, in terms of its mathematical definition, but it is also a powerful tool, because it allows comparing situations for regional entities of sectors. Generally speaking we can distinguish three main domains using the vulnerability concept: The climate change community, the hazard community and social sciences. While the latter have clearly individual vulnerability in their focus, the climate change community tries to have a look into the future considering climate change projections. In contrast the hazard community is more event related, i.e. it often uses time series data of extreme events for hazard analysis. One can say that this community is more hazard related in the sense that physical vulnerability depends on the stress.

Vulnerability is a complex term which has been used in many different ways by many scholarly communities. The concept has been very widely treated in the literature, and the recent review by Villagrán (Villagrán 2006) and Birkmann (Birkmann 2006) draws together some highlights of this range of opinion.

Vulnerability has also been used as a powerful analytical tool for describing states of susceptibility to harm, powerlessness, and marginality of both physical and social systems, and also for guiding normative analysis of actions to enhance well-being through reduction of risk (Adger 2006).

In regard to the assessment and reduction of socio-economic vulnerability (related to climate and weather related hazards) different research communities such as the disaster risk reduction and climate change have taken up the discussion individually (Thomalla *et al.* 2006) generating some misunderstandings between and within both communities. Confusion about the meaning of vulnerability between these communities finds its roots on the use of different terminologies and a common understanding is still lacking despite being pointed out repeatedly in the literature as a research need (Brooks 2003, UNISDR 2007, Janssen and Ostrom 2006).

In the natural hazards community perspective, vulnerability is interpreted in many cases as a function of exposure to a specific set of exogenous biophysical threats arising from global environmental change. It is mainly viewed as a constitutive part of risk, the characterization of the threat(s) and the nature of exposure are the main focus of research. This is now changing and becoming much more in line with climate change research since vulnerability and resilience of socio-economic systems are also being considered.

Regarding climate change research, vulnerability is the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change (Füssel and Klein 2006). Within this community different definitions on vulnerability arise. For example, the "end point" definition sees vulnerability as the residual of climate change impacts minus adaptation (the remaining segments of the possible impacts of climate change that are not targeted through adaptation). In contrast, the "starting point" definition views vulnerability as a general characteristic of societies generated by different social and economic factors and processes.

Many of the discrepancies in the meanings of vulnerability arise from different epistemological orientations (political ecology, human ecology, physical science, spatial analysis) and subsequent methodological practices. Also, there is considerable variation in the choice of hazards themselves (famine, floods, drought, seismic events, and technology (Cutter 1996). Identical terms may have altogether different meanings and a literature review allows identifying how vulnerability terms are defined by several authors. Vulnerability can therefore be broadly defined as:

- The particular state of a system before an event triggers a disaster, described in terms of particular indicators or parameters of such a system.
- The probability of the outcome of a system, expressed in terms of losses, measured in terms of either fatalities or economic impact.
- A combination of a particular state of the system with other factors such as the inherent capacity to resist the impact of the event (resilience) and the capacity to cope with it (coping capacities).

(Birkman 2006)

Despite the confusion of interpretations, some consensus can be found between competing definitions of vulnerability if we frame it simply as *the predisposition of a system to be harmed*. If vulnerability is expressed in this way, we may be able to gather all definitions under the same umbrella. Nevertheless, by doing so, we end up oversimplifying a complex concept without contributing to the clarification of vulnerability across different scientific domains. This is of special relevance in the context of the ENSURE project since both communities (natural hazards and climate change) will share and discuss aspects of vulnerability. Therefore, in order to understand differences and similarities as well as the terminological variation used, a comparison between vulnerability concepts adopted by both communities is necessary.

In the forthcoming chapter, we aim to understand the basic assumptions on the different concepts of vulnerability. An overview on the definition of vulnerability applied by both communities will be carried out. Despite this, we believe that looking at definitions is valuable but not the exclusive tool to extract possible overlaps on the concepts. In our view, a valuable way to draw new insights into a possible integration of vulnerability models is to compare concrete vulnerability case studies (methods, terminology, results) performed by both communities at different spatial scales and across several hazard types.

2 Structure of the deliverable

The deliverable will unfold as follows: On the first part of section 3 an overview of the most recent and frequent conceptualization of vulnerability found in climate change and natural hazards literature is made. In addition, links within the two scientific communities that reflect a common understanding on vulnerability components are drawn.

Section 4 reflects the idea expressed in the introduction that looking exclusively at definitions might not be enough to mode the discussion on misunderstandings of vulnerability formulations forward. Therefore, for both communities, a collection of vulnerability case studies assessments obtained from scientific literature is reviewed and the operation of the stated vulnerability concept is assessed. The results of the case meta-analysis bring section 4 to and end. Here one can find the main reasons why different vulnerability interpretations can be grouped into four classes regardless of hazard studied or scientific community. In addition the distribution of case studies within different classes of vulnerability and risk can be observed and quantified.

Section 5 builds on the results from all the previous sections exposing the links on vulnerability formulation between Climate Change and Natural Hazards communities. We try to derive what similar meanings are carried by different words and what words carry the same meanings. Limitations in the operation of the vulnerability concepts are also approached. Finally section 6 explored the conclusions of the deliverable pointing new challenges and ways for future vulnerability assessments.

3 Vulnerability concept in different frameworks

3.1 Vulnerability in natural hazards context

The concept of vulnerability to disasters comprises a variety of components, allowing for different possible interpretations. There has been heightened scientific interest in this concept since the 1970s and especially the mid-1980s. Nevertheless, its meaning remains vague. In the last decades the focus on disasters and susceptibility to them changed. Vulnerability used to be criticized in the field of natural disasters because it rarely mentioned the underlying causes of increased social vulnerability to hazards or disaster events (Cutter 1996). Today however, more attention is given to the connection between social, economic, political and technical factors as the primary causes than before when natural causes and technical solutions were emphasized. New factors such as ecological problems are being identified but without sufficient understanding about the exact interrelations (Feldbrügge and Braun 2002)

A common theme in the disaster literature is the idea that vulnerability is defined with respect to natural disasters; people, households and communities are vulnerable to damages from a natural disaster (Kreimer and Arnold 2000). The focus on risk and the degree of vulnerability is determined, in part, by social factors; for instance, the literature on vulnerability to famine discusses vulnerability as a predisposition to famine before the impact of a specific trigger event. Vulnerability is usually defined as an underlying condition, distinguished from the risky events that may trigger the outcome (Webb 1993). Blakie 1994 (Blakie et al. 1994) argues that at least since the early 1990s, the risk disaster community recognized that vulnerability includes both elements of risks and responsiveness to risks. Triggers of natural disasters occur, but households and social systems allow them to become (or prevent them from becoming) disasters through their response. A typical definition of vulnerability from this field of research frames vulnerability as 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 disaster" (Blaikie et al. 1994).

Vulnerability is measured as the hazard's outcome for a population such as lives lost, area flooded, or yield decline. The vulnerability assessments produced have been described as useful to determine potential damages and loss of lives from extreme events (Cutter 1996) and also in proposing hazard reduction alternatives where mitigation normally takes the form of structural (engineered) approaches to hazard reduction (Coburn and Spence 1992; Clayton 1994). The definition of vulnerability in the hazards community tends to address primarily to physical systems and it is descriptive rather than explanatory (Füssel 2007). Vulnerability appears as a component of risk whose concept can be generally described, in the risk-hazard research community, by the following equation:

$$\text{Risk} = f(\text{Exposure}, \text{Hazard}, \text{Vulnerability})$$

Equation 1

Although the mathematical formulation of risk seems to be unambiguous and pose no great misunderstanding, its translation to natural language originates numerous interpretations according to a variety of authors. A short and chronologic sorted list of examples on the definition of risk in the hazard and disaster management literature provides some ideas about how the risk concept is formulated in natural language and how it evolved.

- "The concept of risk implies the possibility of suffering a loss" (Burby 1991)
- "The potential for accidental incapacitation or casualty, the chance of dying immediately or in the future as a result of exposure to an hazard" (Lafond and Gosselin 1994).
- "The term risk refers to the expected losses from a given hazard to a given element at risk, over a specified future time period" (Coburn 1994).
- "Risk is a function of the probability of the specified natural hazard event and vulnerability of cultural entities" (Chapman 1994).
- "A compound measure combining the probability and magnitude of an adverse effect" (Adams 1995)
- "Probability x consequence" (Jones and Boer 2003)
- "Risk can be considered as the possibility of suffering harm from a hazard" (Eastman et al. 1997).
- "The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions" (UNISDR 2004).

From the rather simplistic overarching definition of Burby (Burby 1991) to the more elaborated wording provided by UNIDSR (UNIDSR 2004), the concept of risk in the hazard and disaster literature evolved across time incorporating new, and refining existing elements. Aspects like exposure to hazard, time frame period of analysis, inclusion of socio-cultural aspects and vulnerability have been incorporated throughout time in the concept of risk. It's precisely on the inclusion of the term vulnerability that we are most interested in.

It is broadly accepted in the scientific community that risk cannot only be determined as a function of hazard, describing the possibility of physical harm, but must also include the vulnerability of the element at risk (Cannon 1993, Garatwa and Bollin 2001). The UNDP (UNDP 2004) defines therefore a conceptual superstructure for risk including vulnerability as follows:

$$\mathrm{R}isk = \mathrm{Hazard} \times \mathrm{Vulnerability}$$

Equation 2

Here, risk results from the interaction of a hazard and the several components of vulnerability. Bohle 2001 (Bohle 2001) identifies in this overall structure of risk an internal and an external side. The internal sides relates with the capacity of the system to anticipate, cope with and recover from an impact, the internal side corresponds to vulnerability. On the other hand, risk also exhibits an external side that is connected with the intensity and type of hazard. The risk associated with some particular hazard lies in the consequences of that hazard, and increases with both the probability and severity of the hazard. Hazard is defined by the probability of occurrence and its possible severity, while vulnerability usually depicts the conditions inherent in an exposure unit; furthermore, in this perspective of vulnerability, hazard is taken as known and stationary (Downing et al. 1999).

Taubenböck (2008) argues that although the UNDP framework describes the general correlation between hazard and vulnerability, it displays abstraction on the complex relations of both components (vulnerability and hazard) and their various aspects. White et al. (2005) further elaborates on the vulnerability part of the risk equations defining it as follows:

$$\mathrm{Vulnerability} = \frac{\mathrm{Exposure} \times \mathrm{Susceptibility}}{\mathrm{Coping\ Capacity}}$$

Equation 3

The term vulnerability appears to be now much better defined, nevertheless, a quick clarification on the new elements of exposure, susceptibility and coping capacity is still necessary. Exposure is defined by Adger (2006) as being the degree, duration and/or extent in which a system is in contact with or subjected to perturbation. Susceptibility reflects the capacity of individuals or groups, and of socio-economic or physical systems, to resist the impact of the hazard. Coping capacity can be perceived in many different forms, but generally it translates the ability to cope with or adapt to the hazard stress.

Alwang (2001) reports that most disaster management studies are based on some version of the following relationship.

$$\mathrm{Vulnerability} = \mathrm{Hazard} - \mathrm{Coping}$$

Equation 4

Hazard is here defined as a function of: probability, primacy (shock value based on time, elapsed since previous occurrence), predictability (degree of warning available), prevalence (the extent and duration of hazard impacts) and pressure (the intensity of an impact). Coping is a function of perceptions (of risk and potential avenues of action), possibilities (options ranging from avoidance and insurance, prevention, mitigation, coping), private action (degree to which social capital can be invoked), and public action (Webb and Harinarayan 1999, Sharma et al. 2000).

Frameworks for vulnerability/risk assessments are common tools used by the natural hazard community. They help to identify relations between vulnerability/risk elements and serve as guidelines for translating the conceptual thinking into practical work. This paragraph takes a look at some frameworks developed in the natural hazards community context in order to evaluate the placement of the elements "vulnerability" and its relations to other elements proposed in the framework.

The conceptual framework to identify disaster risk proposed by Davidson (1997) views vulnerability, coping capacity, exposure and hazard as separated features contributing to risk (Figure 1). Vulnerability assumes a physical, social, economic and environmental dimension and it's seen as a component to assess risk.

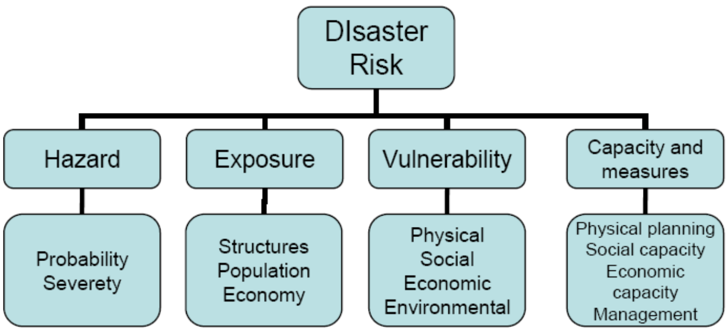

Figure 1 – Conceptual framework to identify disaster risk (Davidson 1997))

Another conceptualization of risk widely applied to research on natural disaster (Granger 2003) is the risk triangle (Crichton 1999). In this conception a triangle serves as a metaphor for illustrating that, and how, risk depends on three components: vulnerability, hazard and exposure (Wolf [1], 2008). This concept, in its original version or slightly modified, has been widely accepted and applied for research on natural disasters (for example Peduzzi et al. 2002, Granger 2003, Dilley et al. 2005).

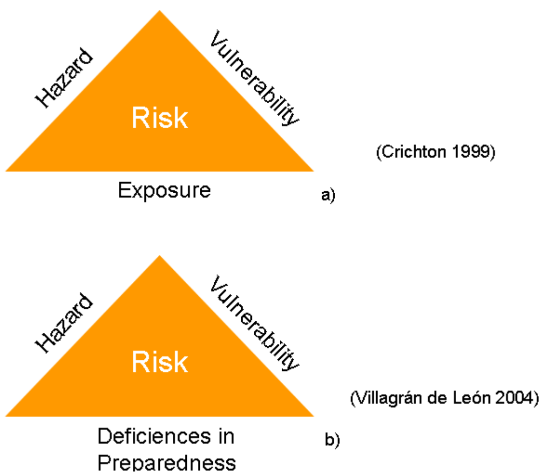

Figure 2 – Conceptualizations of the risk triangle by Crichton (a) and Vilagrán (b)

The mathematical formulation of the risk triangle by Crichton 1999 (Figure 2 a) can be formulated in the following equation:

$$Risk = Hazard \times Exposure \times Vu\ln erability$$

Equation 5

As identified by Wolf [2] et al. (2008) the component of vulnerability is defined in the risk triangle approach with no consideration of an uncertain future, denoted by defining vulnerability as "the extent to which (property) will suffer lost". This point is rather important since it will constitute one of the most differentiating aspects in both communities as we will see in the coming chapters.

Villagrán de León (Villagrán de León 2004) also explains vulnerability in the hazard and risk context. He defines a triangle of risk which consists of three components: vulnerability, hazard and, instead of exposure as in Crichton (1999), Villagrán defines the third component as deficiencies in preparedness (Figure 2 b). He defines vulnerability as the pre-existing conditions that make infrastructures, processes, services and productivity more prone to be affected by an external hazard. Villagrán uses the negative term "Deficiencies in Preparedness" to capture the lack of coping capacities or a specific element at risk. Note that the component "exposure" is not directly mentioned, nevertheless, this author also perceives exposure as a component of risk (Villagrán de León 2004).

Another conceptual framework for vulnerability was developed by the United Nations International Strategy for Disaster Reduction (UN/ISDR). This framework also views vulnerability as a key factor determining risk. Vulnerability can here be classified into social, economic, physical, and environmental components (see Figure 3), similar to the framework proposed by Davidson (Davidson 1997). Although this framework provides an important overview of different phases to be taken into account in disaster reduction, the framework does not indicate how reduction vulnerability can also reduce risk since vulnerability is placed outside preparedness. This makes it difficult to understand the necessity of reducing risk through vulnerability reduction, in fact, in this framework risk and vulnerability cannot be reduced directly. The framework underlines that early warning and preparedness response can reduce the disaster impact, nevertheless, a link between risk factors and the application of risk reduction measures is not included. Furthermore, it was identified that the framework fails in delivering an answer if exposure should be seen as a feature of the hazard or of vulnerability (Birkmann 2006).

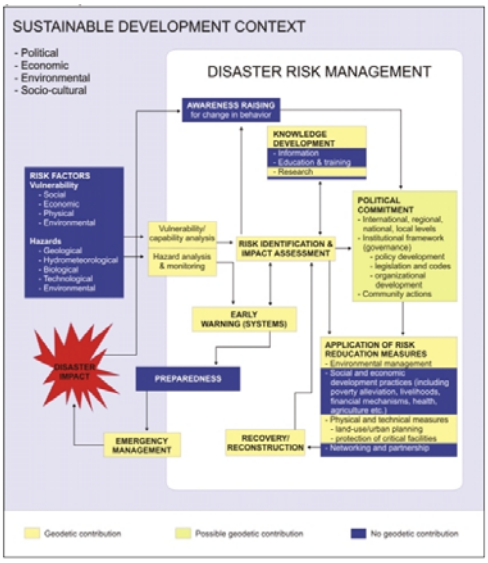

Figure 3 - The ISDR framework for disaster risk reduction (UN/ISDR 2004)

Vulnerability is defined in the UN/ISDR framework as the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of a hazard. This is very close to the definition of the United Nations Development Program (UNDP 2004), the main difference is that the conditions for vulnerability are now further specified as human conditions or processes. The remaining definition is almost the same: Vulnerability is something that enhances the likelihood of the impact of a given hazard.

Finally, for the Press and Release model (PAR model) a disaster is the intersection of two opposing forces (Figure 4). On one side are the forces and processes generating vulnerability and the other side the natural hazard event (or sometimes a slowly unfolding natural process). Increasing pressure on people arise from either their vulnerability or the impact (and severity) of the hazard. The PAR model puts a strong emphasis on vulnerability rooted on social processes and underlying causes that can be ultimately very far from the disaster event itself.

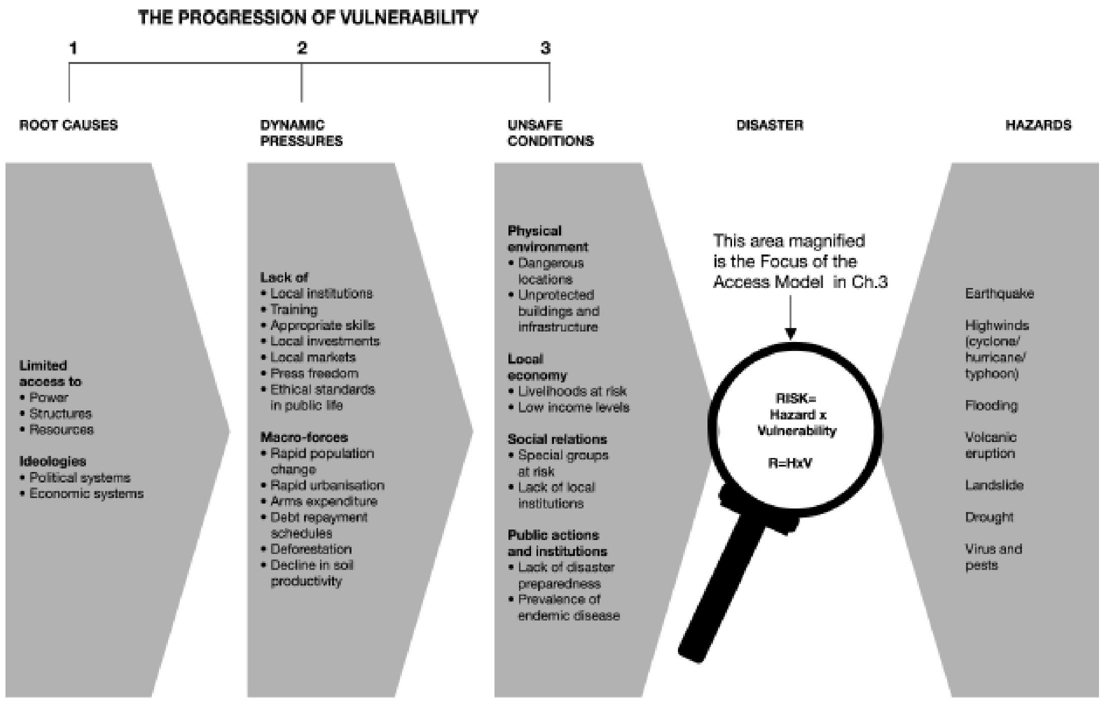

Figure 4 – Graphical representation of the Press and Release model framework

The PAR model forms a 'chain of explanation': It is an analytical tool and subject to a number of inadequacies. One identified weakness is that the generation of vulnerability is not adequately integrated with the way in which hazards themselves affect people; it is a static model (Wisener et al. 2003). It emphasizes the distinction between hazard and social processes in order to stress the social causation of disasters. Hazards in this framework are intertwined with human systems affecting the pattern of assets and livelihoods among people (for instance, affecting land distribution and ownership after floods).

Wisener et al. (2003) argue that to avoid false separation of hazards from social system, a second framework called the Access Model must be pushed forward. The Access Model focuses on the way unsafe conditions arise in relation to the economic and political processes, income and other resources in a society, allowing at he same time the integration of nature in the explanation of hazard impacts. Social systems create the conditions in which hazards have a differential impact on various societies and different groups within society. Nature itself constitutes a part of the resources that are allocated by social processes, and under these conditions people become more or less vulnerable to hazard impacts. The definition of risk here is the same as *Equation 2*.

3.2 Linking vulnerability concepts in a Natural Hazards context

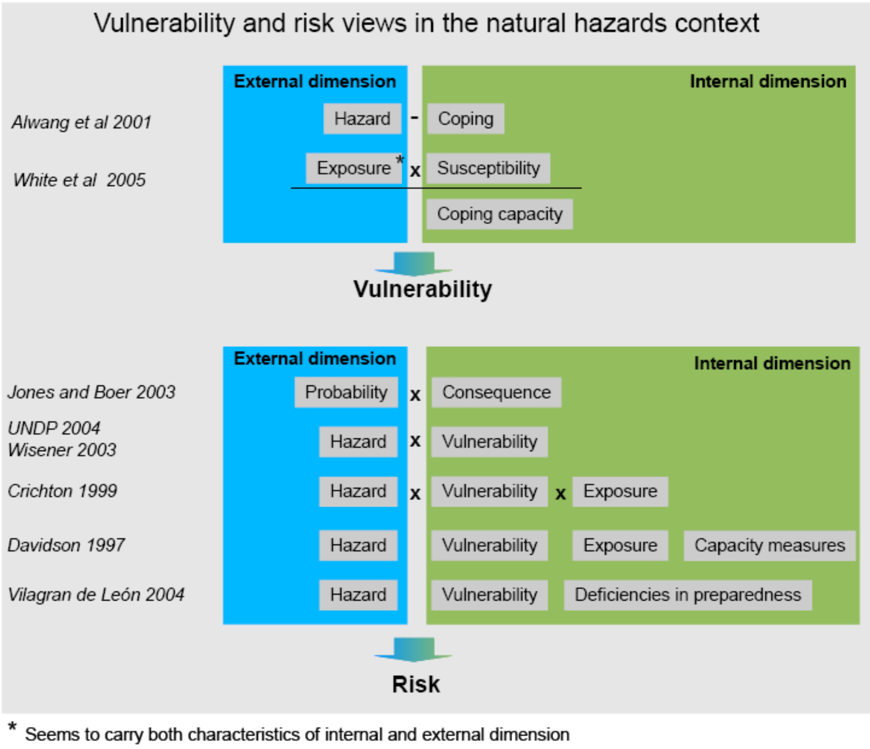

Figure 5 - Vulnerability concepts and vulnerability as part of risk according to several authors in the Natural Hazard context

Summing up, the key aspect of the risk-hazard approach is the clear distinction between two factors that determine the risk of a particular system: The element "hazard", which is a potential damaging physical event, phenomenon or human activity characterized by its location, intensity, frequency and probability. And the element "vulnerability", which denotes the relationship between the severity and the degree of damage caused (Füssel 2007). External and internal sides of both vulnerability and risk concepts were found in different frameworks proposed by several authors.

Alwang (2001) frames hazard as a function of probability, predictability, extent and intensity of the impact, this reflects the external side of vulnerability. The internal side is named coping and seems to be a broad designation for a mixture of perception, possibilities, public and private actions.

White et al. (2005) elaborate on the external side of vulnerability as being represented by exposure. The description of the element "exposure" generates some confusion about the placement in the internal or external dimension of vulnerability. In the definition provided, exposure results both from "*the frequency and severity of weather-related disasters*" or system characteristics such as "*rapid urban growth which increases exposure to landslides, earthquakes or fires*." The wording "frequency and severity" clearly places the element exposure as a external side of vulnerability and in line with the element "hazard" when vulnerability is framed as a constitutive part of risk. On the other hand, mentioning that exposure also results from "*rapid urban growth*" shifts the element "exposure" to the internal dimension of vulnerability and brings the definition closer to the one used when exposure is defined under risk in the frameworks of namely Crichton (1999) and Davidson (1997).

The internal side is defined both by the terms susceptibility and coping capacity. Susceptibility carries the meaning of the ability to resist an impact while coping capacity points to the ability to cope and adapt to the hazard stress. Increased susceptibility is said to result from development measures which erode capacity to cope with and recover from hazard impacts. For example, the running down of state-run social protection or the decline of informal safety net mechanisms associated with some development projects. Susceptibility takes into account social, economic, political, psychological and environmental variables that intervene in producing different impacts amongst people with similar levels of exposure. This definition of susceptibility is close to the definition of the element "exposure" in the risk frameworks, for example in Davidson (1997) where exposure is said to be dependent on social, economic and infrastructural settings. Coping capacity is described as the ability to absorb impacts by guarding against or adapting to them.

In the definition of risk we could also identify the existence of internal and external dimensions. When presented as a constituent part of risk, vulnerability occupies the internal dimension according to all analysed authors. The UNDP (2004) frames vulnerability as the only element in the internal dimension of risk while Crichton (1999) and Davidson (1997) add also the element "exposure" to the internal side. Davidson elaborates further and includes "capacity measures", on the other hand, Vilagran de Léon (2004) excludes the element "exposure" and defines the internal side of risk as constituted by the elements "vulnerability" and "deficiencies in preparedness". When vulnerability is framed as part of risk we can perceive shifts in some elements when compared with the definition proposed by White (2001), on the other hand, similarities in terminology were found.

For example, with the introduction of the element "hazard", the element "exposure" becomes an internal side of risk, in opposition, when vulnerability is defined by White (White et al. 2005), "exposure" occupies the internal side.

The same word, exposure, is used as an element in both the definitions of vulnerability and risk. When "exposure" is defined as an element of risk, it addresses to the elements exposed to a hazard, an inventory of people and artifacts exposed to a hazard (UNDP 2004) or the economic value at risk for a given area and hazard (European Spatial Planning Observation Network 2003). When the element "exposure" is defined as part of vulnerability, it addresses not only to the extent in which a system is subjected to perturbation (Adger 2006) but it also carries the information of duration and degree of the perturbation.

The element "deficiencies in preparedness" is framed by Vilagran (2004) as a negative term for showing the evidence on the lack of coping capacity of a particular element at risk. The element "coping capacity" in the White (2005) framework of vulnerability, although different in terminological terms, resembles in meaning the term "deficiencies in preparedness" because it also refers to the ability to cope with the hazard stress (Taubenböck 2007).

3.3 Vulnerability in a global change context

Taking a similar approach from the previous chapter, the following analysis looks at vulnerability concepts used in a global change context. Here two main frameworks were indentified, the one proposed by the IPCC (2007) and taken as representative for the climate change community and one proposed by Turner et al. (2003) with a focus on sustainability.

Assessments of vulnerability to climate change are aimed at informing the development of policies that reduce the risks associated with climate change. Vulnerability is here described as the system's susceptibility to experience damage, resulting from the impacts of a hazardous event. In this context, the Intergovernmental Panel for Climate Change (IPCC) defines vulnerability as the *"degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes"*. Vulnerability is therefore a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007). Differences in exposure to the various direct effects of climate change and different sensitivities to these direct effects lead to different potential impacts on the system. The adaptive capacity of the system then determines the system vulnerability to these potential impacts (Ionesco, Klein *et al.* 2008). These relationships can be visible in the conceptualization of vulnerability according to the IPCC in Figure 6.

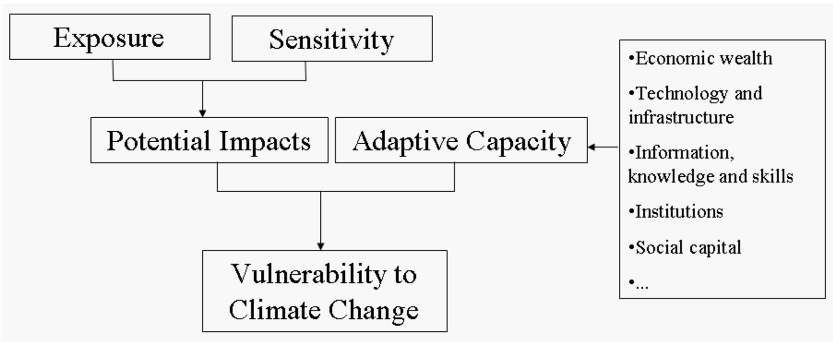

Figure 6 - Graphical representation of the conceptualization of vulnerability to climate change in the IPCC Third Assessment Report (Ionesco, Klein et al.. 2008)

Here vulnerability includes an external dimension, which is represented by the "exposure" of a system to climate variations, as well as an internal dimension, which comprises its "sensitivity" and its "adaptive capacity" to these stressors. Here the term vulnerability can refer to the vulnerable system itself, for example, low-lying islands or coastal cities; to the impact in this system, e.g., flooding of coastal cities and agricultural lands or forced migration; and finally to the mechanism causing these impacts, like the disintegration of the West Antarctic ice sheet as an example.
The conceptual framework of vulnerability for sustainability science (Figure 7) developed by Turner et al. (2003) and taken as representative of the global change community, defines vulnerability in the context of a coupled human-environment system (Turner, Kasperson et al. 2003). Exposure, sensitivity and resilience are part of what constitutes the vulnerability of a system under analysis; this is much closer to the definition pushed forward by the IPCC (2007), as opposed to the risk hazard approach, where vulnerability is considered a constitutive part of risk. This is most likely the main conceptual difference among both communities. In our view a crucial disadvantage of this framework is the inclusion of many elements within vulnerability. This may lead to problems when identifying how to assess each of these components, and how to combine them to obtain the final degree of

vulnerability for the system. Another characteristic of this framework is the inclusion of the adaptation concept as an element that increases resilience.

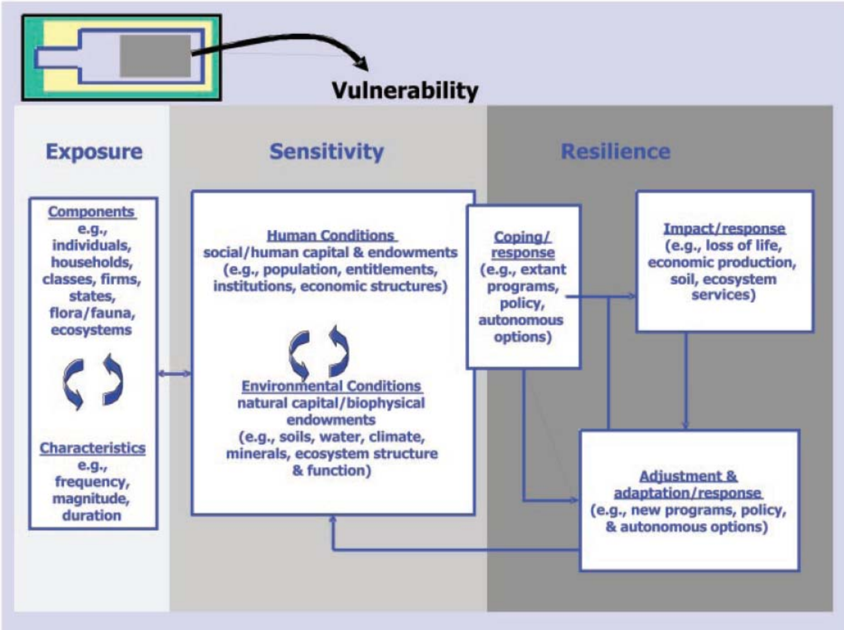

Figure 7 - Vulnerability Framework (Turner, Kasperson et al.. 2003)

As in the natural hazards community, also in the climate change sphere competing interpretations of vulnerability arise. Kelly (Kelly and Adger 2000) identify two main approaches to vulnerability in the climate change literature: 'end-point' and 'starting-point' approaches.

The end-point approach considers vulnerability as the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, and thence to biophysical impact studies and the identification of adaptive options (O'Brien 2007). The net damage or consequence that remains after adaptations in performed defines the degree of vulnerability. Vulnerability here summarizes the net impact of the climate problem, and it is usually quantitatively translated into a monetary cost, change in yield or flow, human mortality, ecosystem damage, or qualitatively as a description of relative or comparative change.

One example to this end-point interpretation can be found in the IPCC Third Assessment Report (TAR), which defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" and sees vulnerability to climate change as a function of exposure, sensitivity and adaptive capacity (McCarthy et al. 2001).

In contrast, the starting-point approach, considers vulnerability as a present inability to cope with external pressures or changes, in this case, the changing climate conditions. Here, vulnerability is considered a characteristic of social and ecological systems that is generated by multiple factors and processes. A focus on prior damage, referred to by Kelly and Adger (2000) as the 'wounded soldier' approach, assumes that addressing present-day vulnerability will reduce vulnerability under future climate conditions (Burton et al.. 2002).

To summarize, the first interpretation, the end-point approach, views vulnerability as a residual of climate change impacts minus adaptation. The second interpretation, which takes vulnerability as a starting-point, views vulnerability as a general characteristic generated by multiple factors and processes.

The differences between these two interpretations can largely be explained by their contextual backgrounds and the research purposes from which they originated. For instances, the end-point approach to vulnerability originated with the goal of quantifying vulnerability to climate change, answering questions such as, "What is the extent of the climate change problem?" and "Do the costs of climate change exceed the costs of greenhouse gas mitigation?" The focus has often been on biophysical vulnerability, whereby the most vulnerable are considered to be those living in the most precarious physical environments, or in environments that will undergo the most dramatic physical changes (Liverman 2001). The starting-point interpretation, on the other hand, has origins in assessments of social vulnerability with the purpose of identifying the character, distribution and causes of vulnerability. Research questions include, "Who is vulnerable to climate change and why?" and "How can vulnerability be reduced?" Many vulnerability studies draw on the entitlements literature regarding access to resources, on political economy in explaining the factors that lead to vulnerability, and on social capital as a means of claiming entitlements and pursuing coping mechanisms (Downing et al. 1995, Kelly and Adger 2000, Adger 2003).

These two different distinctions between the end-point and starting-point in Climate Change are framed by (O'Brien 2007) in two broader interpretations of vulnerability named "contextual" and "outcome". In schematic terms these two interpretations of vulnerability can be described according to Figure 8.

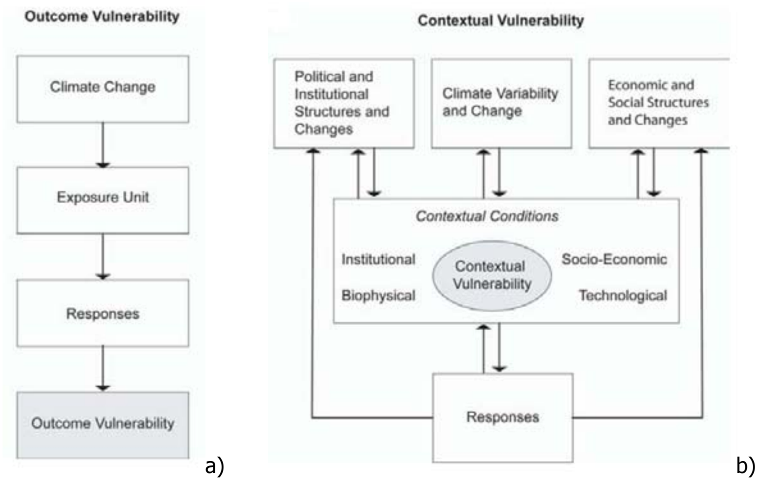

Figure 8 - Frameworks depicting two interpretations of vulnerability to climate change: Outcome vulnerability (a) and Contextual vulnerability (b)

Outcome vulnerability (Figure 8a) is considered as a linear result of the projected impacts of climate change on a particular exposure unit (biophysical or social) offset by adaptation measures. Outcome vulnerability is often used to determine the extent to which different scenarios of greenhouse gas emissions lead to. On the other hand, contextual vulnerability (Figure 8b) is based on a processual and multidimensional view of climate/society interactions. Both climate variability and change are considered to occur in the context of political, institutional, economic and social structures and changes, which interact dynamically with contextual conditions associated with a particular 'exposure unit'. From this perspective, reducing vulnerability involves altering the context in which climate change occurs, so that individuals and groups can better respond to changing conditions.
Wolf [1] (2008) distinguishes two basic approaches of vulnerability under different names based on two criteria: The component of focus in the coupled socio-ecological system and the assessment methods focusing either on possible future scenarios or in the present state analysis.

The approach with strong focus on the ecological component sector is based usually on modeled future scenarios and is close to the "end-point vulnerability" described by (Adger 2000), the "biophysical" referred by (Brooks 2003) or "outcome vulnerability" by (O'Brien 2007). The approach that focuses on social system is more reliant on present properties via measurements carried at the present state and has been termed "starting-point vulnerability", "social" or "contextual" by the same authors mentioned above. Füssel and Klein (2006) refer to a third kind of approach called "integrated" in case studies where ecological and social approaches have been combined.

Much like vulnerability, adaptive capacity is a concept that can also have multiple interpretations in the climate change literature. Adaptive Capacity as defined in the IPCC is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. In the end-point interpretation of vulnerability, adaptive capacity has been used as a measure of whether technological climate change adaptations can be successfully adopted or implemented. In the starting-point interpretation, adaptive capacity refers to the present ability to cope with and respond to stressors and secure livelihoods. Adaptive capacity in the first case refers to future adaptations and vulnerability (Brooks 2003), while adaptive capacity in the second case pertains to present-day vulnerability (Burton et al. 2002).

3.4 Linking vulnerability concepts in a global change context

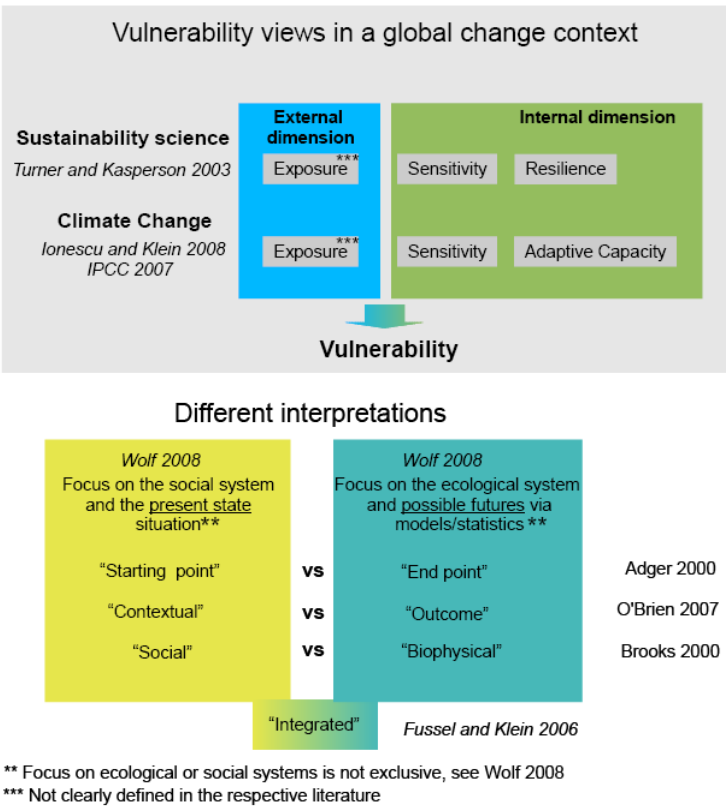

Figure 9 - Vulnerability views in the global change context

In the Climate Change community differences both in the formulation of the concept vulnerability and its operation were found. Competing conceptualization of vulnerability pushed forward by Turner et al.(2003), the IPCC (2007) and Ionesco et al. (2008) only differ in the use of elements "Resilience" and "Adaptive Capacity".

Resilience is defined by Turner as the system's ability to bounce back to a reference state after a disturbance and the capacity of a system to maintain certain structures and functions despite disturbance. Furthermore, resilience of the system is often evaluated in terms of the amount of change a given system can undergo (e.g., how much disturbance or stress it can handle) and still remain within the set of natural or desirable states (i.e., remain within the same 'configuration' of states, rather than maintain a single state)" (Turner et al. 2003). The IPCC (2007) frames resilience as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. Although the term resilience does not appear explicitly on the semantic formulation of vulnerability according to the IPCC, we can see it implicitly when vulnerability is framed as "the degree to which a system is exposed and unable to cope with adverse effects of climate change". The wording "unable to cope with" carries at some extent the same meaning as "system's ability to bounce back to a reference state after a disturbance" presented by Turner et al. (2003). The system with no ability to bounce back is also unable to cope with the disturbance. Some confusion now arises when we take a look at the definition of adaptive capacity stated by the IPCC (IPCC 2007) this is, the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptive capacity is apparently positioned in the Turner's (Turner et al. 2003) under resilience named "adjustments and adaptation/response". (see Figure 7)

The term sensitivity according to the IPCC is defined as "*the degree to which a system is affected, either adversely or beneficially, by climate variability or change*". For example, change in crop yield in response to a change in the mean, range or variability of temperature or damages caused by an increase in the frequency of coastal flooding due to sea-level rise. Turner (2003) pictures sensitivity as determined by human/environment conditions including both social and biophysical capital that influences the existing coping mechanisms, which take effect as the impacts of the exposure are experienced, as well as those coping mechanisms adjusted or created because of the experience. It is interesting to notice that the IPCC states what sensitivity is while Turner explains what sensitivity depends upon.

Exposure is said to be part of vulnerability in both frameworks, nevertheless further definitions on precise meaning of exposure are not delivered. Tuner et al. (2003) frames the element exposure as an interaction between components (individuals, households, ecosystems etc…) and characteristics (frequency, magnitude and duration). The glossary of the IPCC (2007) proceeds in a similar way, this is, a concrete definition of exposure cannot be found and is framed only vaguely as: "The nature and degree to which a system is exposed to significant climatic variations". It seems that Turners framework of vulnerability accounts for all the elements expressed both in the IPCC definition of vulnerability and conceptual framework sharing also the default of not defining all the elements used to define vulnerability.

4 Case study examples of vulnerability and risk

4.1 The role of the case studies

With regard to the ongoing vulnerability research, case studies can fulfill two roles. In terms of a concrete problem it can provide helpful advice for a decision-maker in a certain field, e.g. by indicating which sub-entities region or sector is more vulnerable. This helps to apply specific measures or to invest money. With regard of the research is being done in ENSURE and with regard of scientific progress, case studies have a different role.

It is a fact that the vulnerability discourse focuses on risk and threats, but vulnerability in principle asks for the impact of a stimuli. Considering the situation of climate change we are aware that climate change will have different effects worldwide, but for adequate responses one has to know how large, threatening, etc. they will be. This would be possible when comparable studies are at hand. The reality though is quite different, this is, there are considerable amounts of vulnerability studies and none, or very few of them, are comparable. Thus case studies here act as well as cases from which we have to learn in terms of generalization, transferability, and comparability of concepts.

After identifying the main characteristics of vulnerability concepts and definitions in both the climate change and natural hazards community the following chapter will observe how these concepts do, or do not, materialize in the practical context of vulnerability/risk assessments. Therefore, in the forthcoming chapter a pair of vulnerability/risk studies carried out in the flood risk (natural hazard) and climate change context at different spatial (national and regional levels) will be looked at. Special attention will be given to the formulation of terms like vulnerability or risk, and also, if possible, to the use of scenarios of future vulnerability or descriptions of dynamics behind vulnerability (e.g. by indicator only or by deterministic approaches). In other words, it makes no sense to add additional studies before lessons form the existing ones are obtained. In this light the discussion of a couple of 18 existing case studies aims to distill their essential in terms of the arguments provided in this paper.

Particular project characteristics and wording used to define vulnerability/risk (and related concepts) will be subject of comparison with the theoretical concepts presented in sections 2.1 and 2.3. Ultimately, they will also allow us to bridge different concepts of vulnerability in the theoretical conceptualizations on both communities.

4.2 Case study examples of vulnerability assessments in the Natural Hazards community

Vulnerability studies in the Natural Hazards community only started to become common in the decade of the 1980ies with the so called "emergence and triumph of vulnerability" (Nathan 2005). Before the 1980ies risk and disaster studies were focused on hazard and post-disaster, human intervention was oriented towards a perspective of disaster management. The tools used were typical of engendering and reflected a technicist view on intervention and protection of assets such as population and households. A shift of focus towards the analysis of risk (pre-disaster) more than on disaster was noted during the 1980ies and the vulnerability concept started to emerge from the formulation of risk.

4.2.1 ESPON- Natural and Technological Hazards and Risks in European Regions (Thomé 2006)

The ESPON Natural and Technological Hazards and Risks project focused on the typologisation of risks and hazards and also on the risk profile of regions (hazard potential and vulnerability). The project was multi-hazard oriented (e.g. floods, droughts, earthquakes, fallouts from nuclear power plants, oil spills and hazardous production of goods) and strived to achieve a better understanding of risk management, pointing out comparable situations across EU 27+2.

Risk is defined under the generic form of "Risk = Hazard potential x Vulnerability". On the glossary of terms provided one can find that risk is defined as a "combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence." More specific, risk is "the probability of harmful consequences, or expected loss resulting from interactions between natural or human induced hazards".

Vulnerability defined as "the degree of fragility of a person, a group, a community or an area towards defined hazards". In the glossary of terms, vulnerability is also "a set of conditions and processes resulting from physical, social, economical and environmental factors, which increase the susceptibility of a community to the impact of hazards". The final report points out that vulnerability is "determined by the potential of a natural hazard, the resulting risk and the potential to react to and/or to withstand it, i.e. its adaptability, adaptive capacity and/or coping capacity. The ESPON Hazards project further acknowledges that damage potential and coping capacity are in fact the two main sides of regional vulnerability.

4.2.2 The Foresight Future Flooding Project (Evans 2007)

The aim of the Foresight project was to produce a challenging long-term (30 to 100 years) vision for the future of flood and coastal defence in the United Kingdom (UK), it was commissioned to answer – at a national scale - two questions:

- How might the risks of flooding and coastal erosion change in the UK over the next 100 years?
- What are the best options for Government and the private sector for responding to the future challenges?

In the project, risk is taken as probability x consequences – where consequences relate to people, and the natural and built environments. However, an additional factor – public outrage – was taken into account and will affect the levels of risk that are acceptable to future societies. In terms of the project's conceptualization of vulnerability this was almost entirely defined in terms of economic damages caused by floods.

There was a social vulnerability element, based on work by Tapsell, Penning-Rowsell et al. (2002), but in the end this was of minor importance at this (national) scale of analysis, and no clear and understandable patterns could be found. Scenarios were used to assess the possible scale and nature of future risks, and to assess options for responding to those risks. These scenarios embodied different socioeconomic visions of the UK, and different degrees of climate change.

4.2.3 Intrinsic vulnerability, hazard and risk mapping for karst aquifers: A case study (Mimi 2009)

The aim of the study was to present intrinsic vulnerability, hazard and risk mapping for the aquifers underlying Ramallah district, West Bank and Palestine. Another aim of this research was the application, for the first time in Palestine, of the intrinsic vulnerability, hazard and risk mapping that could serve as a non-subjective mathematical tool for a rational management of groundwater resources and subsequent land use planning.

Several methods exist for intrinsic vulnerability mapping of groundwater. A new method for mapping vulnerability, within the framework of COST 620 was put forth: the PI method. PI stands for the two factors that are taken into consideration: protective cover (P) and the infiltration conditions (I). Vulnerability is therefore defined as the score of the protective factor π as a function of protectiveness and infiltration. V=PxI

Risk was defined in this case study as the probability that groundwater in the aquifer will become contaminated, to an unacceptable level, by activities on the immediately overlying land-surface

Risk = 1/(hazard index) * π

We can assume that this case study follows the general risk definition of risk= Hazard x Vulnerability

4.2.4 A case study Karst groundwater protection: First application of a Pan-European approach to vulnerability, hazard and risk mapping in the Sierra de Líbar (Southern Spain) (Andreo 2006)

In this case studies two concepts of vulnerability were tested and validated by means of tracing tests, hydrological, hydrochemical and isotope methods. The first vulnerability concept tested was the intrinsic vulnerability of an aquifer. The approach was similar to the one used in the previous case study this is, vulnerability was viewed as a function of protectiveness and infiltration.

On the second method vulnerability is assessed as the product of three factors: Concentration of flow (C), Overlying layers (O) and Precipitation (P). As the method is made for resource protection, the karst network development inside the aquifer is not considered.

The O factor refers to the protection of the unsaturated zone of the aquifer against a contaminant event. The C factor takes into account the surface conditions that control water flowing towards zones of rapid infiltration, which have less capacity to attenuate contamination. The P factor considers influence of precipitation, both quantity and intensity, on the transport of contaminants and, thus, in the vulnerability.

Risk is here said to depend on the hazard (origin), the vulnerability of the system (pathway) and the potential consequences of a contamination event.

4.2.5 Spatial data for landslide susceptibility, hazard, and vulnerability assessment: An overview (van Westen 2008)

The aim of this study was to discuss a number of issues related to the use of spatial information for landslide susceptibility, hazard, and vulnerability assessment.

Vulnerability was here perceived as being composed of a measure including the magnitude and the elements at risk of land slides.

Risk was defined as being composed of hazard, vulnerability and amount. It was not totally clear the meaning of the word "amount". We assume here that "amount" resembles the definitions of exposure in the natural hazards literature. If that is the case then the definition of risk becomes redundant since the idea of exposure was already present while evaluating the elements at risk when determining vulnerability

4.2.6 A conceptual framework for quantitative estimation of physical vulnerability to landslides (Uzielli 2008)

This study illustrates a method for a scenario-based quantitative estimation of physical vulnerability of the built environment to landslides.

The rationale and main features of the procedure are presented in the context of quantitative risk estimation. Vulnerability is defined quantitatively as a function of landslide intensity and the susceptibility of vulnerable elements.

Vulnerability was therefore defined under the formula $V = I \times S$, were S and I are respectively intensity and susceptibility

Susceptibility refers to the lack of inherent capacity of the elements in the spatial extension under investigation to preserve their physical integrity and functionality in the course of the physical interaction with a generic sliding mass. On the other hand, intensity was considered to be a set of spatially distributed parameters describing the destructiveness of a landslide.

Risk in this context was said to be constituted by Hazard x Vulnerability x Value of elements at risk.

4.2.7 Probabilistic assessment of vulnerability to landslide: Application to the village of Lichtenstein, Baden-Württemberg, Germany (Kaynia 2008)

Similar to the study before, also here Vulnerability (V) is defined in terms of both the landslide intensity (I) and of the susceptibility (S) of the elements at risk: $V = I \times S$

This representation of vulnerability reflects independence between the intensity I and the susceptibility S in a probabilistic sense, but permits to quantify the contribution of each influencing factor in an empirical way.

The intensity parameter accounts for kinetic and kinematic characteristics of the interaction between the sliding mass and the reference area while susceptibility expresses the lack of inherent capacity of the elements in the spatial extension under investigation to preserve physical integrity and functionality in the course of the physical interaction with a generic sliding mass.

Risk was defined under the structure: Risk = Hazard x Vulnerability x Consequence

4.2.8 Flood Risk and Flood Hazard Maps – Visualisation of Hydrological Risks (Spachinger 2008)

The main focus of the project was a user-oriented transfer of the results to different stakeholder groups (e.g. outputs of hydrological and hydrodynamic models) necessary modifications and final output in exemplary maps, which were finally valuated by test persons from target groups.

Risk was defined as a function of probability of occurrence and extent of damage while extent of damage is constituted by the two factors, damage potential and vulnerability. An economic approach was chosen to assess vulnerability calculated for different types of buildings by using damage functions depending on the water depth.

4.2.9 Earthquake Damage Scenarios of the Building Stock of Potenza (Southern Italy) Including Site Effects (Dolce 2003)

In this study damage scenarios relevant to the building stock of the town of Potenza, Southern Italy, are presented.

Seismic vulnerability of a building was defined as its proneness to be damaged by an earthquake. Based on a quantitative assessment of seismic vulnerability, the probability of damage to a given building type (caused by earthquakes of various intensities) can be predicted. Seismic vulnerability seems here to be independent from the intensity. This is, damage probability is related to both the vulnerability and the intensity of the hazard while vulnerability is connected to the structural characteristics of the building.

4.2.10 Lifelines earthquake vulnerability assessment: a systemic approach (Meneoni 2002)

This study aimed at developing a model to evaluate lifelines seismic vulnerability, considering physical, functional, and organizational factors as deeply interconnected one to the other.

The notion of systemic vulnerability provided the framework for the study. Systemic vulnerability measures how prone is a system to damage or failure not only as a consequence of some kind of physical damage occurring to one of its components, but also as the indirect effect of some physical, functional, or organizational failure suffered by other systems. Also here the vulnerability was viewed as independent from the intensity of the hazard.

The objective was to focus on the present conditions that make the lifelines prone to any kind of intensity from a hazardous event, in this case, an earthquake. This idea seems to be closely connected to the notion of susceptibility presented before in other case studies.

4.2.11 Urban sustainability in the presence of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology (Fedeski 2007)

The paper outlines a methodology design for the specific purpose of assessing the impact of climate change on the risk from floods and geological hazards, so that the vulnerability of different areas of a city can be compared and appropriate adaptation strategies developed. The methodology presented in outline is capable of making combined estimates of cost due to several hazards such as geological and floods.

Vulnerability is here elaborated as the susceptibility of buildings to the hazard while risk is envisioned as a function of Hazard, Vulnerability and Exposure

4.3 Vulnerability assessments in Climate Change

Vulnerability assessments carried in the Climate Change context show a trend towards the integration of interdisciplinary analyses regarding potential consequences, integration of impact and adaptation assessments and also the connection of climate change impacts with other stresses and stressors. Some authors divide vulnerability assessments in Climate Change in first and second generation (Burton et al. 2002).

The first generation is usually "impact driven" and is oriented towards mitigation. "What matters in this connection is the extent to which the gross impact of climate change can be reduced by adaptation" (Burton et al. 2002). Scenarios are extensively used to translate impacts, namely via modeling in various natural, economic and social sectors. This approach relies on future scenarios and directs attention towards future impacts of climate change rather than towards present vulnerability. Due to the use of scenarios, this is, narratives of a possible future, uncertainty tends to be high in the first generation vulnerability assessments. The assessments are usually for the long term and carried out at a spatial scale that ranges from national to global and aims mostly to determine possible mitigation policies.

The second generation vulnerability assessments aims to determine the vulnerability of certain sectors or regions to climate change, in concert with other stress factors and considering the potential of feasible adaptations to reduce adverse impacts (Füssel and Klein 2006). The point of departure is the present, in terms of the distribution of vulnerability, existing adaptations to the climatic environment, and the way that current policies and development practices serve to reduce or exacerbate vulnerability.

Modeled climatic conditions and socio-economic scenarios are used in assessing and prioritizing policy options, but only to set the context for future adaptations. Rather than comprising a separate climate policy, the identified adaptation options should ideally be incorporated into a wide range of policies; for example, agricultural, water resources, public health and development policies (Burton et al. 2002). The main difference, compared to first-generation vulnerability assessments, is thus the more thorough assessment of society's ability to effectively respond to anticipated risks through various kinds of adaptations. In doing so they help to prioritize the allocation of resources for adaptation measures (Füssel and Klein 2006).

4.3.1 A-TEAM Advanced Terrestrial Ecosystem Analysis and Modelling (Schröter 2004)

The A-TEAM study aimed at assessing the vulnerability of human sectors relying on ecosystem services with respect to global change. The project was driven in order to answer which regions in Europe are most vulnerable to global change, which climate scenario is the least harmful for a sector within Europe (e.g. Agriculture, forestry, etc.) and finally, which sectors are the most vulnerable in a certain European region.

Vulnerability was defined as "the undesirable state of being open to damage". A more detailed definition can be found reflecting both the aims and the sectoral orientation of the project. In other words, vulnerability is said to be the "degree to which an ecosystem service is sensitive to global environmental change and the degree to which the sector that relies on the service is unable to adapt to the changes". The vulnerability of an area depends here on three elements: its exposure to environmental change, the sensitivity of the ecosystem service to that change and the adaptive capacity of the sector which relies on the ecosystem service.

Exposure was derived from the use of a consistent of multiple, spatially explicit global change scenarios. Potential impacts are said to result both from exposure and sensitivity and were obtained by performing both a stakeholder-guided process (that provided a range of indicators for ecosystem services that are related to the sectors) and the run of several and ecosystem modeling techniques under the same inputs of global change scenarios. Lastly, adaptive capacity was assessed by the development of a spatially explicit and quantitative generic index based on six determinants which were identified by the IPCC Third Assessment Report: power, flexibility, freedom, motivation, knowledge and urgency. A total of 12 indicators such as gross domestic product, female activity rate, age structure, literacy index and urbanization were used.

4.3.2 Climate Change in Germany: Vulnerability and Adaptation of Climate Sensitive Sectors (Zebisch 2005)

The object of this study conducted for Germany was to analyze its current and potential future impacts on seven climate-sensitive sectors (water management, agriculture, forestry, nature conservation, health, tourism and transport).

Vulnerability is defined here as the likelihood of a specific human-environment system to experience harm due to changes in society or the environment, accounting for its adaptive capacity. Vulnerability to current and future global change depends strongly on the initial situation. The vulnerability of a human-environment system to global change depends mainly on three factors, in addition to its predisposition: The characteristics of climate change and other elements of global change in the respective region, how large are the potential impacts of global change within the region on specific sectors (forest, biodiversity, agriculture, water) and what is the degree of adaptation in the specific sectors within the region to the potential impacts. To assess vulnerability results on scenarios of potential impacts of global change in Germany, findings from other studies and projects and results from regional expert surveys were integrated.

Adaptation to climate impacts is defined as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or capitalizes on beneficial opportunities (IPCC 2001). The study goes even further on stressing the aspect of adaptation differentiating between vulnerability without adaptation (normally business as usual) and vulnerability with further adaptation (when adaptive capacity is fully used).

4.3.3 The North-Rhine Westphalia Study (NRW) (Kropp 2006)

The following case study analyses the possible future vulnerability of the German federal state of North-Rhine Westphalia to extreme weather events intensified as a result of climate change. The main objective is to identify the municipalities within the state that are most likely to be adversely affected by these changes.

As discussed above, several essential criteria constitute vulnerability, like sensitivity of a region and exposure to a hazard. For this case study, sensitivity is determined by a region's socio-economic characteristics that can make it more susceptible to suffer harm from a hazard. Hazards in the case study are extreme weather events, while the sensitivity is represented by representative characteristics of the region. The scenario period for the climate data is 2010 to 2039 and for further views on the changes to be expected, the scenario data is related and compared to the current condition.

As a basis for this vulnerability assessment a systematic stocktaking of all conceivable types of damage caused by extreme weather events was carried out. A set of basic vulnerability indicators for each category of damage was then identified. In general, these indicators can be used as measures for the degree of susceptibility of a given sector or region in the face of certain climate stimuli, and are therefore suitable for comparative risk assessments. The ultimate objective of this vulnerability analysis is the identification of possible adaptation measures that allow the minimization of adverse impacts that are expected from the exposure to a certain hazard.

4.3.4 Vulnerability and adaptation to climate variability and water stress in Uttarakhand State, India (Kelkar 2008)

The study presents the results from a participatory approach to investigate vulnerability and adaptive capacity to climate variability and water stress in the Lakhar watershed in Uttarakhand State, India. is study aims to assess the vulnerability and adaptive capacity of households engaged in agriculture in Lakhwar sub-basin to climate variability and water stress.

Vulnerability is here recognized to be the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress. Although the notion of adaptive capacity is not expressed in the definition of vulnerability, it was assessed via participatory approach and is view as contributing to reducing vulnerability, this is the most vulnerable are considered to be those who are most exposed to perturbations, who possess a limited capacity for a adaptation, and who are least resilient to recovery (Bohle et al.. 1994).

4.3.5 Mapping vulnerability to multiple stressors: climate change and globalization in India (O’Brien 2004)

The paper pushed forward a methodology for investigating regional vulnerability of agriculture to climate change in combination with other global stressors. The method, which relies on both vulnerability mapping and local-level case studies, may be used to assess differential vulnerability for any particular sector within a nation or region, and it can serve as a basis for targeting policy interventions.

Vulnerability is understood as a function of three components: Adaptive capacity, sensitivity and exposure. Adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences. It is considered "a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities (McCarthy et al., 2001). Sensitivity is the degree to which a system will respond to a change in climate, either positively or negatively and exposure is seen as the degree of climate stress upon a particular unit of analysis.

4.3.6 Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada (Ford 2006)

This study develops a vulnerability-based approach to characterize the human implications of climate change in Arctic Bay, Canada. It focuses on community vulnerabilities associated with resource harvesting and the processes through which people adapt to them in the context of livelihood assets, constraints, and outside influences.

The paper views vulnerability as a function of exposure-sensitivity of a community to climate change effects and its adaptive capacity to deal with that exposure. Adaptive capacity is interpreted as the community's potential or ability to address, plan for, or adapt to exposure-sensitivity. Exposure-sensitivity is dependant upon both the characteristics of climatic conditions and the nature of the community in question.

The characteristics of climate-related conditions include magnitude, frequency, spatial dispersion, duration, speed of onset, timing and temporal spacing of conditions. The nature of the community concerns its location and structure relative to the climatic risks.

4.3.7 Modelling vulnerability and resilience to climate change: A case study of India and Indian states (Antoinette 2005)

The vulnerability of India and Indian states to climate change was assessed using the Vulnerability-Resilience Indicator Prototype (VRIP). The model was adapted from the global/country version to account for Indian dietary practices and data availability with regard to freshwater resources.

Vulnerability is understood as the response to climate exposure, expressed as sensitivities to climate, and societal coping and adaptive capabilities. Adaptive capabilities are assessed based on society's human resources, economic capacity and natural capital while sensitivity evaluation relies on the food and water security, settlement security, aspects of the health of people, and natural resources of a region.

4.4 Comparing case studies

Table 1 provides a resume of the case study characteristics that were analysed on the context of this study. By structuring particular characteristics in a table it becomes now easier to compare the use of concepts like vulnerability and risk.

Table 1 - Vulnerability and risk definition presented in the analysed case studies

Natural hazards case studies			
Title	***Author***	***Vulnerability***	***Risk***
Intrinsic vulnerability, hazard and risk mapping for karst aquifers: A case study	Mimi Z.A.	Defined by the score of the protective factor π as a function of protectiveness and infiltration	Probability that groundwater in the aquifer will become contaminated to an unacceptable level by activities on the immediately overlying land-surface
Spatial data for landslide susceptibility, hazard, and vulnerability assessment: An overview	van Westen C.J.	Defined as a measure of elements at risk	Hazard x Vulnerability x Amount
Karst groundwater protection: First application of a Pan-European approach to vulnerability, hazard and risk mapping in the Sierra de Líbar (Southern Spain)	Andreo B.	Intrinsic Vulnerability = C x O x P C - Surface conditions that control water flowing O - Overlying layers P - Precipitation	Depends on the hazard (origin), the vulnerability of the system (pathway) and the potential consequences of a contamination event.
A conceptual framework for quantitative estimation of physical vulnerability to landslides	Uzielli M.	V = I x S I – Intensity S -Susceptibility	Hazard x Vulnerability x Value of elements at risk
Flood Risk and Flood Hazard Maps – Visualisation of Hydrological Risks	Spachinger K.	An economic approach was chosen to assess vulnerability. Calculated for different types of buildings using damage functions depending on the water depth.	Risk is defined as a function of probability of occurrence and extent of damage
Probabilistic assessment of vulnerability to landslide: Application to the village of Lichtenstein, Baden-Württemberg, Germany	Kaynia A.M.	Vulnerability is defined in terms of both the landslide intensity and of the susceptibility of the elements at risk V = S x I	No clear definition found
ESPON – Natural and Technological Hazards and Risks in European Regions.	Thomé S	A set of conditions and processes resulting from physical, social, economical and environmental factors, which increase the susceptibility of a community to the impact of hazards.	Hazard Potential x Vulnerability
The foresight future flooding project.	Evans E.P.	In terms of the project's conceptualization of vulnerability this was almost entirely defined in terms of economic damages caused by floods.	Probability x Consequence
Earthquake Damage Scenarios of the Building Stock of Potenza (Southern Italy) Including Site Effects	Dolce M,	Seismic vulnerability of a building can be defined as its proneness to be damaged by an earthquake	No clear definition found
Lifelines earthquake vulnerability assessment: a systemic approach	Menoni S.	How prone is a system to damage or failure, not only as a consequence of some kind of physical damage occurring to one of its components, but also as the indirect effect of some physical, functional, or organizational failure suffered by other systems.	No clear definition found

Urban sustainability in the presence of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology	Fedeski M.	The susceptibility of the buildings to the hazard were it to occur	Hazard x Vulnerability x Exposure
Climate change case studies			
Title	***Author***	***Vulnerability***	***Risk***
Vulnerability and adaptation to climate variability and water stress in Uttarakhand State, India	Kelkar U	Degree to which a system/subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress	No clear definition found
Mapping vulnerability to multiple stressors: climate change and globalization in India	O'Brien K.	vulnerability is characterized as a function of three components: adaptive capacity, sensitivity, and exposure	No clear definition found
Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada	Ford J.D.	Function of exposure-sensitivity of a community to climate change effects and its adaptive capacity to deal with that exposure.	No clear definition found
Modeling Vulnerability and Resilience to climate change: A case study of India and Indian states	Antoinette L.	A response to climate exposure, expressed as sensitivities to climate, and societal coping and adaptive capabilities.	No clear definition found
A-TEAM Advanced Terrestrial Ecosystem Analysis and Modeling.	Schröter D.	The degree to which an ecosystem service is sensitive to global environmental change and the degree to which the sector that relies on the service is unable to adapt to the changes.	No clear definition found
Climate Change in Germany: Vulnerability and Adaptation of Climate Sensitive Sectors.	Zebisch M.	The likelihood of a specific human-environment system to experience harm due to changes in society or the environment, accounting for its adaptive capacity	No clear definition found
The North-Rhine Westphalia Study.	Kropp J.	The degree of susceptibility of a given sector or region in the face of certain climate stimuli	No clear definition found

The data structuring and a careful analysis of each study methodology allowed us to group different definitions of vulnerability and risk into four and five large classes respectively. This was based on both the language and wording used on the definitions and how vulnerability and risk concepts were operationalized in the framework of the respective study.

4.4.1 Grouping risk

The concept of risk, as analysed before, has a long tradition on the natural hazards literature. It was therefore no surprise to find a variety of definitions in the case studies, all of which could be traced back to the several risk concepts investigated before and resumed on figure 5.

Definitions of risk found were: **"Probability x Consequence"**, **"Hazard x Vulnerability"**, **"Hazard x Vulnerability x Exposure"**, **"Hazard x Vulnerability x Consequence"** and also case studies with an absence of a concrete definition of risk **"No clear definition"**.

These were the case of all climate change case studies and, at much smaller extent, some case studies from the natural hazards community.

This fact constituted no surprise since the search for case studies was mostly oriented towards vulnerability. The appearance of risk definitions on vulnerability oriented case studies in the natural hazards community shows how interconnected these two concepts are. In addition, the absence of a risk definition in all climate change case studies was also expected since this community focuses its work on vulnerability concepts and not risk.

The elaboration of the risk classes was straightforward and obeyed only to the wording presented in each case study. Some definitions of risk from Uzielli et al. (2008) and Westen et al. (2008) were rephrased in order to suit one of the previous mentioned risk classes. This rephrasing did not alter the meaning of the definition it self, for example, Uzelli et al, (2008) defines risk as being the product of "hazard x vulnerability x values of elements at risk", elements at risk could be perceived in the case study as exposure.

4.4.2 Grouping vulnerability

If grouping risk was quite an easy task, grouping vulnerability on the other hand was a harder deal to achieve. Four vulnerability definition classes could be distilled from the case study examples analysed. A simple approach relying only on the definitions wording could not be made. It was noted that the definitions were very variable in terms of vocabulary used although many referred to the same ideas.

One class that became visible from the early reading of each case study was the idea of vulnerability has a set of characteristics of a system that make it prone to harm independent of the intensity of the hazard considered. This class was named **"Susceptibility"**. The case studies in this class revealed that physical, structural and even operational characteristics of a system were determined to assess the systems vulnerability to a specific hazard but not to a specific magnitude. For example the "*Lifelines earthquake vulnerability assessment: a systemic approach*" (Meneoni 2002) assesses vulnerability of lifelines to the threat of the hazard earthquake without taking into account the intensity of the hazard. Systems structural characteristics like number of pipelines or buildings and organizational issues like coordination among lifelines service suppliers are used to assess vulnerability both in the emergency and reconstruction phase independent of the magnitude of the hazard.

A similar example is the case study for ground water contamination "*Intrinsic vulnerability, hazard and risk mapping for karst aquifers: A case study*" (Mimi 2009). Like the name suggests, the evaluation of vulnerability in this case study is aimed at the intrinsic vulnerability of a aquifer. The vulnerability is said to be a function of protectiveness and infiltration, this is, structural and physical characteristics of the soil without taking into account the magnitude of the hazard, in this case a pollutant.

A second vulnerability definition class perceived encompasses the case studies were the proneness of a system was dependent on both the characteristics of the system and the magnitude of the hazard. This class was named **"Susceptibility and Intensity"**. In these case studies vulnerability was perceived as the combined effect of the characteristics of a system that make it prone to an hazard and the intensity of the hazard itself. The case study "*Probabilistic assessment of vulnerability to landslide: Application to the village of Lichtenstein, Baden-Württemberg, Germany*" (Kaynia 2008) is a good example how vulnerability is defined both in terms of susceptibility and intensity. Susceptibility here was taken as the lack of inherent capacity of the elements in the spatial extension under investigation to preserve their physical integrity and functionality in the course of the physical interaction with a generic sliding mass. On the other hand, intensity was defined as the kinetic and kinematic characteristics of the interaction between the sliding mass and the reference area. Similarly Uzielli et al.(2008) also defines vulnerability as a combination of susceptibility and intensity, is this case susceptibility is defined as a set of spatially distributed parameters describing the destructiveness of a landslide, for example, maximum velocity and total displacement. This vulnerability definition class accounts for other case studies than the ones related with land slides, for example in the case study "*Flood Risk and Flood Hazard Maps – Visualization of Hydrological Risks*" (Spachinger 2008) vulnerability was calculated for different types of buildings using damage functions depending on the water depth, this is, dependent on the magnitude of the hazard.

The third vulnerability definition class was named **"Sensitivity and Adaptive Capacity"**. This vulnerability definition class holds for all the case studies that view vulnerability as an interaction between how sensitive a system is to a perturbation and what are the mechanisms it possesses to deal with the perturbation. An example of such case study is the "*Modeling Vulnerability and Resilience to climate change: A case study of India and Indian states*" (Antoinette 2005). Here vulnerability is viewed as a response to climate exposure, expressed as sensitivities to climate, and societal coping and adaptive capabilities. At a first glance it appears that vulnerability depends on the magnitude of the stimuli, in this case climate, but by looking on how the sensitivity and adaptive capacity parts of vulnerability were operated we realize that in fact vulnerability is here independent of the stimuli. Sensitivity was operated as based on the evaluation of a region's food and water security, its settlement security, aspects of the health of people, and natural resources. Adaptive capacity was based on society's human resources, economic capacity and natural capital. Here no assumption is made about the intensity of the stimuli. The "sensitivity" part of this vulnerability definition class resembles the "susceptibility" part of the previous two. In fact, we have the opinion that the underlying principle of assessing the physical characteristics of an aquifer that make it prone to infiltration is the same as evaluating the social or food security characteristics of an Indian region that make it prone to climate. Both sensitivity and susceptibility seem to carry the same meaning, this is: the characteristics of a system that make it more prone to suffer harm from a stimulus.

Finally, the last vulnerability definition class was named "**Exposure and Sensitivity and Adaptive capacity**". This is in fact the classical IPCC definition of vulnerability already mentioned in section 2.3. An example of this kind of vulnerability interpretation is the case study "V*ulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada*" (Ford 2006). Here vulnerability is termed as a "function of exposure-sensitivity of a community to climate change effects and its adaptive capacity to deal with that exposure". We can see that now vulnerability is dependent on the magnitude of the stimuli, in this case, exposure was determined by climate-related conditions including magnitude, frequency, spatial dispersion and duration, speed of onset, timing, and temporal spacing. On the other hand sensitivity was based on the nature of the community concerns, its location and structure relative to the climatic risks.

Once again the idea of sensitivity being similar to susceptibility emerges. For example it is said that the location and structure of s community contributes to assess vulnerability. The structure and location of the community is until this point independent from hazard, this is, it is viewed as an inherent characteristic that makes a generic community prone to harm. Notice how close this interpretation of sensitivity is from the interpretation of susceptibility in "A conceptual framework for quantitative estimation of physical vulnerability to landslides". Susceptibility is here defined as the lack of inherent capacity of the elements to preserve their physical integrity in the course of the physical interaction with a generic sliding mass.

4.4.3 Results from the case study meta-analysis

Table 2 shows a resumes of the statistics made based on the number, vulnerability class, risk class and community (natural hazards and climate change).

Table 2 - Synthesis of the meta-analysis results

Vulnerability class	% of the total case studies	% in natural hazards case studies	% in climate change case studies
Susceptibility	38.8	54.5	14.3
Susceptibility and Intensity	27.8	45.5	0
Sensitivity and Adp. Capacity	5.8	0	17.3
Exposure, susceptibility and Adp Capacity	27.8	0	71.4
Risk class	% of the total case studies	% in natural hazards case studies	% in climate change case studies
Probability x Consequence	5.5	9.1	0
Hazard x Vulnerability	11.0	18.1	0
Hazard x Vulnerability x Exposure	22.0	36.4	0
Hazard x Vulnerability x Consequence	5.5	9.1	0
No clear definition of risk	56.0	27.3	0

On the overall case studies vulnerability was mostly viewed as the characteristics of a particular system that make it prone to a stimulus independent of its magnitude. About 38% of all case studies defined vulnerability as depending on the systems "Susceptibility". The vulnerability definition class named as "Sensitivity and Adaptive capacity" only scored 5.8% of the overall case studies making it the least common definition class present.

Trends appear when the results are disaggregated by community type. They show a clear contrast between the natural hazards and the climate change community. While in the natural hazards community all case studies viewed vulnerability belonging to either the "Susceptibility" or "Susceptibility and Intensity" classes, in climate change community about 71% of the case studies defined vulnerability as being a combination of "Exposure, Susceptibility and Adaptive capacity".

Almost all climate change case studies (88,7%) included the element "adaptive capacity" on their definition of vulnerability, on the other hand, none of the analysed case studies on natural hazards seems to include explicitly adaptive capacity when elaborating a vulnerability definition. If this is the case, one of the largest differences between the two communities conceptualization of vulnerability seems to persist on the presence or absence of the element "adaptive capacity".

Figure 10 shows how the case studies distribute across the different vulnerability and risk classes according to a particular hazard or target. The diversity of case studies, ranging from assessing vulnerability of communities in the Arctic to studies performed on the vulnerability of land slides in Germany, gives us the possibility of grouping particular case studies in particular vulnerability classes.

For instances, despite the differences in the definition of risk, it was observed that all examples dealing with floods and land slides view vulnerability as defined under the class

"**Susceptibility and Intensity**". On the other hand, vulnerability cases dealing with ground water contamination appear to share the idea that vulnerability is defined under the class "**Susceptibility**". For the case studies belonging to climate change no apparent preference by any vulnerability definition class was observed. This was noted even within the case studies that deal with the same objective, in this case, assessing vulnerability of regions or states.

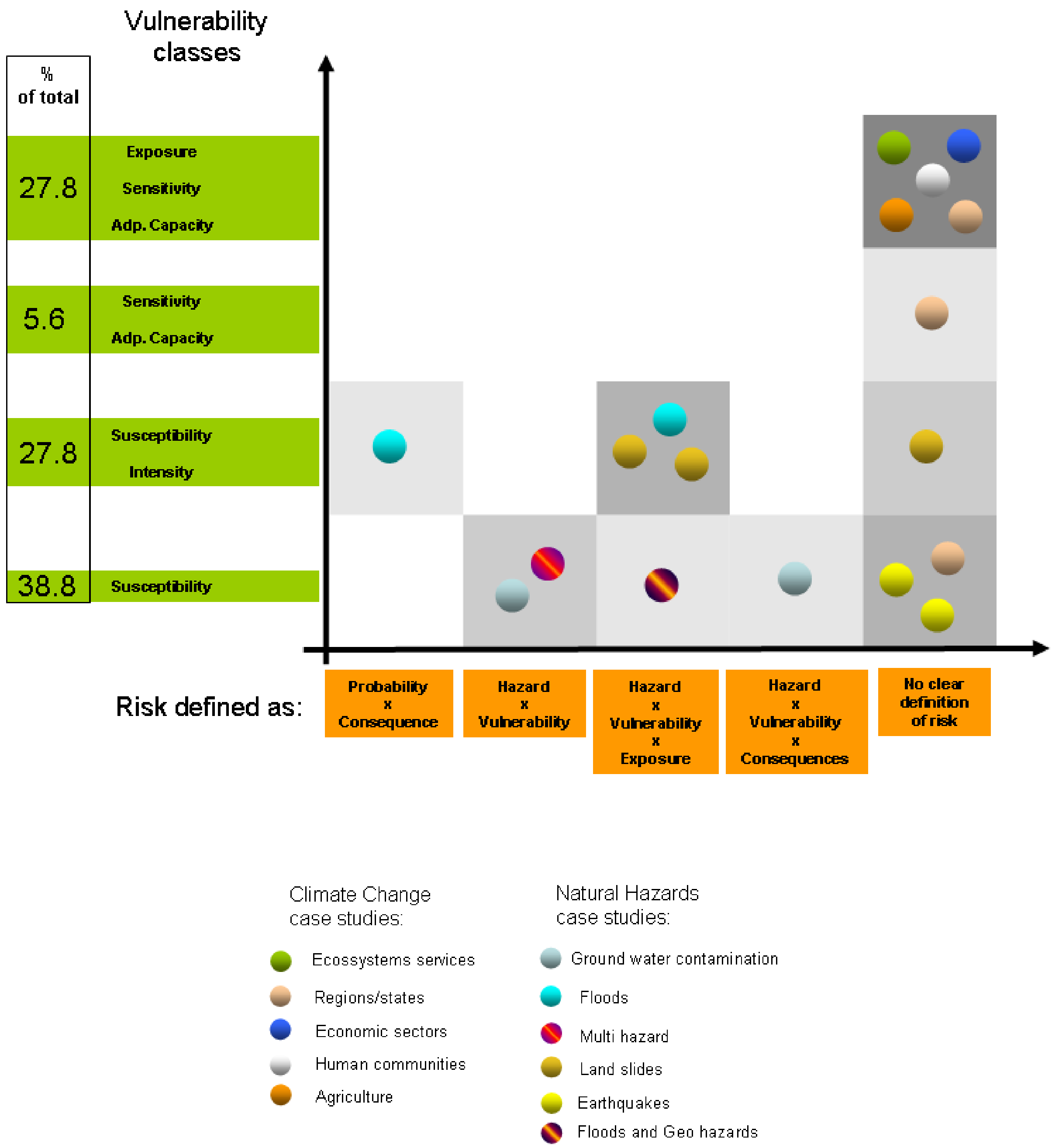

Figure 10 - Distribution of case studies across the vulnerability and risk classes regarding hazard and objective type

5 Discussion

5.1 First remarks

Regarding vulnerability, so far the different scientific communities have been mostly working in isolation (Thomalla, Downing et al.. 2006) and an increasing need to bridge between approaches and scientific communities is recognized. As noted before, there cannot be one universal definition of vulnerability as it is always scale-dependant, multi-dimensional and a dynamic concept. Therefore it will have to be done for every single situation, which makes the comparability of results from different concepts very difficult (Birkmann 2006). The quest for integration on the vulnerability perspective of both communities is therefore hard. In addition, vulnerability is a relative concept in the sense that accurate statements are possible only if one clearly specifies the entity that is vulnerable, the stimulus to which it is vulnerable and the preference criteria to evaluate the outcome of the interaction between the entity and the stimulus (Ionesco, Klein et al. 2008).

In an analysis of theoretical definitions it is very likely that residual ambiguities remain due to the imprecision of natural language. Nevertheless, these definitions serve as a good starting point for the analysis that aims to produce some clarity in the theoretical foundations of vulnerability. A problem that limits the scope is that not all concepts used in a definition of vulnerability are themselves defined (Hinkel 2008). This could be observed in section 2.4 which tried to bridge competing conceptualizations of vulnerability. The most notorious example was the case of the element "exposure". In both frameworks analysed exposure is mentioned as an element of vulnerability but remains without a clear definition of its meaning. For example, according to Turner et al. (2003) exposure is said to depend on an interaction between components like individuals or ecosystems and the characteristics of the hazard such as magnitude and intensity. Although this is useful, a clear concrete definition of exposure is missing. The same happens at the IPCC where exposure is used to define vulnerability but lacks its own concrete definition on the glossary of terms.

5.2 Bridging the frameworks used in natural hazards and global change

One starting point of analysis is the placement of the concept "vulnerability" in both communities' frameworks. Within the Climate Change community, exposure, sensitivity and adaptive capacity are part of what constitutes the vulnerability of a system under analysis as opposed to the risk hazard approach, where vulnerability is mostly considered a constitutive part of risk. The natural hazard framework conceptualizes vulnerability as the dose/response relationship between an exogenous hazard to a system and its adverse effects; therefore, this notion of vulnerability is believed to correspond most closely to the element "sensitivity" in the IPCC terminology (Füssel and Klein 2006).

Also close relation between the elements "coping capacity" and "adaptive capacity" could be found. Both refer to action taken by affected groups in response to hazard, but while coping capacity is related to the systems characteristics that enable losses to be absorbed, adaptation involves a permanent change in the systems themselves, usually driven by repeated exposure to hazard and/or to other longer term adverse trends which make those systems unviable, for example environmental degradation, climate change, socio-political tensions or poor governance.

The principal difference between the natural hazards risk-based approach and the IPCC biophysical vulnerability approach is that risk is generally described in terms of probability, whereas the IPCC and the climate change community in general tend to describe (biophysical) vulnerability simply as a function of certain variables. Nonetheless, the determinants of both biophysical vulnerability and risk are essentially the same - hazard and social vulnerability (Brooks 2003). For example, the element “hazard” is described by Crichton (1999) and Blaikie et al., (1994) as having “varying degrees of intensity and severity” and refers to statistical likelihoods of hazards obtained from long records. These represent a probabilistic view of the uncertain future. On the other hand, probabilities of climate projections are almost absent in the climate change community where large attention is given to the description of impact uncertainty.

The “biophysical” interpretation of vulnerability suggests both a physical component associated with the nature of the hazard, its first-order physical impacts, and a biological or social component associated with the properties of the affected system that act to amplify or reduce the damage resulting from these first-order impacts. This interpretation reflects very much the vulnerability view expressed by the IPCC (2007) where vulnerability is phrased as being dependent on the magnitude of climate change (nature of hazard), its sensitivity (properties of the affected system) and the systems adaptive capacity. Brooks (Brooks 2003) identifies that this interpretation of vulnerability from the IPCC has much to do with the concept of risk elaborated in the natural hazards community (also Wolf[2] et al.. 2008).

In the same report the climate change interpretation of vulnerability named “social”, this is, the inherent conditions that make the system vulnerable independently of the hazard and that determine the outcome impacts. Environmental variables will vary in response to human activity, as populations exploit resources and manage the environment for their benefit in the short or long term. The “social” interpretation is quoted by Brooks (2003) has being very close to the concept of vulnerability in the natural hazards community when vulnerability is framed under risk. Here it is said that vulnerability is view as independent from the hazard. Nevertheless, while looking at particular case studies, Wolf[2] et al., (2008) found that vulnerability was indeed defined specifically as a function of the hazard and, therefore, the link between a “social” interpretation of vulnerability in climate change and the element vulnerability in the natural hazards is not undisputed.

Vulnerability to climate change, as conceptualized in climate change, is a broad concept that accounts for the main stressors affecting a system (including also non-climatic stressors) and consideration of the socio-economic factors that determine the differential potential of communities to adapt to changing conditions.

In general, climate change scientists frame vulnerability in a wider spatial context. This means that most of climate impacts studies are carried out at a national or regional scale (see section 3.3). Due to the nature of the processes studied by the climate change community, it is not feasible and even senseless to assess vulnerability at detailed scales, something that is quite common in the natural hazards community. This poses an interesting paradox: On the one hand reducing vulnerability of local communities to natural hazards needs to take into account climate change, on the other hand, the most effective vulnerability reduction often takes place locally (Schipper and Pelling 2006). When aiming to understand the operation of vulnerability concepts, these two extreme operating scales, global (mostly in climate change) and local (mostly in natural hazards), are not so adequate. The key, in our opinion, is to aim for an intermediate scale of complexity (Kropp et al.. 2006).

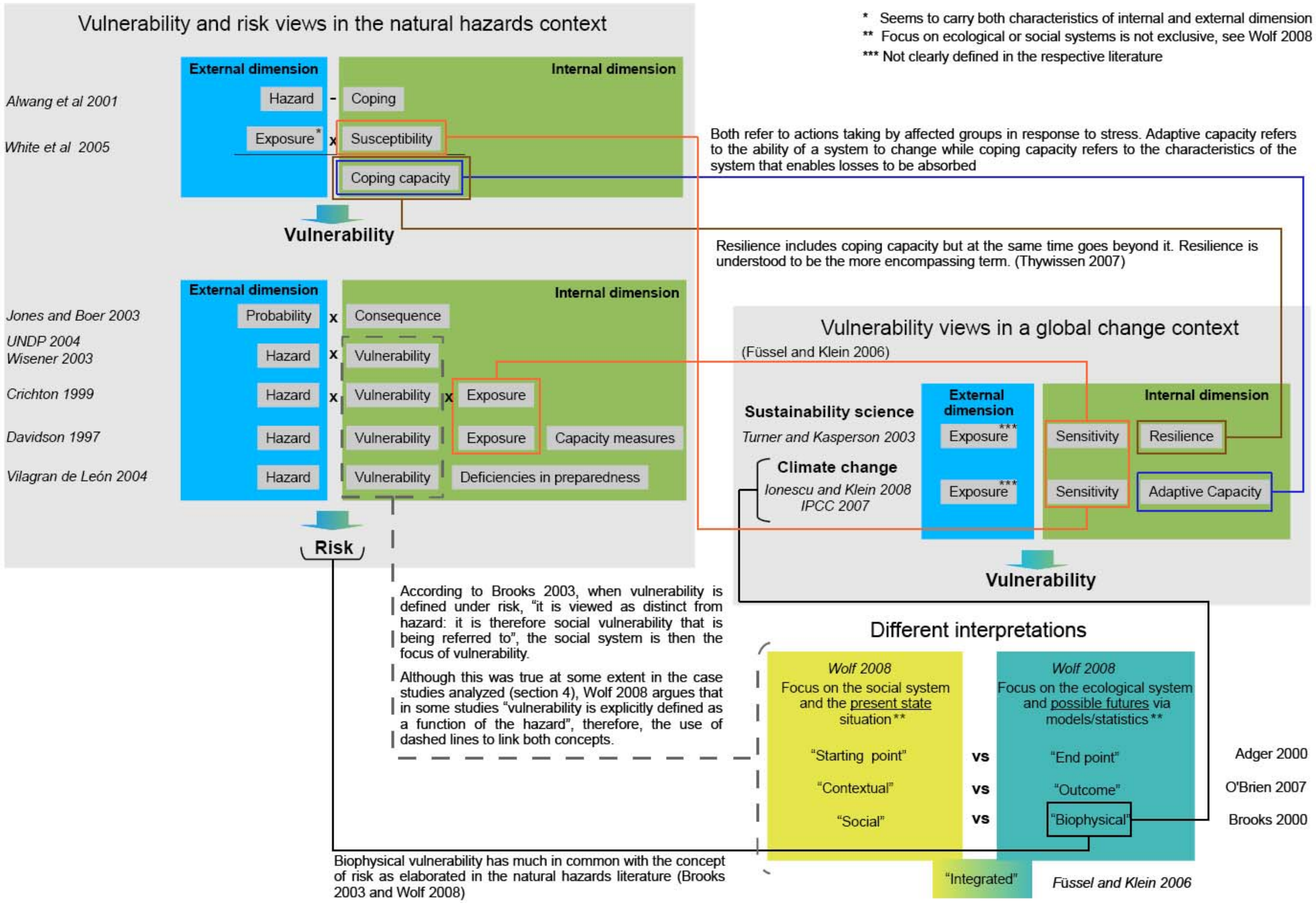

Figure 11 - Synthesis and relations between natural hazard and global change vulnerability/risk elements

Figure 11 shows the main characteristics regarding the approach taken by both communities in order to assess vulnerability. One can already perceive some of the aspects of the different approaches in the case studies analysed. For instances, the high interdisciplinary characteristics of the climate change vulnerability studies translated that a large number of sectors, for example: forest, agriculture, biodiversity and water. (see section 3.3.1) The vulnerability assessments studied in climate change are strongly scientifically based. Although efforts of including participatory contributions of regional expert surveys were noted (see section 3.3.2), for the NRW case study (see section 3.3.3) the basis for the vulnerability assessment consisted on a systematic stocktaking of all conceivable types of damage caused by extreme weather events.

The vulnerability perspective is quite strong in the climate change case studies analysed here. They both follow the orientation provided by the IPCC framework with both studies viewing exposure and sensitivity as factors contributing to vulnerability. In both studies was mentioned that future vulnerability depends at great extent of the present state situation positioning these studies in line with the "social", "contextual" or "starting point" interpretations of vulnerability as defined by Wolf [1] et al., (2008).

5.3 *Insights brought by the case studies*

Frameworks on vulnerability just frame the theoretical foundations for future practical work of assessing vulnerability. This means that hardly any theoretical thinking behind a framework can be as detailed as the practical work that a vulnerability assessment imply.
It became clear from the evaluation of concrete case studies that new links and further clarification of the concept "vulnerability" could be better achieved rather than looking at the confusing linguistic description derived from conceptualization.
By understanding how vulnerability was operated in both communities it became clear that the concepts "susceptibility" used by the natural hazards community and the concept "sensitivity" used in climate change are in fact closely related and therefore the difference of concepts in this case lays almost exclusively on semantic. Like noted in section 3.4.2, susceptibility and sensitivity reflect the characteristics of a particular system that make it prone to impacts by a particular stimulus.

Although the concept coping capacity in the natural hazard sphere and adaptive capacity in climate change share some similarities, the review made in the case studies showed that coping capacity and adaptive capacity are hard to operate in the practical work carried by both communities. Looking at the case studies from the natural hazards research, it was observed that coping capacity is very seldom incorporated while assessing vulnerability. None of the analysed case studies belonging to the natural hazards community presented any conceptualization of coping capacity. We must here highlight the fact that the narrow number of case studies might bias this interpretation, nevertheless is worth to notice that despite the concept of coping capacity being quoted several times in the natural hazard literature (Alwang et al. 2001, UNDP 2004, Peltonen 2006) no inclusion of coping capacity both in the definition of the concept or in the practical work carried by the case studies can be found. Another explanation might have to do with the fact that the sample of case studies was clearly directed towards physical vulnerability. Studies looking at social vulnerability or food security might bring new insights on this matter.

On the other hand, adaptive capacity in the climate change community was present in the definition of vulnerability and was operated in more than 88% of the case studies. Nevertheless difficulties in doing so were evident and most case studies relied on an expert or local knowledge assessments (for example in *Vulnerability and adaptation to climate variability and water stress in Uttarakhand State, India* and *Climate Change in Germany: Vulnerability and Adaptation of Climate Sensitive Sectors (Kelkar 2008)*) or to socio-economic parameters.
There was also a case in the climate change community were adaptive capacity was not assessed. In the NRW study (Kropp 2006) no adaptive capacity indicators were pushed forward and no internal differentiation of adaptive capacity occurred. Nevertheless it is noted in the study that a stock-taking adaptive capacity would be needed.

In the natural hazards case studies oriented to assess the vulnerability of floods, the concepts used and the parameters employed are the traditional ones of economic flood damage potential. In opposition to this, the analyzed vulnerability studies carried by the climate change community hardly incorporate any economic valuation of damages; this was consistent in both spatial scales analyzed. There is increasing effort to incorporate a social dimension in the natural hazard assessments, since it has been highlighted as an important factor in recent floods, e.g. 2002 floods in Europe and the United Kingdom summer floods in 2007. The social system remains therefore represented in a very superficial way. It was not clear whether this is just because this kind of flood risk analysis lags conceptually behind other studies of vulnerability to hazards, or whether there are other more methodological issues related to the difficulty of forecasting social dimensions of hazards far into the future.

The use of models and scenarios for different time steps is a very pronounced characteristic of vulnerability assessments in climate change. The models used are both socio-economic and climatic in order to test climate impacts under certain policy and development assumptions. On the natural hazards community, also the use of socio-economic models as perceived at a national scale. On a regional scale, normative decisions were used in the natural hazards approach, for example, governmental guidance regarding sea level rise values for flood risk calculation. Governmental guidance was not perceived in the analysed climate change vulnerability assessment underlying the idea of a scientific rather than community based assessment.

The final aim of the vulnerability studies presented carried by the climate change community was the implementation of adaptation measures in order to reduce the vulnerability of the system. Due to the inclusion of the adaptation concept in their frameworks it is very common that future vulnerability in climate change is presented in two different ways: If no adaptation measures are implemented (usually named "business as usual") and if adaptation measures are taken into account. Being highly interdisciplinary, climate change vulnerability studies tend to focus on a constellation of hazards that may affect the system, it is therefore common to find measures of vulnerability to floods, droughts, heat haves, sea level rise, agriculture or tourism in the same study. The approach at a regional scale is strongly sector oriented while the overarching element for vulnerability assessment is the climatic system.

The focus of the natural hazards community is to assess and reduce the risk of a system to a particular hazard and also, with increasingly trends in the community, looking on how to increase the resilience of the system. Usually this community deals with the risk of one particular hazard (although multi hazards vulnerability/ risk assessments can also be found) and its implications across several sectors. In order to reduce the risk some options/decisions will have to be made and the consequent risk reduction is evaluated usually in terms of monetary losses avoided.

In conclusion, by decomposing vulnerability into components and taking a deep look on how case studies operate vulnerability, it was possible to observe that the translation of conceptual ideas does not always find a correspondence with the operational level.

Although there is a growing need for information on the vulnerability of coupled human – environment systems, there is little consensus on best practices in the literature (Polsky et al. 2007). In particular, how to develop a overarching definition of vulnerability that could be shared among different disciplines and how to structure vulnerability assessments so that their findings are comparable and generalizations can be made (Polsky et al. 2007).
This discussion aims at contributing to the clarification of the use of vulnerability concepts both in the natural hazards and climate change community by looking on how in practice these issues are addressed at a case study level. It was possible to observe operating similarities in concepts that shared different names such as sensitivity and susceptibility. The opposite case was also observed, this is, similar notions of adaptive capacity and coping capacity are mentioned by both communities but the level of practical implementation was rather different. This means one cannot just simply compare results attached to terms that are conceptually and linguistically similar. Looking at how concepts are formulated is valuable but further steps in investigating more in deep and diverse case studies collection could play a valuable role in improving the understanding the vulnerability concept models used by the natural hazards and the climate change communities.

6 Conclusions

When talking about vulnerability, both communities have much to learn from each other in aspects such as the use of models and scenarios and on methodologies for valuing assets. Climate change community could benefit from experiences gained in natural hazards studies. This community has it's own well developed fields of research on vulnerability, although there are important differences with vulnerability assessment carried out in the context of climate change (Ionesco, Klein et al.. 2008). To achieve this some kind of common understanding of vulnerability must be developed. By looking at case studies many differences that go beyond definitions on words and concepts between both communities are found. Since all the terms in this context are already overloaded with meanings, the solution of this problem cannot be an agreement on detailed definitions of concepts because these remain just as imprecise as the (scientific and everyday language) concepts they are defined upon (Wolf [2] et al.. 2008). In addition, a researcher interpretation on the concept vulnerability can be most precisely seen at the case study level, where actual vulnerability measurement methods are described.

The impact models developed by the climate change community would greatly benefit disaster risk managers in preparing for such impacts and adapting current disaster risk strategies. For instance, climate change experts could share information regarding the disappearance of particular glaciers providing water to specific communities, which in the short term is expected to cause increased water supply and severe water shortages in the long term. Similarly, the historical disaster record (particularly for hydrometeorological hazards) used by the disaster risk reduction managers and their robust vulnerability-and-capacity assessment tools would inform the work of climate change policy makers.
Approaches of climate change vulnerability assessments and those for natural hazards seem to be converging. A particular important contribution to this was the shift from a climate scenario applied to biophysical impacts assessments (first generation) to examining the relationship between current climate variability and current adaptation (second generation) before considering future climate and adaptation in the broad context of environmental stressors, socio-economic change and sustainable development.

6.1 Future challenges for vulnerability assessments

More than twenty years ago, Timmerman (1981) questioned the use of the term vulnerability, stating that a term of such broad use to be almost useless for careful description at the present, except as a rhetoric indicator of areas of greatest concern (Timmermann 1981). The concept of vulnerability has been widening, moving from vulnerability as an internal risk factor towards a multi dimensional concept encompassing physical, social, economic environmental and institutional features. In consequence, the so called integrated vulnerability frameworks became more and more elaborated and complex.

In order for the term vulnerability not to become useless as mentioned by Timmerman (1981), we need to move beyond the idea of complexity of things to frameworks that are synthetic and capture the essential processes. Vulnerability assessments should therefore stress significant human-environment relations as a coupled system, one that can be an endogenous source of stress by itself; this means that its own dynamics can be a source of future vulnerability. We should also understand when developing our studies that vulnerability processes unfold at varying scales. Changes at particular local places are often connected to broader scale phenomenon such as globalization, macro political processes as well as ongoing change in the global biosphere.

A shared conceptual framework dealing with vulnerability may not solve the problem, since there is the danger that common language may still hide divergent assumptions (Pickett et al.. 2005). Nevertheless the ENSURE project should be a learning platform where both communities can considerably improve their vulnerability assessment methodologies, once again, not by discussing over and over the meaning of words but by assessing weaknesses and strengths of each case study carried out, discussing more on the basis of results and operations instead of concepts.

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