Chapter 2. Determinants of Risk: Exposure and Vulnerability

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Executive Summary

Vulnerability and exposure are key determinants of disaster risk. Trends in vulnerability and exposure are the main causes behind observed trends in disasters losses. A better understanding of risk, including vulnerability and exposure, is essential for adaptation strategies and practices. [2.1, 2.2, 2.7, 2.8]

Disaster risk originates from a combination of social processes and their interaction with the environment. Determinants of risk include hazards, exposure and vulnerability. The causal factors of vulnerability are susceptibility/exposure, eco-social and economic fragility and lack of resilience. Exposure is the inventory of assets and interrelations of human systems that can be affected. Resilience includes the capacity to anticipate, cope and recover. [2.3, 2.4]

Vulnerability and exposure are highly context specific, including physical, environmental, economic, social, cultural, institutional and governance dimensions. Vulnerability is highly differentiated, including by wealth, gender, age, race/ethnicity/religion, disability, and class/caste. Vulnerability and exposure are very dynamic, because the context is non-stationary. [2.2, 2.5, 2.7]

The evolution of vulnerability and exposure partly depends on the approaches taken in dealing with hazards and change. Such approaches range from a focus on the short term, which may inadvertently lead to maladaptation, to long-term strategies that explicitly foster resilience. Lack of capacity to cope and adapt leads to vulnerability. [2.4]

Key drivers of trends in vulnerability and exposure include population growth and changing demographics, urbanization, economic development, environmental degradation, science and technology, as well as institutional and governance dimensions. Important complexities arise from accumulation of risk, dynamic changes in vulnerabilities, and different phases of crises and disaster situations. [2.7]

Climate change has the potential to affect not only the frequency and intensity of climate and weather extremes, but also vulnerability and exposure, for instance through impacts on the number of people in poverty or suffering from food and water insecurity, the social segregation of society, diminishing human and social capital, general health levels especially amongst the poor, where people live, and governance**.** [2.7]

Comprehensive assessment and effective communication of risk are important for reducing vulnerability. However, there are methodological and data gaps in risk assessment that need to be filled to inform proper interventions (adaptation). Vulnerability profiles -- summaries of data and other information on who and what is vulnerable when and where -- can help to quickly identify the determinants of risk for a system and sectors at risk. Vulnerability and risk indicators, criteria or indices are important tools for risk monitoring and vulnerability analysis. However, no indicator fits all purposes, and improvements are needed to better capture dynamic aspects of vulnerability and risk, including societal response. [2.2, 2.6, 2.8]

Impediments to information flow (including bottom-up and top-down) are key determinants of risk. Effective communication of risks requires new formats of communication that deal appropriately with uncertainty and complexity. [2.8]

2.1. Introduction and Scope

Many adaptation efforts have started to address the implications of potential changes in the frequency and intensity of extreme events. To properly assess the impact of such changes, a good understanding of exposure and vulnerability to climate-related hazards is essential. However, exposure and vulnerability are not simply a steady baseline against which risk evolves primarily due to changes in hazards. In fact, changes in exposure and vulnerability generally create larger and faster trends in risk than changes in climate and weather extremes due to anthropogenic climate change (e.g. Bouwer *et. al*., 2007; Pielke and Landsea, 1998). Hence, effective strategies and practices to manage future climate risk depend on a solid understanding of the dimensions of exposure and vulnerability to climate-related hazards, as well as a proper assessment of trends in those dimensions. This chapter aims to provide that underpinning of the SREX, by exploring the determinants of risk and thus demonstrating the fundamental entry points for risk reduction and adaptation.

In that context, it is important to note that the constituency that supports improved risk management has historically proven limited in bringing about many of the changes that have been recommended by disaster risk reduction and climate adaptation researchers alike, especially those that focus on modifying social and development pressures in order to reduce vulnerability. Key to addressing present and future risks include integration of bottom up and top down information, clarifying the risks of living in a particular location, and overcoming impediments to the flow of information across scales. Despite the significant efforts of these communities, the vulnerability of many individuals and communities to natural hazards continues to increase considerably (Thomalla *et al*., 2006). Behind the analytical questions regarding the transparency of risk, are broader questions about the public sphere and the public goods provided – or not provided -- by governments, civil society organizations and market actors. These questions become particularly pertinent in the context of climate change, which in many cases has the largest impacts on those already vulnerable to current climate variability and extremes. Answers to these questions must address not just information about risk, but particularly appropriate instruments, incentives and institutions to better manage risk in the context of development (e.g. Bettencourt *et al.,* 2006). These issues will be explored more explicitly in chapters 5, 6, 7 and 8, but they do shape the analytical perspective of this chapter in assessing the determinants of risk.

The first sections of this chapter elucidate the conceptual determinants of risk, showing that risk originates from a combination of social processes and their interaction with the environment (2.2-2.3), and highlighting the role of coping and adaptive capacities as determinants of risk (2.4). The subsequent descriptive sections describe the different dimensions of vulnerability and exposure (2.5), a set of vulnerability profiles in specific sectoral contexts (2.6), and finally trends in vulnerability and exposure (2.7). Given that exposure and vulnerability are highly context specific, these sections are by definition limited to a general overview. A methodological discussion (2.8) of approaches to identify and assess risk provides indications of how the dimensions of exposure and vulnerability can be explored in specific contexts, such as adaptation planning, and the central role of risk perception and risk communication. The chapter concludes with a crosscutting discussion of risk accumulation, the nature of disasters, and barriers to overcome (2.9) and research gaps (2.10).

2.2. Defining Determinants of Risk: Hazard, Exposure, and Vulnerability

Disaster risk can be defined as the probability of future damage and loss associated with the occurrence of environmental hazards where levels and types of loss are determined by the levels of exposure and vulnerability of society (UNDRO, 1980; Cardona, 1990; UNISDR, 2004, 2009b; Birkmann, 2006a/b). Risk is the result of the interactions in time and space of probable physical events with exposed vulnerable elements of the social systems (Cuny, 1984; Davis and Wall, 1992). Through such interactions, these physical events are transformed into hazards with the potential to generate future loss and damage. It is in the latency of risk that the opportunity for risk prevention, mitigation and transfer exists, employing diverse adaptation or disaster risk management principles, strategies and instruments (Lavell, 1996, 1999a). Disaster risk management may be defined as a social process that searches to reduce, predict and control disaster risk drivers in a development framework, by means of the design and implementation of appropriate policies, strategies, instruments and mechanisms (Cardona and Barbat, 2000). Effective risk reduction and adaptation requires shift from focus on the disaster event towards understanding of disaster risk (Cardona *et al.,* 2005).

A disaster itself may be defined as a social condition whereby the normal functioning of society has been severely interrupted by the levels of loss, damage and impact suffered (Cardona, 1990; Alexander, 1993, 2000; Quarantelli, 1998; Birkmann 2006b). This damage and loss may, under certain circumstances, reach such levels and consequences that it can be defined as a large-scale "disaster" or "catastrophe". On the other hand, events with lower levels of loss and damage, (albeit still with high impacts on lives and livelihoods at smaller levels of aggregation, such as the household, community or municipality), it is now common to talk of small- and medium-scale disasters (Marulanda *et al.,* 2008, 2009, 2010; United Nations, 2009). Disasters, large or small, are the product of a complex relationship between the physical world, the natural and built environment, and society, its behaviour, functioning, organization and development (Quarantelli, 1998). At the same time the disaster itself leads to new social processes and new or transformed risk conditions. Disasters associated with environmental hazards reflect and signify unmanaged risk and may also be seen as representing unresolved development problems (Westgate *et al*., 1976; Wijkman and Timberlake, 1984). Risk is a continuum, and disaster one of its many "moments" or "materializations" (Lavell, 2005; ICSU-LAC, 2010).

The concept of hazard is used to refer to a latent threat that can be expressed as the potential occurrence of natural, socio-natural or anthropogenic events that may have physical, social, economic and environmental impact in a given area and over a certain period of time (White, 1973; UNDRO, 1980; Cardona, 1990; Birkmann, 2006b). Each hazard is characterised by its location, frequency and intensity. A natural hazard means the potential occurrence of an extreme geophysical or hydrometeorological event that may cause severe effects to exposed and vulnerable elements (UNDHA, 1992). The study of hazards typically involves the natural, earth- and applied sciences.

At present the effects of climate change on frequencies and intensities of hazard events are a key field of research (ICSU-LAC, 2010). In this context hazards can be the extreme weather phenomena themselves –such as intense tropical storms–, or they can be the result of the physical impacts of climate extremes on the natural environment, especially through the local hydrology –such as a deficit or excess in rainfall that results in a drought or flood. Subsequently, these hazards may have impacts or adverse effects on natural (ecosystems) and human systems (socio-economic).

When the intensity or recurrence of hazard events is partly determined by environmental degradation and human intervention in natural ecosystems, the origin of hazard can be considered as socio-natural. These hazards are created where human activity intersects with natural ecosystems. Changes in the environment and global climate change are the most notable examples of socio-natural hazard phenomena (Lavell 1996, 1999a).

Vulnerability refers to the propensity of exposed elements such as human beings and their livelihoods to suffer damage and loss when impacted by single or diverse hazard events (UNDRO, 1980; Timmerman, 1981; Maskrey, 1984; Cardona, 1986, 1990; Liverman, 1990; Cannon 1994, 2006; Blaikie *et al.,* 1996; UNISDR, 2004, 2009b; Birkmann, 2006b, Thywissen, 2006. In the context of disaster risk, vulnerability, its facets, factors and levels are generally seen as a result of defined social processes. That is to say, vulnerability is the most palpable manifestation of the social construction of risk (Aysan, 1993; Blaikie *et al.,* 1996; Wisner *et al.,* 2004). The physical world and the potential for hazard it presents are given a social dimension and significance by human behaviour and its results in terms of the organisation, structuring and functioning of society and its support elements (Wilches-Chaux, 1989; Wisner *et al.,* 2004). Such social construction includes (ICSU-LAC, 2010):

- How human action influences the levels of exposure and vulnerability in the face of different physical events.
- How human intervention in the environment (degradation or transformation) leads to the creation of new hazards or an increase in the levels or damage potential of existing ones (socio-natural).
- How human perception, understanding and assimilation of the factors of risk influence their reactions, prioritization and decision making processes.

The term vulnerability has been employed by a large number of authors in other contexts of social sciences to refer to disadvantaged conditions. Thus, for instance, people refer to vulnerable groups when they talk about the elderly, children or women, without specifying what these groups are vulnerable to. However, following on from what we have stated above, it is important to ask ourselves: Vulnerable to what? (Wisner *et al.,* 2004) In other words, hazard and vulnerability are mutually concomitant and lead to risk. If there is no hazard it is not feasible to be vulnerable when seen from the perspective of the potential damage or loss the occurrence of an event might signify. In the same way, no hazard can exist for an element or system if such an element is not exposed and vulnerable to the potential event. Even though this might seem to be an unnecessary subtlety, it is important to make this distinction, given that the adjective vulnerable is employed in different ways in problem areas other than the disaster field (psychology, public health, social protection, poverty studies, etc). A population might be vulnerable to hurricanes, for example, but not to earthquakes or floods; notwithstanding other ways of approaching vulnerability help show synergies and trade-offs useful for risk understanding (Alwang et al 2001; Cardona et al, 2003; Lopez-Calva and Ortiz, 2008; UN, 2009).

Table 2-1 presents a compilation of the definitions of vulnerability gathered and categorised by domain; i.e. risk assessment, climate change, social/institutional vulnerability, integrated. An extensive review of the terminology was carried put by Thywissen (2006) and includes a long list of definitions used for the term vulnerability.

[INSERT TABLE 2-1 HERE:
Table 2-1: Definitions of the term vulnerability as described in the literature reviewed.]

Disaster risk and disaster, in summary, originate from a combination of social processes and their interaction with the environment. The notion of social construction of risk is now widely used to capture the idea that society, in its interaction with the changing physical world, constructs disaster risk by transforming physical events into hazards through social processes that increase the exposure and vulnerability of population groups, their livelihoods, production, support infrastructure and services (Chambers, 1989; Cannon, 1994; Wisner, 2006a; Carreño *et al.*, 2007a). Disaster risk and disasters have been constantly on the rise over the last five decades. This trend may be exacerbated by climate change, unless concerted actions to reduce risk and adapt to the changing climate are not enacted, including corrective and prospective interventions to address disaster risks (Lavell, 1996, 1999a, 2005).

From the research angle, natural and engineering (applied) sciences provide a basic platform and understanding of environmental processes (in terms of geomorphology, ecology, etc.) and physical vulnerability. On the other hand, social science provides an understanding of the social, economic, cultural and political rationale for the types of intervention experienced (Cutter, 1994; Kasperson *et al.,* 1988).

The challenge for the natural and applied sciences is to provide relevant information to individual and collective decision makers, especially on potential consequences and possible strategies to reduce risk. However, basic scientific information is not enough. Effective risk management also requires a good understanding of the underlying vulnerabilities, as well as effective communication and dissemination of risk knowledge. As disaster risk is not an autonomous or externally generated circumstance to which society reacts, adapts or responds (as is the case with natural phenomena or events per se), but rather, the result of the interaction of society and the natural or built environment, it is in the knowledge of this relationship and the factors influencing it that effective risk management can be achieved (Susman *et al.,* 1983, Comfort *et al.,* 1999; Renn, 1992; Vogel and O'Brien, 2004). This requires varying types of relationships and coordination between social and basic, natural or applied sciences (ICSU-LAC 2010). However, despite the many calls for interdisciplinary and trans-disciplinary methods and research, efforts to understand and address disaster risk are still dominated by partial approaches and contributions whereby the different sciences and disciplines contribute their specialized knowledge to the understanding of diverse facets of the problem, all of undoubted importance, but which do not define or delimit the overall disaster risk as such (ICSU-LAC, 2010). This is why some authors suggest that as yet we do not have an integrated conceptual framework, a common theory, for studying risk, which is jointly adopted or understood by the specialised sciences or disciplines (Cardona, 2004).

2.3. Vulnerability Factors

The notion of risk, in general, denotes simultaneously a possibility and a reality. It is an abstraction of a transformation process and reflects an undesirable state of reality which has not yet materialized. The social materialization of risk can be understood by thinking risk in terms *a becoming-real* of a social construction (Beck, 2000, 2008; Adam and Van Loon, 2000). If the distinction between reality and possibility is accepted, then risk could be understood as the possibility that an undesirable state of reality (adverse effects) will occur as a result of natural or socio-natural events (Luhmann, 1990). Subsequently, risk can be something measurable in probabilistic terms, what is useful for resource allocation, but also its intervention can be based on social values and preferences (Renn, 1992).

The conceptual frameworks used to understand and interpret disaster risk and the associated terminologies have not only varied over time, but also differ according to the disciplinary perspective considered. Although researchers and professionals working in the disaster areas may believe that they are talking about the same concept, serious differences exist that impede the decision-making effectiveness; i.e. successful, efficient, and effective risk reduction implementation (Cardona, 2004).

As stated previously, risk is the result of the interaction in time and space of exposed and susceptible persons, their livelihoods and support infrastructures and, potentially damaging physical events. Therefore, understanding risk minimally requires knowledge about (ICSU-LAC, 2010):

- *Hazards*, including how human intervention in the natural environment leads to the creation of new hazards
- *Exposure*: how persons, property, infrastructure and goods and the environment itself are exposed to potentially damaging events (due to their location and physical susceptibility)
- *Vulnerability* of persons and their livelihoods, including the allocation and distribution of social and economic resources in favour of, or against the achievement of resistance, resilience and security.

In other words, vulnerability is the "state of reality" that underlies the concept of disaster risk. It is the causal reality that determines the severity of damage when a hazard event occurs. Vulnerability reflects susceptibility, the intrinsic predisposition to being affected (lack of resistance); the conditions that favour or facilitate damage (lack of resilience). 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 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). On the other hand, UNISDR defines vulnerability as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of hazards (UNISDR, 2009b). Many believe that it is not possible to assess vulnerability however it is fundamentally important to understand how vulnerability is generated, how it increases, and how it builds up (Maskrey, 1984, 1989; Lavell, 1996, 1999a; O'Brien *et al.,* 2004b; Cardona, 1996, 2004, 2010). The evaluation and follow-up of vulnerability and risk is needed to make sure that all those who might be affected, as well as those responsible for risk management, are made aware of it and can identify its causes (Maskrey, 1993a/b, 1994b, 1998; Mansilla, 1996). To this end, evaluation and follow-up must be undertaken using methods that facilitate an understanding of the problem and that can help guide the decision-making process.

2.3.1. Conceptual Frameworks of Vulnerability and Disaster Risk

In general, vulnerability describes a condition of people that derives from the political and economic context. In this sense, vulnerable groups are not only at risk because they are exposed to a hazard but as a result of marginality, of everyday patterns of social interaction and organisation, and access to resources (Bankoff, 2004; Morrow, 1999). Thus the effects of a disaster on any particular household result from a complex set of interacting conditions. Cannon (2006) suggests that disparities in income distribution, wealth and power are ultimately the major factors of vulnerability. Wisner (1993) then suggests that the notion of vulnerability could be expanded to include also processes and effects of marginalisation. Wisner (2003) defines guidelines to generate vulnerability profiles, taking into consideration sources of environmental, social and economic marginality. However, it is important to keep in mind that people and communities should not be perceived only or mainly as victims, and this to avoid evading the relevant problem of what causes vulnerability (Cannon, 2000). Households and communities are active managers of vulnerability (Pelling, 1997, 2003).

The concept of vulnerability clearly involves varying magnitudes: some people experience higher intensities of impact than others (Wisner *et al.,* 2004). Allen (2003) and others suggest that there are theoretical, pragmatic and ethical reasons to suggest that the community scale is the most appropriate scale at which to target vulnerability, yet some vulnerability issues can only be addressed by governments or even at supranational level. However, mainstreaming of appropriate disaster risk management into development planning faces obstacles such as lack of political will and geographic inequity (UNDP, 2004).

Twigg (2001), Birkmann (2005) and Birkmann (2006) give an overview of conceptual frameworks, definitions and approaches for assessment of vulnerability to natural hazards. Cutter *et al.* (2008a,b) also carry out a comparative analysis of vulnerability frameworks. Adger (2006) reviews different approaches from the human ecology perspective (i.e. entitlements, analysis of the underlying causes of vulnerability), the natural hazard perspective (i.e. identification of vulnerable group and regions) and the Pressure and Release (PAR) model. Füssel and Klein (2006) review the evolution of the concepts and methods of vulnerability assessment in the climate change community, and include a glossary of the main concepts underlying the IPCC approach. Schröter *et al.* (2005) uses the notion of coupled system to define and assess global change vulnerability. Adger and Brooks (2003) also draw a link between vulnerability and global environmental change.

Thomalla *et al.* (2006) and Mitchell and van Aalst (2009) examine commonalities and differences between the climate change adaptation and disaster risk reduction communities, and identify key areas of convergence. It results that the two communities perceive differently the nature and timescale of the threat: if impacts due to climate change are surrounded by uncertainty, considerable knowledge and certainty exists about the events characteristics and exposures related to extreme environmental conditions, due to historical experiences. In the other hand, the disaster risk management community is increasingly adopting an anticipatory and forward-looking approach, but bringing it in-line with the longer-term perspective of the climate change community on future vulnerabilities. Climate change adaptation increasingly places emphasis on improving the capacity of governments and communities to address existing vulnerabilities to current climate variability and climatic extremes (Thomalla *et al.,* 2006). O'Brien *et al.* (2004b) pleas for an integration of 'underlying causes' of vulnerability and adaptive capacity in climate change impact assessments rather than focusing on the adaptive capacity and technical measures only.

The PAR model (Blaikie *et al.,* 1994; Wisner *et al.,* 2004) links discrete risk with political economy of resources and normative disaster management and intervention (Adger 2006). The framework is common to risk research and places weight on the social conditions of exposure. Risk is explicitly defined as a function of the perturbation, stressor, or stress and the vulnerability of the exposed unit (Turner *et al.,* 2003). According to Bankoff (2004), the PAR model is still a-historic and reductive; time is treated like an independent variable, and social memory, although difficult to measure, could be a crucial influence on behaviour and perceptions of vulnerability. It fails to adequately address the coupled human–environment system associated with the proximity to a hazard (Cutter *et al.,* 2008a,b). The Sustainability Livelihoods Framework developed by the Department for International Development (DFID) includes three main categories of vulnerability factors. Trends: population, resources, economic, politics and technological; shock: human health, natural, economics, conflict and crop/livestock health shocks; seasonality: seasonal shift in prices, production, food availability, employment opportunities and health (Cannon, 2006). Cardona (1999a,b, 2001) develops and *holistic approach to risk assessment* based on three main components: physical exposure and susceptibility, socioeconomic fragility, and lack of resilience or capacity to anticipate, cope and recover. Similarly, the IPCC definition focuses on vulnerability as a function of exposure, susceptibility or sensitivity to damage and adaptive capacity, including the capacity to recover from impacts (McCarthy *et al.,* 2001; IPCC, 2007; O'Brien *et al.,* 2008). The application of the framework used in Barbat *et al.* (2008) links physical vulnerability to other dimensions of vulnerability and allows understanding the social construction of risk and alternatives for risk reduction in the development context. The disaster risk and reduction and climate change communities aim at integrating the environmental and social perspectives. In this view, vulnerability is a function of the biophysical system and social response and how this manifests itself locally, or the hazardousness of place (Cutter *et al.,* 2008a/b). The vulnerability framework developed by Turner *et al.* (2003) is structured around the concept of coupled human–environment system and accounts for interactions in the system's responses to hazards and its vulnerability. This vulnerability framework is representative of the global environmental change community and defines vulnerability in a broad sense (Birkmann, 2005, 2006). The framework developed by Cardona and Barbat (2000) includes explicitly different scales of analysis and the interactions between them. Brooks (2003) developed a conceptual framework that may be applied consistently to studies of vulnerability and adaptation related to the impacts of climate variability and change within human systems. By distinguishing between social and biophysical vulnerability this approach aims at resolving the different formulations of vulnerability in the climate change literature. Schröter *et al.* (2005) propose a method to guide vulnerability assessments of coupled human–environment systems. It aims at informing the decision-making process about options for adapting to the effects of global change. The BBC framework, based on (Bogardi and Birkmann (2004) and Cardona, 1999a/b, 2001) incorporates the perspective of sustainable development into the assessment of vulnerability (Birkmann, 2006b). It distinguishes between the response before a disaster occurs (preparedness/risk reduction) and the response after (disaster emergency management). The BBC framework analysis vulnerability in a dynamic context and stresses the integration of the environmental dimension of vulnerability. It considers the links between communities and specific services and the vulnerability of ecosystem components to hazards (Renaud, 2006). Cutter *et al.* (2008a,b) describe the *Disaster Resilience of Place (DROP)* conceptual framework, conceived to improve comparative assessment of disaster resilience at the local or community level. It also includes a candidate set of variables for measuring resilience. Taking into account that the measurement of vulnerability is a challenge and using the more compatible approaches of the abovementioned frameworks (Cardona, 1999a, 2001; Cardona and Hurtado, 2000a/b; Cardona and Barbat, 2000; Turner *et al.,* 2003; IDEA, 2005; Birkmann, 2006b; Carreño *et al.,* 2007a/b) the MOVE project (Methods for Improvement of Vulnerability Assessment in Europe) have considered that vulnerability is related to the degree of *exposure*, *susceptibility/fragility and lack of resilience* of a socio-ecological system that favors adverse effects. Figure 2-1 describes this framework addressing vulnerability and disaster risk to natural and socio-natural hazards, emphasizing the association of risk assessment, risk management, adaptation and decisionmaking. It provides a summary of the causal and intervention aspects associated with this holistic vision of risk and vulnerability.

[INSERT FIGURE 2-1 HERE:
Figure 2-1. MOVE project framework on vulnerability and disaster risk assessment and management. Source: MOVE (2010).]

2.3.2. Interactions between Hazards and Society

The exposure is the social and material context represented by persons, resources, infrastructure, production, goods, services and ecosystems that may be affected by a hazard event. It is the inventory of components of society and environment that are exposed to the hazard from spatial and temporal point of view (Cardona 1986, 1990; UNISDR 2004, 2009b). If population and economic resources were not placed in potentially dangerous locations, no problem of disaster risk would exist. In fact land use and territorial planning are key factors in risk control and prevention. However, due to the intrinsically and fluctuating hazardous nature of the environment, increasing population growth, diverse demands for location and the gradual decrease in availability of safer lands, amongst other factors, it is almost inevitable that humans and human endeavour are many times located in potentially dangerous places. In fact, given that the same places are many times both endowed with natural resources and also periodically exposed to hazard (slopes, river flood plains, coasts, etc), location in hazardous areas is all but inevitable. Land use and territorial planning, or other forms of rationalizing location is, therefore, to reduce to a minimum unnecessary exposure and vulnerability to damaging events. Where exposure to events is impossible to avoid, land-use planning and location decisions must be accompanied by other structural or non structural methods for preventing or mitigating risk. Land use plans must be based on location and vulnerability reduction strategies and methods (UNISDR, 2009a). Migration, development models, regional commerce, economic dependency, global trends and transitions, among others, are also key issues related to exposure and physical susceptibility at local level.

Clearly the starting point for land use and territorial planning is knowledge of the natural environment, its resource and hazard base, the carrying capacity and limits to human usage, amongst other factors. At the same time, natural and basic sciences may provide information and knowledge as to the limits of the natural environment when faced with diverse humanly promoted land use options and processes and the potential for new humanly induced hazards- e.g. the degradation of aquifers due to urban development; increases in run off rates due to use of asphalt and concrete, and needed urban flood controls; possible local climate changes due to urban growth and the heat island effect.

From the perspective of the social sciences, location is the product of differing economic, social, cultural and political rationales where information on the physical base of the land, carrying capacity, limits to growth etc are ‘data’ or information filtered by social lenses and considered expeditiously or not according to convenience, social, economic and political calculation and needs, amongst other factors. The diversity of contexts to be found may be illustrated at an individual or family level examining two extremes (Lavell, 1999a, 2005).

Firstly, the economically well-off who conscientiously locate in areas known to be exposed to potentially very damaging event such as earthquakes and forest fires, due to the amenity value of these locations, and where they “reduce” risk through the use of safe building techniques, social protection mechanisms and insurance, for example. And, at the other extreme, poor families that locate in highly hazardous areas, due to the lack of access to the formal and more physically secure land market and where the risk of disaster is constantly traded off against the risk of every day life such that even where they are offered relocation they refuse to move due to the access they have to other survival resources *in locus*. Other sectors of society are located between these extremes and manage other location rationales.

From a governmental angle, although control of hazards should be an intrinsic part of governance rationales it is well known that the local, subnational, national and international scales in fact contribute enormously to unsafe location and increases in vulnerability. The granting of building permits in prohibited areas and the provision of basic urban services in areas highly exposed to hazards both serve to ‘institutionalize risk’ and in the end form part of what may be called ‘implicit’ urban policy. Under other circumstances and in other places governments strictly adhere to land use planning and hazard control location principles. Migration, development models, regional commerce, economic dependency, global trends and transitions, among others, are also key issues related to exposure and physical susceptibility at local level. Understanding this diversity of contexts and decisions is an intrinsic challenge for social science research.

As in the case of the study of socio-natural hazard processes, the relations between natural, basic, applied and social sciences in gaining an understanding of location, exposure and sensitivity may at times be one of sequenced inputs, the social interpretation of location and the search for control being based on a knowledge of the 'natural' limits to location and the ways in which human intervention can change the nature of the environment and the hazards it presents.

Seen from a more interactive stance it is once more with regard to research method, stakeholder participation and mechanisms for information and knowledge dissemination that more interaction between the sciences may be foreseen and planned for in understanding and intervening in location decisions. And, a lot of what information access is all about will inevitably pass through the filter of legal requisites and demands. Thus, one aspect of information generation and use is the way in which this is made available to collective or institutional primary decision makers (government and private sector, in particular). Another matter is with regard to the access to information afforded secondary, civil society and family level decision makers. Clearly the relations between social, natural, applied and basic science are fundamental in circumstances where social communication and democratic access to information are critical factors in helping reducing risk.

2.3.3. Vulnerability from a Social Viewpoint: Causal Factors

Understanding vulnerability requires an analysis of the contexts (physical, institutional, social, economic, etc.), characteristics and structure of human beings and their livelihoods that predispose them to such damage, loss and difficulties in recovery**.** Explanation of vulnerability constitutes a fundamental part of the definition of the notion and in this explanation varied aspects of a physical, technical, social and economic nature intervene, which require the presence and interaction of diverse sciences.

Vulnerability is the result of different social and environmental processes and the characteristics and conditions they give rise to. From a disaster risk perspective, it is a condition that exists with reference to a concrete hazard context and is, therefore 'determined', delimited or contextualized with reference to defined and delimited physical events. That is to say, a community is not vulnerable in general –although there are what could be called 'general vulnerability factors'–, but rather, vulnerable when faced with determined hazard conditions. Thus, vulnerability in relation to earthquakes is not necessarily the same as in relation to hurricanes, drought, or floods. Or, vulnerability used in reference to multi hazard contexts is not the same as in mono hazard exposure. This simple affirmation signifies that all vulnerability analyses or studies and all interventions to reduce or control vulnerability must be informed by a thorough understanding of the nature of the different potentially damaging physical factors that threaten different zones and populations.

Here one of the outstanding questions relates to the types, levels of sophistication, forms of expression and delimitation of the physical factors required for different types of vulnerability analysis and the methods used to get to this information, ranging from community based hazard and vulnerability analysis through to formal scientific research. Once again this signifies that the methods of generating and disseminating information amongst interest groups and stakeholders are as relevant a question and practice as is the generation of scientific information in itself. Information without communication is of little use where the final objective of research is social improvement and change.

Whilst accepting this general principle as to the hazard specific nature of vulnerability, it is also clear that certain factors, such as poverty, the lack of social networks and social support mechanisms, will aggravate or affect vulnerability levels irrespective of the type of hazard. This type of generic factor is different from the hazard-specific factors and assumes a different position in the intervention equation and the nature of risk management processes (ICSU-LAC, 2010).

Vulnerability of human settlements and ecosystems is intrinsically tied to different socio-cultural and environmental processes (Cutter ,1994; Kasperson *et al.,* 1988; Cutter *et al.,* 2008a,b). In any case it refers to susceptibilities or fragilities of the exposed elements; i.e. to the likelihood to be affected, but also it is related to the lack of resilience of the society and environment. Vulnerability is also closely tied environmental degradation (in both urban and rural contexts). This degradation may include local effects of global climate change.

When seen from a social viewpoint, vulnerability signifies a lack or deficit of sustainability. In this regard, risk is constructed socially, even though it has a relationship to physical and natural space. In many places, increases in vulnerability are likely to be related to factors such as rapid and uncontrollable urban growth and environmental deterioration. These lead to losses in the quality of life, the destruction of natural resources and landscape, and loss of genetic and cultural diversity. In order to analyse vulnerability as part of wider societal patterns it is necessary to identify the deep rooted and underlying causes of vulnerability and the mechanisms and dynamic processes that transform these into insecure conditions. All this leads to the conclusion that the underlying causes of vulnerability are social, economic, environmental, and political processes that affect the distribution of resources among different groups, which in turn reflect the distribution of power in society.

Some global processes are particularly significant drivers of risk. These include population growth, rapid urban development, international financial pressures, environmental degradation, and global warming. To take but a limited number of examples, urbanization processes have been an important factor in damage in urban areas; population increase helps to explain increases in the numbers of persons affected by floods and prolonged droughts; and deforestation increases the chances of flooding and landslides (Blaikie at al 1994; Glade, 2003; Wisner 2004, Bradshaw et al, 2007).

The causal factors of vulnerability have been defined as follows (Cardona, 1999a/b, 2001, 2010; Cardona and Barbat, 2000; Cardona and Hurtado, 2000a/b; Carreño *et al.*, 2007a; McCarthy *et al.,* 2001; IPCC, 2007; ICSU-LAC, 2010, MOVE 2010):

- *Susceptibility* (*exposure*): physical predisposition of human beings, infrastructure and environment to be affected by a dangerous phenomenon due to its lack of resistance and location in the area of influence of the phenomenon.
- *Fragility* (*eco-social and economic*): predisposition of society and ecosystems to suffer harm resulting from the levels of fragility and disadvantageous conditions and relative weaknesses related to social, economic, ecological issues.
- *Lack of resilience* (*or ability to anticipate, cope and recover)*: limitations in access to and mobilization of the resources of the human beings and their institutions, and incapacity to adapt and respond in absorbing the socio-ecological and economic impact. The resilience includes the capacity to anticipate, cope and recover.

Several indicators or indices have been proposed to measure vulnerability from a comprehensive and multidisciplinary perspective. Their use intends to capture favourable conditions for direct physical impacts –such as exposure and susceptibility– as well as indirect and, at times, intangible impacts –such as socio-ecological fragilities and lack of resilience– of hazard events (IDEA, 2005; Cardona, 2006; Carreño *et al.,* 2007a). Therefore, according to this approach, exposure and physical susceptibility are necessarily 'hard' conditions for the existence of physical risk, or first order effects, and these are hazard dependent. The propensity to suffer negative impacts as a result of the socio-ecological fragilities and not being able to adequately face disasters, are circumstances of the context that can be considered 'soft' conditions, related to second order effects that aggravate the impact and usually are non-hazard dependent.

Vogel and O'Brien (2004) stress the fact that vulnerability is multi-dimensional and differential –i.e. varies across physical space and among and within social groups; scale-dependent with regard to time, space and units of analysis such as individual, household, region, system; and dynamic– characteristics and driving forces of vulnerability change over time (Leichenko and O'Brien, 2008). Especially the social dimension of vulnerability includes various themes such as social inequalities regarding income, age or gender, as well as characteristics of communities and the built environment, such as the level of urbanisation, growth rates, economic vitality, etc. (Cutter et al., 2003). However, although human society is the main focus of the concepts of vulnerability, some argue that human vulnerability can only be adequately characterised while simultaneously considering the vulnerability of the surrounding eco-sphere.

In summary, risk understanding depends on the understanding of how vulnerability can be captured in its different dimensions and spheres, and taking into account that vulnerability correlates with physical susceptibility (including the built environment), ecological fragility, social-cultural issues and socio-economic contexts. In addition, vulnerability is heavily influenced by the resilience; i.e. the adaptive ability of a socio-ecological system to absorb negative impacts as result of its capacity to anticipate, cope and recover quickly from damaging events. The lack of resilience means an important factor of vulnerability. In the framework of climate sensitivity resilience also means capacity of the system to learn about and adapt to a changing hazard situation. The promotion of resilient and adaptive societies requires a paradigm shift away from the primary focus on natural hazards and extreme weather events towards the identification, assessment and ranking of vulnerability (Maskrey 1993b; Birkmann 2006a/b).

2.4. Coping and Adaptive Capacities

Coping and adaptive capacity is an essential aspect of the ability to reduce risk. Most definitions of risk suggest that one major determinant of vulnerability is the lack of resilience or capacity, as described in Sections 2.2 and 2.3. In some frameworks, capacity is considered an important component of the reaction to an extreme event, and in others it is already taken into account when describing vulnerability to the event. Evidence indicates that capacity features in all stages of intervention of the 'disaster cycle or continuum': risk reduction and prevention, preparedness, response, recovery and reconstruction (Cardona et al, 2003; Lavell, 2005). Presence of capacity may suggest that impacts will be less extreme and/or the recovery time will be shorter, but high capacity to recover quickly –ex post– does not guarantee equal levels of capacity to anticipate –ex ante–. Regardless of where it is placed in the conceptual frameworks, capacity to cope and adapt are frequently seen as the target of policies and projects, which are based on the notion that strengthening capacity will lead to risk reduction. There is no consensus on whether capacity to cope and to adapt are the same, or by extension whether activities to build coping capacity are the same as those to build adaptive capacity. The two are often used interchangeably.
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This section discusses the role of capacity in risk reduction, introducing the different aspects of capacity, drivers and barriers of capacity and how to move from building to applying capacity. IPCC AR4 covered elements of adaptive capacity, options and constraints (Adger et al., 2007). This section expands the discussion by focusing on the role of capacity in exposure and vulnerability reduction, and by comparing coping and adaptive capacity, following Section 1.4. It includes a discussion on drivers and barriers of capacity, and concludes with ideas for moving from capacity to action on reducing risk.

This section discusses capacity in terms of coping and adaptive capacity, but acknowledges that very little scholarship talks explicitly about coping capacity, unless making an explicit distinction between coping and adaptive capacity. It is therefore not possible to make the assumption that every disasters-related mention of capacity describes what we define here as coping capacity. When capacity is discussed, it therefore refers to both or either adaptive and coping capacity, or else it is specified.

2.4.1. Capacity and Vulnerability

While the previous generation of risk studies focused on the hazards, recent reversal of this paradigm has placed equal focus on the vulnerability side of the equation (see Figure 2-1). Emphasising that risk can be reduced through vulnerability is an acknowledgement of the power of social, political, environmental and economic factors in driving risk. While these factors drive risk on one hand, they can on the other hand be the source of capacity to reduce it (Carreño et al 2007a; Gaillard, 2010). This section addresses different treatments of the relationship between capacity and vulnerability, in order to identify the dimensions of capacity and how it relates to climate change and disaster risk. It is important to recognise that 'capacity' is used liberally in the contexts of both climate change and disaster risk, but this section refers only to coping and adaptive capacity, which respectively refer to the ability to cope and adapt in the face of risk.

Much risk reduction work uses existing capacity as a baseline for understanding how vulnerable people are to a specific hazard. The relationship between capacity and vulnerability is described differently among different schools of thought, stemming from different uses in the fields of development, disaster risk management and climate change adaptation. Gaillard (2010: 223) notes that the concepts capacity, vulnerability as well as resilience 'played a pivotal role in the progressive emergence of the vulnerability paradigm within the scientific realm'. Roughly, the literature describes the relationship between vulnerability and capacity in three ways, which are not mutually exclusive (Brooks et al, 2005; Yomani, 2001; Moss et al 2001; IPCC TAR, 2001; Smit and Wandel, 2006):

1) Vulnerability is the result of a lack of capacity
2) Vulnerability is the opposite of capacity
3) Capacity is one element of vulnerability.

The difference can be seen in the variations of the conceptual equation Risk = Hazard x Vulnerability (e.g. Blaikie et al., 1994), where capacity is either left out, assumed to already have been 'subtracted' from vulnerability, or included, as in the versions Risk = (Hazard x Vulnerability)/Capacity or Risk = Hazard + Vulnerability – Capacity. Similarly, building capacity is seen as the means for vulnerability reduction (Downing and Patwardhan, 2004; Gaillard, 2010). Resilience also plays a role in the discussion on capacity and vulnerability (Cardona 2001, Birkmann, 2006a). Resilience is also seen as the opposite of vulnerability (Gaillard, 2010), making the distinction between capacity and resilience necessary, although this distinction can be hard to delineate in reality. Some say that resilience includes coping capacity but at the same time goes beyond it (Cardona 2004, 2010; IDEA 2005, Thywissen, 2006). Timmerman (1981) defines resilience as the capacity of a system to absorb and recover from the occurrence of a hazardous event. Cutter et al (2008) describe this as 'absorptive capacity'.

Although there is a difference between coping and adaptive capacity (see below), coping capacity can be considered a part of adaptive capacity. Figure 2-2 shows how vulnerability, resilience and adaptive capacity have been related to each other differently in the global environmental change and hazards fields. Cutter et al (2008) review perspectives in global environmental change work that place (A) resilience as a part of adaptive capacity, (B) adaptive capacity as a part of vulnerability or (C) nests them as part of an overall framework of vulnerability. From the hazards perspective, they note views where (D) resilience as the ability to bounce back is a part of vulnerability, (E) adaptive capacity is seen as part of resilience, or (F) vulnerability and resilience as separate but related concepts (Cutter et al, 2008).

[INSERT FIGURE 2-2 HERE:
Figure 2-2. Conceptual framework relating adaptive capacity, resilience and vulnerability in the global environmental change and hazards communities of practice. Source: Cutter et al. (2008).]

The relationship between capacity and vulnerability is interpreted differently in the climate change community of practice and the disaster risk management community of practice. There is a history of examining vulnerability and capacity in humanitarian work, which has contributed the Vulnerability and Capacity Analysis/Assessment approach (VCA) (Davis et al, 2004), which uses a variety of development-focused field methodologies. This approach stems from the original work by Anderson and Woodrow (1989, second edition 1998). The purpose of these assessments is to 'provide analytical data to support better informed decisions on the planning and implementation of risk reduction measures' (Davis et al, 2004). Weighing vulnerability and capacity against each other has not always been part of the process of response and recovery, however. Anderson and Woodrow pointed to a lack of understanding of how processes of response and recovery following disasters contributed to vulnerability. Throughout the 1980s vulnerability became a central focus of much work on disasters, in some circles overshadowing the role played by hazards in driving risk. Some have noted that the overt emphasis on vulnerability tended to ignore capacity, focusing too much on the negative aspects of vulnerability (Davis et al, 2004). Recognising the role of capacity in reducing risk also indicates an acknowledgement that people are not 'helpless victims' (Gaillard, 2010: 222).

In the climate change approach, capacity was also initially subsumed under vulnerability. The first handbooks and guidelines for adaptation emphasised impacts and vulnerability assessment as the necessary steps for determining adaptation options (Feenstra *et al.,* 1998; Kates *et al.,* 1985; Carter *et al.,* 1994; Benioff *et al.,* 1996). This can be understood in that climate change vulnerability was often placed in direct opposition to capacity. As a result, vulnerability that was measured was seen as the remainder after capacity had been taken into account.

Gaillard (2010) suggests that one difference between capacity and vulnerability that makes them difficult to juxtapose, is that capacity is often rooted in endogenous resources and relies on traditional knowledge, indigenous skills and technologies and solidarity networks, whereas vulnerability depends on exogenous structural constraints.

Although extensive theoretical scholarship discusses the links between capacity, vulnerability and resilience, in reality it can be unclear. Nelson and Finan (2009) describe a case in northeast Brazil where the public actions related to drought mitigation have on the one hand reduced the vulnerability of rainfed farmers to some adverse effects of drought by providing safety nets and other relief programmes, but this has resulted in a reduction in resilience of the social-ecological rainfed farming system. Davis *et al*. (2004), IDEA (2005), Carreño *et al*. (2007a/b) and Gaillard (2010) note that capacity and vulnerability should not be positioned as opposites because communities that are highly vulnerable may in fact display high capacity in certain aspects. This reflects the many elements of risk reduction and the multiple capacity needs across them. Alwang *et al*. (2001: 18) also underscore that vulnerability is dynamic and determined by numerous factors, thus high capacity in the ability to respond to an extreme event does not accurately reflect vulnerability.

Interestingly, coping and adaptive capacity both feature in the definition of vulnerability in the IPCC AR4, specifically that vulnerability is defined as the degree to which a system is unable to cope with adverse effects of climate change, including climate variability and extremes and is a function of a system's adaptive capacity. This approach suggests that with respect vulnerability, coping capacity is a measure of how likely a system is to be affected, and –the lack of– adaptive capacity is a determinant of vulnerability.

As set out in Section 1.4, there is a difference in understanding and use of the terms coping and adapting. In some cases, the two are considered synonyms or coping capacity is considered a subset of adaptive capacity (Patterson et al, 2010), whereas in other cases the distinction between them is considered large. In the latter case, a number of conceptual and practical differences are highlighted. Here we draw on some of these distinctions to discuss differences between coping and adaptive capacity.

Although coping capacity is often used interchangeably with adaptive capacity in the climate change literature, Cutter et al (2008) point out that adaptive capacity is more likely to feature in global environmental change perspectives and is less prevalent in the hazards discourse where the term 'mitigation' is used instead.

Adaptive capacity refers to the ability of a system to adapt to climate change, but it can also be used in the context of disaster risk. Because adaptive capacity is considered to determine 'the ability of an individual, family, community or other social group to adjust to changes in the environment guaranteeing survival and sustainability' (Lavell, 1999b: 8), many believe that in the context of uncertain environmental changes, adaptive capacity will be of key significance. Dayton-Johnson (2004) defines adaptive capacity as the 'vulnerability of a society before disaster strikes and its resilience after the fact'. The IPCC AR4 defined it as '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' (Parry et al, 2007). Some ways of classifying adaptive capacity include 'baseline adaptive capacity' (Dore and Etkin, 2003), which refers to the capacity that allows countries to adapt to existing climate variability, and 'socially optimal adaptive capacity', which is determined by the norms and rules in individual locations (Dore and Etkin, 2003). Another definition of adaptive capacity is the 'property of a system to adjust its characteristics or behaviour, in order to expand its coping range under existing climate variability, or future climate conditions' (Brooks and Adger, 2004). This links adaptive capacity to coping capacity, because coping range is synonymous with coping capacity, referring to the boundaries of systems' ability to cope (Yohe and Tol, 2002).

In simple terms, coping capacity refers to the 'ability of people, organisations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters' (UNISDR, 2009b). Coping capacity is typically used in humanitarian discourse to indicate the extent to which a system can survive the impacts of an extreme event. It suggests that people can deal with some degree of destabilisation, and acknowledges that at a certain point this capacity may be exceeded. Eriksen et al (2005) link coping capacity to entitlements – the set of commodity bundles that can be commanded – during an adverse event. The ability to mobilise this capacity in an emergency is the manifestation of coping strategies (Gaillard, 2010).

The capacity described by the disasters community in the past decades does not frequently distinguish between 'coping' or 'adaptive' capacities, and instead the term is used to indicate positive characteristics or circumstances that could be seen to offset vulnerability. Because the approach is focused on disasters, it has been associated with the immediate-term coping needs, and contrasts from the long-term perspective generally discussed in the context of climate change, where the aim is to adapt to changes. There has been considerable discussion throughout the vulnerability and poverty and climate change scholarly communities about whether coping strategies are a stepping stone toward adaptation, or toward maladaptation (Eriksen et al, 2005; Yohe and Tol, 2002) (see Chapter 1). This can also be applied in the context of capacity. Useful alternative terminology is to talk about capacity to change and adjust (Nelson and Finan, 2009) for adaptive capacity and capacity to absorb instead of coping capacity (Cutter et al, 2008).

In the climate change community of practice, adaptive capacity has been at the forefront of thinking regarding how to respond to the impacts of climate change, but it was initially seen as a characteristic to build interventions on, and only later has been recognised as the target of interventions (Adger et al, 2004). The UNFCCC, for instance, states in its ultimate objective that action to reduce greenhouse gas emissions be guided by the time needed for ecosystems to adapt naturally to the impacts of climate change. This suggests an implicit notion that the limits for emissions are to be guided by the limits to natural adaptive capacity. Consequently, adaptive capacity has been a central issue in the climate change policy debates since their inception, although the IPCC TAR noted that scholarship on adaptive capacity was at the time 'extremely limited in the climate change field' (Smit et al, 2001: 895).

Regardless of what it has been called, it is now recognised that there are different elements of the disaster continuum that all require different capacities. These capacity needs are discussed in the following section.

2.4.2. Different Capacity Needs

Capacity can be seen from two perspectives: existing capacity and missing capacity. At its core, risk reduction initiatives aim either to use existing adaptive capacity as a baseline, or to build it up if it does not exist or is inadequate. However, this is an oversimplification of the dimensions of capacity. Capacity to anticipate a disaster requires a different set of skills, networks, and capitals than capacity to respond to and recover from a disaster (Lavell, 1994; Lavell and Franco, 1996; Cardona, 2001, 2010; Carreño et al, 2007a/b; ICSU-LAC, 2010; MOVE 2010).

Just like vulnerability and resilience, capacity is dynamic and will change over time. Cutter et al (2008) and Marulanda et al (2008b, 2009, 2010) point out how capacity diminishes in situations were communities have to cope with recurrent hazards, because dealing with one event takes away assets that make people not only more vulnerable to the next event, but also reduce their capacity to absorb and recover from the event.

The discussion in Section 2.4.1 indicates that there are differing perspectives on how coping and adaptive capacity relate. When coping and adapting are viewed as different, it follows that the capacity needs for each are also different (Cooper et al, 2008). This section discusses different capacity needs in the different stages of the disaster cycle: anticipation, response, and recovery.

There are different dimensions of capacity that recur in the literature, including the location, timing, and the actors involved. Capacity varies from place to place, and also has a temporal component (Yohe and Tol, 2002). Capacity determinants vary across systems, sectors and regions and between developed and developing countries (McCarthy et al, 2001) as well as within countries (Kates, 2000). There is also indication that a local focus is more appropriate than a macro-scale focus (Smit and Wandel, 2006). One of the advantages of local assessments of capacity is the ability to reflect differences on a local scale.

The scale also has implications for the unit of analysis. It is therefore relevant to ask whose capacity is in focus. Communities are considered a vital action space for building capacity (Yodmani, 2001; Gaillard, 2010; Van Aalst et al, 2008), and are often a unit of analysis for capacity assessment (Patterson et al, 2010). There is some discussion about the extent to which this reflects differential needs, vulnerabilities and capacities however. Yodmani (2001) notes that involvement of communities in building capacity facilitates appropriate interventions, however in a community context, individuals can be limited in their capacity due to institutional and policy structures over which they have little power (Patterson et al, 2010). Brooks et al (2005) instead suggest a focus on national level adaptive capacity, as an appropriate scale for policy formulation.

Capacity to cope depends on assets, opportunities, social networks, local and external institutions, as well as people's perceptions of their capacity. Responses to hazards are determined by a conceptual understanding of the reason for the hazards; for some this means more prayers, for others it means being better prepared. An expanding body of knowledge on the role of culture in influencing how people perceive and respond to risk underscores the importance of including these dimensions in the entire cycle of disaster response-recovery and adaptation (Kellman et al, 2009; Dekens, 2007a and 2007b; Schipper, 2010; Gaillard, 2010; O'Brien; Wolf et al; Adger et al). Perception and beliefs also determine how vulnerable people categorise themselves (e.g. Klein, 2009; etc).

General requirements for capacity are access to resources and entitlements (Gaillard, 2010), as well as livelihood diversity (Yodmani, 2001). Brooks et al (2005) underscore the importance of the temporal dimension. Needs change over time and throughout the disaster cycle. The following sections discuss capacity needs at different stages in the disaster continuum.

2.4.2.1. Capacity to Anticipate

Disasters are defined by their ability to overwhelm people's immediate capacities to cope (Anderson and Woodrow, 1998). Strengthening capacity to anticipate disasters is a key *ex ante* way to ensure that these events do not engulf people's ability to manage and do not leave them significantly worse off after. Anticipating disasters involves warning and preparedness but goes beyond it to include ensuring other *ex ante* actions such as risk prevention and reduction; i.e. daily decisions and actions to minimise both vulnerability and exposure to hazard events. Development planning, including land-use and urban planning, hydrologic basin and territorial ordering, hazard-resistant building codes enforcement and landscape design are all activities that can reduce exposure and vulnerability to hazards (Cardona, 2001, 2010). All play a role in disaster anticipation, and the ability to carry these out in an effective and risk reduction way will enhance anticipatory capacity. Capacity to anticipate also requires diversifying income sources, maintaining social networks, taking collective action to avoid development plans that put people at higher risk (Maskrey, 1989, 1994b; Lavell, 1994, 1999b, 2005). Successful anticipation relies on all of these components, some of which will be more important depending on the circumstances.

Anticipatory capacity also depends on capacity to prepare for a disaster. This is a form of risk management that differs from anticipatory risk prevention and reduction. Preparedness includes prevision, monitoring of hazards and dissemination of information and warnings (including early warning), having emergency plans and accessible evacuation information (including maps, shelters, emergency supplies). The 2004 Indian Ocean tsunami highlighted the importance of early warning systems. There are still regions in the world (e.g. the Mediterranean) that don't have early warning systems. The Indian Ocean early warning system was recently established but is not yet fully functional in every member country and as a fully integrated system. Building early warning systems is a complex process, both technically and socially. To date, far more effort has focused on getting the technology done, very little has been done to understand human aspects and to enable the positioning of early warning systems in different cultural contexts (Cardona, 1996b; Thomalla et al., 2009 and forthcoming). Particularly important here are different risk perceptions arising from different values and beliefs. Long-term support is needed to build the capacity of sub-national institutions to develop, implement, maintain and improve early warning systems (Cardona, 1996b; Thomalla et al., 2009 and forthcoming). Cannon (2008) notes that there are limits to the sort of preparedness that can be taken on the local level. Citing the storm shelters in Bangladesh, he notes that this type of investment is not feasible for the household of village level.

Even where disaster has not yet materialized, risk and risk factors are always present and may be the subject of conscious human modification, reduction or control. Risk prevention and reduction may be understood as a series of elements, measures and tools directed towards intervention in hazards and vulnerabilities with the objective of reducing existing or controlling future possible risks (Cardona et al, 2003). This concept of anticipation can be differentiated from another group of tools whose objective has been the improvement of intervention in disasters once these occur: response and recover (Cardona el at, 2003; Lavell, 2005).

Up to the beginning of the 1990s, disaster preparedness and humanitarian response dominated disaster practice. Risk reduction (corrective and prospective) was not a priority for public policy or in terms of social action in general. However, in the face of growing evidence as to significant increases in disaster losses and the inevitable increase in financial and human resources dedicated to disaster response and recovery have been increasing recognition of the need to promote prevention and risk reduction over time (Lavell 1994, 1999b, 2005). Notwithstanding, different actors, stakeholders and interests influence the capacity to anticipate a disaster. Actions to minimise exposure and vulnerability of one group of people may come at the cost of increasing it for another.

2.4.2.2. Capacity to Respond

The response phase is during and immediately after an extreme event. Response capacity helps people cope in this period. Responding spans everything from people's own initial reactions to a hazard upon its impact to the phase immediately following, which is typically characterised by the external assistance. Capacity to respond can thus be broken down into sub-components that describe the internal or inherent capacity as well as the external capacity that comes in the form of relief assistance through medial attention and supplies, and food as well as volunteers, shelter and other urgent supplies.

Recurring disasters break down the drivers of coping capacity, increasing vulnerability to hazards (Wisner and Adams, 2003; Marulanda et al, 2008b, 2009, 2010; United Nations, 2009). Unprecedented hazards may also overwhelm existing coping capacity. External emergency assistance following a disaster buffers existing coping capacity (REF), but may also be eroded in event of frequent, recurring hazards. Internal and external capacity are not unrelated. External assistance may have adverse consequences on internal capacity in the short, medium and long term (Anderson and Woodrow, 1989). When emergency response is not in line with development priorities, it is likely to leave people worse off than before, reversing decades of development (DfID, 2004; Anderson and Woodrow, 1989; 1991).

The emergency response phase is when the greatest amount of resources are available, most commonly through humanitarian assistance (REF). While some consider this process necessary, it is also disruptive, often leaving people in temporary shelters for extended periods. Humanitarian operations are complex in themselves, with lack of co-ordination among external agencies, between external agencies and local authorities, between external agencies and local people and community based organizations, etc., and issues such as abuse of refugees, corruption (Bailey, 2008; Transparency International, 2010). It has been suggested that the disruption caused by relief operations can in some cases be worse than the disruption caused by a disaster, as embodied in the phrase: 'First the earthquake, then the disaster' (Oliver-Smith, 1999: 86).

Humanitarian aid and relief interventions have also been discussed in the context of their role in reinforcing or even amplifying existing vulnerabilities (Anderson and Woodrow, 1991, 1998; Wisner, 2001a; Schipper and Pelling, 2005; various gender refs). The direct conflict between humanitarian aid and development has also been highlighted (Bull-Kamanga et al., 1999). Evidence for these observations can be found extensively in the field. It has been noted that sustainable food security is threatened by certain short-term interventions, such as food-for-work programmes, which are considered by some to be medium-term solutions. In some cases, outside relief in the form of food aid has gone from short-term, temporary emergency relief to long-term, continuous donations. This is the case for Ethiopia, a country that has received food aid since an initial damaging drought in 1974 and now has an adult generation that has been entirely nourished on aid food.

There is a considerable literature assessing the success of relief programmes such as food-for-work and similar safety net programmes that have been implemented for instance in Ethiopia (Lind and Jalleta, 2005). This literature focuses on the role of these programmes vis-à-vis bringing people out of poverty. In particular, the discussion centres on how to approach chronic vs. transient vulnerability/poverty. Chronic vulnerability suggests that people are inherently vulnerable to natural hazards, whereas transient vulnerability means that people are likely to recover from their temporary loss of coping capacity. This approach suggests that there are both larger, underlying drivers of vulnerability, such as those described by Wisner et al. (2004) as well as temporary factors that create transient states of vulnerability. Compound emergencies/complex emergencies/compound events, such as when natural hazards hit during a war, or when a storm occurs at the same time as an earthquake, shift people to a different dimension of vulnerability.

Wisner (2001a) shows how poorly constructed shelters where people were placed temporarily in El Salvador following 1998 Hurricane Mitch turned into ‘permanent’ housing when NGO support ran out. When two strong earthquakes hit in January and February 2001, the shelters collapsed, leaving the people homeless again. This example illustrates the perils associated with emergency measures that focus only on the relief phase, and do not take the recovery phase into account.

There is substantial debate on the role played by migration in adaptation, and whether the ability to migrate demonstrates adaptive capacity (EACH-FOR, 2007). A global research effort to understand whether the concept of environmental change-induced migration exists in reality showed many surprising results, including that migration is already part of the adaptive repertoire of many people, and that a significant amount of capacity is needed in order to migrate.

2.4.2.3. Capacity to Recover

Capacity to recover is not only dependent on the extent of a physical impact, but also on the ability to resume livelihood activities (Hutton and Haque, 2003) and return to previous levels of development or better. The phrase ‘building back better’ reflects the acknowledgement that reconstruction processes that aim to return to ‘normalcy’ often are out of synch with the evolving process of development (Mitchell, 2008). Because reconstruction processes often do not take people’s livelihoods into account, instead focusing on their safety, new settlements are often located where people do not want to be. Innumerable examples indicate how people who have been resettled return back to their original location, moving into dilapidated houses or setting up new housing (even if more solid housing is available elsewhere, e.g, El Salvador after Mitch) simply because the new location does not allow them easy access to their fields (for farmers), to markets or roads, to the sea (e.g. Sri Lanka after the tsunami). There are also social reasons why people return to the same location, even if they aware of the risks. The poorer people become, the more likely that risk has lower priority than the threats of homelessness, lack of employment, illness and hunger (Huttan and Haque, 2003; Maskrey, 1994b).

The recovery and reconstruction phases after a disaster provide an opportunity to rethink previous conditions and address the root causes of risk, looking to avoiding reconstruct the vulnerability (IDB, 2007), but often the process is too rushed to enable effective reflection, discussion and consensus building (Christoplos, 2006). Several examples have shown that capacity to recover is severely limited by poverty (Chambers, 1983; Ingham, 1993; Hutton and Haque, 2003), where people are driven further down the poverty spiral, never returning to their previous conditions.

There are few studies looking at how the process of recovery from large disasters relates to adaptation to climate change (Christoplos et al., 2010; Thomalla et al, 2009) but it has been acknowledged that important lessons can be drawn for understanding how to build adaptive capacity (Pelling and Schipper, 2009). The study examining 10 years after Hurricane Mitch in Nicaragua indicated that an evolution of rhetoric from risk management terminology to climate change terminology was not accompanied by a shift in attitude and emphasis from response-focused activities toward preparedness (Christoplos et al, 2010).

Lessons learned from studying the 2004 Indian Ocean tsumani (Thomalla et al, 2009; Thomalla et al, forthcoming) suggest that:

- Social vulnerability to multiple hazards, particularly rare extreme events tends to be poorly understood. Many vulnerability and capacity assessments (both by NGOs and academics) are poorly conducted and don’t identify and address the complexity of causes and drivers of vulnerability.
- There is an increasing focus away from vulnerability assessment towards resilience building. However,

resilience is poorly understood and a lot needs to be done to go from theory to practice. Questions include: What are appropriate levels, characteristics and indicators of resilience, and how can we monitor and evaluate whether we are successful in building resilience? How can resilience be built without understanding vulnerabilities?

- One of the key issues in sub-national disaster risk reduction initiatives is a need to better define the roles and responsibilities of government and NGO actors and to improve coordination between them. Without mechanisms for joint target setting, coordination, monitoring and evaluation, there is much duplication of efforts, competition and tension between actors.
- Disaster risk reduction is only meaningful and prioritised by local government authorities if it is perceived to be relevant in the context of other, more pressing day-to-day issues, such as poverty reduction, livelihood improvement, natural resource management, and community development. Projects that demonstrate these linkages and emphasise win-win outcomes are likely to be more successful at the local level.

2.4.3. Factors of Capacity: Drivers and Barriers

Since the TAR recognised the dearth of scholarship on adaptive capacity (Smit et al, 2001), much effort has gone into developing knowledge on what constitutes adaptive capacity and how it can be built (Adger et al, 2004).

Early work points to factors of capacity such as: an integrated economy; urbanisation; information technology; attention to human rights; agricultural capacity; strong international institutions; access to insurance; and class structure (Handmer et al, 1999; Cannon, 1994). Others identify life expectancy; degree of urbanisation; access to public health facilities; community organisations; existing planning regulations at national and local levels; institutional and decision-making frameworks; existing warning and protection from natural hazards; functioning government; and health and well-being (Klein, 2001; Brooks et al, 2005; Barnett, 2005). Although they acknowledge that adaptive capacity is not only a factor of wealth, Ahmed and Ahmad underscore the importance of provision of resources for enhancing 'the capacity and endurance of the affected people to cope with adversities' (2000: 100).

As a way of understanding adaptive capacity further, numerous scholars have developed indicator systems. These are used both to measure adaptive capacity as well as to identify entry points for enhancing the capacity (Adger and Vincent, 2005; Eriksen and Kelly, 2007; Downing et al, 2001; Brooks et al 2005; Lioubimtseva and Henebry, 2009; Swanson et al., 2007).

Indicators can be a useful starting point for a discussion on what qualifies as an appropriate proxy for capacity, in order to determine what sort of factors act as barriers and drivers. When rooted in the poverty and livelihoods discourse on vulnerability (Chambers, 1989; Swift, 1989), proxies for capacity look very similar to indicators of development, despite the significant argument about the causal structure of vulnerability, which underscores that vulnerability is not the same as poverty (Chambers, 1989; Ribot, 1996). It may be tempting to suggest that any driver of development is also a driver of vulnerability, however there is not always empirical evidence about how the factors actually affect adaptive capacity. It may instead be easier to identify the barriers to adaptive capacity.

Lopez-Marrero (2010) says that an integrated approach taking into account resources as well as the cognitive aspects of adaptive capacity is necessary, but little research has been on cognitive determinants and factors that influence action.

Access to and the availability of resources is considered to be the major factor for adaptive capacity (Brouwer et al. 2007; Ford et al. 2008; Pelling 1997; Reid et al. 2007), but there are other aspects as well: cultural norms, the availability of information and the role of scientific information in decisionmaking, and political feasibility.

Although economic resources are not the only limit to building capacity, they are still important. Corruption is considered a taboo subject (Transparency International) but plays a part in translating how financial resources affect capacity.

Barriers and drivers of adaptive capacity are location specific.

2.4.4. From Capacity to Action

Although there are no real examples of long-term processes of adaptation to anthropogenic climate change, there is history of adaptation taking place across time and space (Adger and Brooks, 2003). There is limited knowledge on how to move from what is considered sufficient adaptive capacity to ensuring that adaptation takes place. What needs to be done to move from capacity to action? Mortimore (2010: 135) suggests that local adaptive capacity is a 'platform for constructing enabling development policies'. Eakin and Lemos (2010) also note the limited empirical research on how institutions affect adaptive capacity and shape the means to build it further.

2.5. Dimensions of Exposure and Vulnerability

This section presents some of the major dimensions of exposure and vulnerability in relation to, variously, hazards, disasters, climate change and extreme events, which represent distinct scholarly communities. Their definitions and applications of the, sometimes confounded, terms exposure and vulnerability, although quite specific to them, together contribute to a very broad range of dimensions which some have sought to integrate (e.g. Füssel, 2005). The largest body of evidence refers to vulnerability rather than exposure and the distinction is often not made explicit.

O'Brien *et al*. (2008) recognize the complex interactions of biophysical, social, economic, political, institutional, technological and cultural conditions as constitutive of a general 'social vulnerability' approach (2008: 13). This they contrast with a hazard-centred, 'physical vulnerability' approach emphasizing the bio-geo-physical and technological interpretations of vulnerability. The former focuses chiefly on physical processes of exposure and vulnerability creation and reduction through e.g. engineering and technological interventions. The latter approach goes beyond this to include also the complex, societal, root causes of vulnerability to climate change and extreme events, which require similarly complex societal responses for their reduction.

The social dimension of vulnerability includes various themes such as social inequalities regarding income, age or gender, as well as characteristics of communities and the built environment, such as the level of urbanisation, growth rates, economic vitality, etc. (Cutter *at al.,* 2000). Although human society is the main focus of the concepts of vulnerability, a fundamental question has to be clarified as to whether human vulnerability can be adequately characterised without considering simultaneously the vulnerability of the "surrounding" eco-sphere. Vogel and O'Brien (2004) stress the fact that vulnerability is *multi-dimensional and differential* – i.e. varies across physical space and among and within social groups; is *scale-dependent* with regard to time, space and units of analysis such as individual, household, region, system; and *dynamic* – characteristics and driving forces of vulnerability change over time.

At present, comprehensive or integrated approaches for vulnerability and risk understanding consider different dimensions or aspects of vulnerability as proposed by Wilches-Chaux (1989). These dimensions are correlated to human security components and include physical, environmental, economic, social, political, institutional, educational, cultural, and ideological dimensions. This deconstructive approach helps us visualize vulnerability from different angles and perspectives that involve also technological, anthropological and psychological aspects. This facilitates an understanding of vulnerability as a dynamic and changing circumstance or condition.

In identifying the dimensions of exposure and vulnerability, the literature (and the definitions) can cross certain conceptual boundaries. For example, the answer to the question, "vulnerable to what?" can refer to an external hazard or threat or to the outcome. Dilley and Boudreau (2001) identify this as a particular problem in food-related contexts where the typical answer might be, vulnerable to "famine", "food insecurity", or "hunger", which are adverse outcomes rather than the precipitating events or shocks.

Out of the many possible vulnerabilities Schneider *et al.* (2007) recognize “key vulnerabilities” associated with many climate-sensitive systems, such as “food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets and modes of oceanic and atmospheric circulation.” (Schneider *et al.,* 2007: 781). A temporal dimension –i.e. whether the vulnerability is likely to be realized sooner rather than later– is an important element in determining whether a vulnerability dimension can be termed “key” (Bazerman, 2005; Schneider *et al.,* 2007: 785).

This section aims to be reasonably comprehensive without being exhaustive and combines both ‘social vulnerability’ and ‘physical vulnerability’ approaches. The discussion is organized under the following main headings (with important sub-headings):

- Physical
- Environmental
- Economic
- Social
- Cultural
- Institutional and governance

In practice, vulnerability in its realization will be a composite of two or more of these main dimensions. An additional subsection discusses interactions and integrations. Finally, there are issues related to timing and timescales, as well as spatial and functional scales.

2.5.1 Physical Dimensions

The physical dimension of vulnerability begins with the recognition of a link between an extreme physical or natural phenomenon and a vulnerable human group (Westgate and O’Keefe, 1976). It comprises aspects of geography, location, place (Wilbanks, 2003); settlement patterns; and physical structures (Shah, 1995; UNISDR, 2004):

> *“Physical exposure of human beings and the fragility of economic assets to disasters have been partly shaped by patterns of settlement. Beneficial climatic and soil conditions that have spurred economic activities are associated with hazard-prone landscapes. Both volcanic slopes and flood plains historically have attracted human activities.” (UNISDR 2004).*

However, physical vulnerability also encompasses the non-human/social. It also refers to infrastructure or environmental elements located in hazard prone areas or with deficiencies in resistance or susceptibility to damage (Wilches-Chaux 1989). It,can include vulnerable *systems* such as low-lying islands, coastal zones, mountain regions, drylands, and islands identified as Local Agenda 21 priorities (UNCED, 1992; Dow 1992: 420); also *impacts* to these systems (e.g. flooding of coastal cities and agricultural lands or forced migration); and/or the *mechanisms* causing these impacts (e.g. disintegration of particular ice sheets) (Schneider *et al.,* 2007: 783; Füssel and Klein, 2006).

2.5.1.1. Geography, Location, Place

There are very different vulnerabilities in different world regions. Broadly speaking, developing countries are recognized as facing the greater impacts and having the most vulnerable populations, least able to easily adapt to changes in *inter alia* temperature, water resources, agricultural production, human health and biodiversity (McCarthy *et al.,* 2001; IPCC, 2001; Beg *et al.,* 2002). This is of course a simplification (and see Bankoff 2001: 19 for a critique of essentialising, cultural discourses which malign large parts of the world as “disease-ridden, poverty-stricken and disaster-prone”) but does distinguish the distributional aspects of climate change. Dilley *et al.* (2005) have identified ‘disaster hotspots’ by combining hazard exposure with historical vulnerability to categorize a geographical distribution of hazards –areas that are at relatively higher single– or multiple-hazard risk –at the sub-national scale.

Also vulnerable are threatened systems confined to narrow geographical ranges (McCarthy *et al.,* 2001) and, less clearly delineated, trade corridors (link to the *economic* dimension below) which are extended, cross boundary regions vulnerable to extreme events. Temperature and precipitation changes arising from climate change can be expected to have both positive and negative impacts around the world. Such changes may reduce the growing period that would in turn affect agricultural zones in many parts of the world albeit this must then take account of mitigation and adaptation actions, which could affect vulnerability status (see below Section 2.5). Downing (1991) discusses just such a scenario but goes further by extending the dimensions of vulnerability to 'vulnerability to hunger' in an African context.

Highly vulnerable locations include small island developing states (SIDS) because of the proportion of their land mass which is exposed to rising sea levels or storms (UNISDR 2004; Nichols 2004; Pelling and Uitto 2001). But the most biophysically vulnerable locations may not always intersect with the most vulnerable populations (Cutter *et al.,* 2000).

The physical dimension refers to a location-specific context for human–environment interaction (Smithers and Smit 1997, 131 that should also recognize that vulnerability is manifested at a specific point in space and time and is "a product of various processes operating at various geographic levels. Processes may converge differently at different points in space or time, creating a very different manifestation of vulnerability" (Eriksen, Brown and Kelly, 2005). Furthermore, Cutter's (1996) 'hazards of place' model of vulnerability expressly refers to the temporal dimension (see below) which argues for a more nuanced approach recognizing the dynamic nature of place vulnerability.

2.5.1.2. Settlement Patterns and Development Trajectories

There are specific vulnerability dimensions to do with urbanization (Hardoy and Gustavo Pandiella 2009) and rurality (Nelson *et al.,* 2010a, 2010b).

Rapid urbanization has been shown to be vulnerable to disaster risk (Sánchez-Rodríguez *et al.,* 2005) and especially the development of megacities with high population densities (Mitchell, 1999a, 1999b) leading to greater numbers exposed and increased vulnerability through, inter alia, poor infrastructural development Uitto 1998). Mitchell (1999b) identifies increased polarization and spatial segregation of groups with different degrees of vulnerability to disaster as an emerging problem. This is supported by Cutter and Finch's (2008) empirical evidence from the USA (between 1960 and 2008) of the spatial patterning of social vulnerability. Those components that consistently increased social vulnerability were density (urbanization), race/ethnicity (see below) and socioeconomic status. The level of development of the built environment, age, race/ethnicity, and gender, account for nearly half of the variability in social vulnerability among U.S. counties in their Social Vulnerability Index (SoVI). The study found considerable regional variability and that social vulnerability had become more dispersed.

The built environment can be either protective of, or subject to, climate extremes. It is both vulnerability perpetrator and victim. Inadequate structures make victims of their occupants and conversely, adequate structures can reduce human vulnerability. The continuing toll of deaths and injuries in unsafe schools (UNISDR, 2009a), hospitals and health facilities (PAHO/World Bank, 2004), domestic structures (Hewitt, 1997), lifelines and critical infrastructure () and infrastructure more broadly (Freeman and Warner 2001) are indicative of the vulnerability of many parts of the built environment and the creation of a 'social geography of harm' (Hewitt, 1997). The deaths and injuries of children in their schools is a dereliction of a collective duty of care given the technical abilities worldwide to build such structures safely (UNISDR, 2007c). Reducing the vulnerability of hospitals and other health care facilities protects the safety of patients, staff and visitors, as well as the investment in infrastructure, and ensures the continuance of health response when disasters occur (PAHO/World Bank, 2004).

Climate change and urban heat island effects are likely to exacerbate the risk of heat waves (Wilby, 2007; Haines *et al.,* 2006; Lisø *et al.,* 2003) and will impact vulnerable social groups (eg elderly, young, sick) particularly but will also have an impact on energy use and economy. Building design is not adequate for an existing rising trend in (particularly night-time) temperatures in Japan and thus will require recognition and attention in the context of longer term climate change adaptation (Shimoda, 2003). Building for safety (Aysan, 1993; Aysan *et al.,* 1995; Coburn *et al.,* 1995)

The urban and the rural are inextricably linked. Inhabitants of rural areas are often dependent on cities for employment and as a migratory destination of last resort. Cities depend on rural areas for food, water, labour and other resources. All of these (and more) can be impacted by climate related variability and extremes. In either case, it is necessary to identify the many exogenous factors that affect a households' livelihood security. Eakin's (2005) examination of rural Mexico presents empirical findings of the interactions (e.g. between neoliberalism and the opening up of agricultural markets, and the agricultural impacts of climatic extremes) which amplify or mitigate risky outcomes (p. 1936). The findings point to economic uncertainty over environmental risk which most influences agricultural households' decision making (p. 1923).

2.5.2. Environmental Dimensions

Maladaptive human/social-environment relations can put people at risk and increase vulnerability; extreme events and processes due to climate change may exacerbate existing risks. There are key links between development, environmental management and disaster reduction (e.g. Van Aalst and Burton, 2002). Furthermore, it is important to consider property rights which govern the use of natural resources and link social and ecological resilience (Adger, 2000) or vulnerability.

There are many examples of the breakdown of society-environment relations that make people vulnerable to extreme events (Bohle *et al.,* 1994) and highlight the vulnerability of/to ecosystem services (Metzger *et al.,* 2006). Destruction of environmental protection afforded by mangrove forest and other wetland habitats has increased both the exposure and vulnerability of coastal populations to storms in many parts of the world (Badola and Hussain, 2005; Day *et al.,* 2007). Similarly, increasing location of housing in fire-prone areas is giving rise to greater human and property damage from San Francisco (Wisner, 1999) to Sydney (Handmer, 1999). Destruction of forest and other habitat on steep slopes exacerbates erosion of productive soils and amplifies landslide risks. The extent to which this exposure leads to or exacerbates vulnerability requires further analysis of local conditions in which some groups or locvations are less able to anticipate, cope or recover from disasters,

The vulnerabilities arising from floodplain encroachment are typical of the intricate and finely balanced relationships between human-environment systems of which we have been aware for some time (Kates, 1971; White, 1974). Increasing human occupancy can put not only the lives and property of human beings at risk but can damage floodplain ecology. The vulnerability of human beings comes about even in the face of actions designed to reduce the hazard. Structural responses and adaptations (e.g. provision of embankments, channel modification and other physical alteration to the floodplain environment) designed ostensibly to reduce flood risk can have the reverse result. This is variously known as the levee effect (Kates, 1971; White, 1974), the escalator effect (Parker, 1995), or the 'safe development paradox' (Burby, 2006) in which floodplain encroachment increases flood damages, which then induce structural flood protection initiatives, which then reduce perceived hazard and encourage further encroachment, which then initiates a recurrence of the sequence.

"In the case of the generation of new, or the exacerbation of existing hazards associated with human intervention in the environment, research must elucidate the rationale for the type of human intervention undertaken, the limits and opportunities the environment presents when faced with such interventions and the options or alternatives that may exist for achieving the same social or economic goals but without the generation of such adverse environmental impacts and results" (Lavell, 1999a, 2000; ICSU-LAC, 2009).

2.5.3. Economic Dimensions

This dimension includes economy as a *hazard* – a trigger for an extreme event; as an *outcome* of an extreme event; and as a *condition* of vulnerability to an extreme event. While all vulnerability dimensions are complex and difficult to measure, the economic dimension has some challenges in both delineating the boundaries of concern and quantifying the evidence. "What is known is only a small part of what matters. Many climate change impacts have been identified but not estimated, and there are undoubtedly yet to be identified impacts too. Some of these impacts are clearly negative, and some clearly positive." (Tol, 2007).

[INSERT TABLE 2-2 HERE
Table 2-2: People exposed to and killed in disasters in low and high human development countries, respectively, as a percentage of total number of people exposed to and killed by disasters. Source: Birkmann, 2006a: 174 (after Peduzzi, 2005).]

Economic vulnerability can be understood as the susceptibility of the economic system including public and private sectors to potential (direct) disaster damage and loss (Rose, 2000; Mechler, 2004) and refers to the ability of affected individuals, communities, businesses and governments to absorb or cushion the damage (Rose 2004). The degree of economic vulnerability is exhibited post event by the magnitude and duration of the indirect follow on effects. These effects can comprise business interruption costs to firms unable to access inputs from their suppliers or service their customers, income losses of households unable to get to work, or the deterioration of the fiscal stance post disasters as less taxes are collected and significant public relief and reconstruction expenditure is required. On a macroeconomic level, adverse impacts include effects on GDP, consumption and the fiscal position (Otero and Marti, 1995). Key drivers of economic vulnerability are low levels of income and GDP, constrained tax revenue, low domestic savings, shallow financial markets and high indebtedness with little access to external finance (OAS, 1991; Benson and Clay 2000; Mechler, 2004).

Economic vulnerability to external shocks, including natural disasters, has been inexactly defined in the literature and conceptualizations often have overlapped with risk, resilience or exposure. One line of research focussing on financial vulnerability, as a subset of economic vulnerability, framed the problem in terms of risk preference and aversion, a conceptualization more common to economists. Risk aversion denotes the ability of economic agents to financially absorb risk (Arrow and Lind, 1970). An agent is considered averse to risk if it cannot easily absorb losses and, absent further means to reduce risk, requires informal or formal outside mechanisms for sharing risk. There are many ways for absorbing the financial burdens of disasters, with market-based insurance being one, albeit prominent, option. Households often use informal mechanisms relying on family and relatives abroad; governments may simply rely on their tax base or international assistance. Yet, it is a fact that in the face of large and covariate risks, such ad hoc mechanisms often break down, particularly in developing countries (see Linnerooth-Bayer and Mechler, 2007).

Research on financial vulnerability to disasters has hitherto focused on developing countries' financial vulnerability describing financial vulnerability as a country's ability to access domestic and foreign savings for financing post disaster relief and reconstruction needs in order to quickly recover and avoid substantial adverse ripple effects (Mechler et al., 2006; Cardona, 2009; Cummins and Mahul, 2008; Marulanda et al, 2008a). Given reported and estimated substantial financial vulnerability and risk aversion in many exposed countries, as well as the emergence of novel public-private partnership instruments for pricing and transferring catastrophe risks globally, has motivated developing country governments, as well as development institutions, NGOs and other donor organizations, to consider pre-disaster financial instruments as an important component of disaster risk management (Linnerooth-Bayer, Mechler and Pflug, 2005).

Human vulnerability to natural hazards and income poverty are largely co-dependent (UNISDR, 2004; Adger, 1999) but poverty does not equal vulnerability (e.g., Blaikie *et al.,* 1994). Given the relationship between poverty and vulnerability, it can be argued (Tol *et al.,* 2004) that economic growth could reduce vulnerability (with caveats). However, increasing economic growth would not necessarily decrease climate impacts. It has the potential – indeed the likelihood – of simultaneously increasing greenhouse gas emissions.). Conversely, would reducing greenhouse gas emissions, with a likely concomitant reduction in economic growth, necessarily reduce the impacts of climate change? There are many questions about the likely impacts of varying economic policy changes (Tol *et al.,* 2004). Some vulnerability factors are closely associated with certain types of development models and initiatives (UNISDR, 2004; UNDP, 2004) but the picture is complex.

2.5.3.1. Work and Livelihoods

Work and livelihoods are impacted by extreme events and by the responses to extreme events. Humanitarian/disaster relief in response to extreme events can induce dependency and weaken local economic systems (references) but livelihood-based relief is of growing importance (references –Mihir Bhatt/All India Disaster Mitigation Institute). This recognition of social vulnerability through a lack of, or shock to, the ways people make a living or subsist, comes out of the development field's work on Sustainable Livelihoods Approaches (Chambers and Conway, 1992; Carney *et al.,* 1999; Ashley and Carney, 1999). This recognizes disasters and extreme events as stresses and shocks within livelihood development processes (Cannon *et al.,* 2003) (see Kelman and Mather, 2008, for a discussion of cases applying it to volcanic events).

Livelihoods can be precarious –even those in developed countries not thought to be obviously vulnerable. The recent global economic downturn will have impacts on a diverse group of people's vulnerability status (individuals' economic position, livelihood/employment, reduction in donors' contributions to mitigation/adaptation and response). Market systems and sectors likely to be affected by, and to different degrees vulnerable to, climate change include livestock, forestry and fisheries industries and energy, construction, insurance, tourism and recreation sectors (Schneider *et al.,* 2007: 790).

The Stern Review underlines the significance of economic dimensions of climate change and estimates that doing nothing about climate change could lead to damage costs of 20% of global GDP (Stern, 2006 p. Vi).

2.5.3.2. Wealth

Much of the literature on exposure and vulnerability deals with a lack of wealth – i.e. poverty – rather than the wealthy themselves. However, wealthy countries and wealthy individuals are increasingly exposed to climate related extremes through lifestyle choices which place them in hazard-prone locations. The extent to which they are also vulnerable is a moot point. As Cutter et al (200) point out, "wealth enables individuals to absorb and recover from losses more quickly using insurance, social safety nets, and entitlement programs" (page 717) and thus they are made less vulnerable. However, at larger scales, aggregations of such individuals could make communities and the infrastructure on which they depend, vulnerable to economic impact. The insurance safety net can be removed or made extremely costly if insurance and reinsurance companies face excessive or repeated payouts.

Furthermore, it is not just the risk of economic damage in rich countries themselves but the way such disasters can disrupt global economies (Mitchell 1999: 32). The 1987 windstorm in the UK closed down the London Stock Exchange and may have helped prompt the worst international stock market crisis since the Great Depression (Mitchell et al 1989).

2.5.4. Social Dimensions

The social dimension is itself multi-faceted, and encompasses several of the issues discussed above. Primarily, it focuses on societies and collectivities, rather than individuals, however, some still use the 'individual' descriptor to clarify issues of scale and units of analysis (Adger and Kelly, 1999; O'Brien *et al.,* 2008). Notions of the individual are also useful when considering for instance psychological trauma in disasters (e.g. Few, 2007) although analysis is usually aggregated to a defined social group (men, women, etc.); and risk perception (Slovic, 2000; Oppenheimer and Todorov, 2006; Schneider *et al.,* 2007). The social dimension includes elements such as: education, health and well-being, but also housing (link to built environment); as well as work/livelihoods (discussed above under 'Economic Dimensions') and elements related to the cultural aspects of collectivities of people at various levels (discussed below under "Cultural Dimensions") as well as Institutional and Governance Dimensions, such as forms of social networking and social capital/assets, political vulnerability; as well as interaction related to migration and land tenure.

2.5.4.1. Education

The education dimension ranges across the vulnerability of educational building structures; issues related to access to education; and also access to information and knowledge. Priority 3 of the Hyogo Framework for Action 2005-2015 recommends the use of knowledge, innovation and education to build a culture of safety and resilience at all levels (UNISDR, 2007a). A well-informed and motivated population can lead to disaster risk reduction but it requires the collection and dissemination of knowledge and information on hazards, vulnerabilities and capacities. However, “It is not information per se that determines action, but how people interpret it in the context of their experience, beliefs and expectations. Perceptions of risks and hazards are culturally and socially constructed, and social groups construct different meanings for potentially hazardous situations” (McIvor and Paton, 2007: 80).

Many lives have been lost through the inability of education infrastructure to withstand extreme events. This has been particularly evident in the case of earthquake hazards but it is also seen in storms and floods for example. Even without fatalities, there is still considerable physical and psychological damage caused to children, their teachers and the wider community through school building damage. Improving education infrastructure safety can have less obvious benefits, as can be seen in the case of cyclone-prone Madagascar where significant cyclone damage occurs each year. The Malagasy Government initiated the Development Intervention Fund IV (FID1 IV) project to reduce cyclone risk, including in school construction and retrofitting. In doing so, awareness and understanding of disaster issues was increased within the community (UNISDR 2007c).

The impact of extreme events can limit the ability of parents to afford to educate their children or require them (especially girl children) to work to meet basic needs. Improved educational (and health) status can help reduce vulnerability and can limit human losses in a disaster *(*UNISDR, 2004).

2.5.4.2. Health and Well-Being

The health dimension includes differential effects in different regions and on different social groups (Few, 2007; McMichael *et al.,* 2003; Haines *et al.,* 2007; van Lieshout *et al.,* 2004; Costello *et al.,* 2009). It also includes, in a link to the institutional dimension, environmental health and public health issues, infrastructure and conditions (Street *et al.,* 2005).

The health dimensions of disasters are difficult to measure because of difficulties in attributing the health condition directly to the extreme event because of secondary effects; in addition, some of the effects are delayed in time, which again makes it difficult to attribute to the event (Bennet, 1970; Hales *et al.,* 2003).

Situational/context specific analysis is needed because there is considerable variation in vulnerability of different social groups to health impacts. For example, in the case of temperature related events, seasonal variations in winter mortality in temperate countries suggest the elderly (75 and older) are particularly vulnerable (Hales *et al.,* 2003). Evidence from heat waves show vulnerability is through a complex mix of factors including age, physiological status, gender norms influencing behaviour (e.g. excess deaths occurring through exertion in high temperatures) (Hales *et al.,* 2003). Klinenberg’s (2002) study of the Chicago heatwave of 1995 identified that older males were twice as likely to die as older females who might have been considered to be the more vulnerable group. Where other studies have broken down fatalities and morbidity by social group, greater vulnerability has varied (Hales *et al.,* 2003). Thus, we do not have a simple bivariate relationship between extreme events and health but they are moderated and mediated by a sometimes complex set of other variables.

2.5.5. Cultural Dimensions

The broad term ‘culture’ embraces a bewildering complexity of elements that can relate to a way of life, behaviour, taste, ethnicity, ethics, values, beliefs, customs, ideas, institutions, art and intellectual achievements that affect, are produced or are shared by a particular society. In essence, all these characteristics can be summarised to describe culture as ‘the expression of humankind within society’. (Aysan and Oliver, 1987)

Culture is variously used to describe many aspects of extreme risks from natural disasters or climate change, including the:

- Cultural aspects of risk perception
- Negative culture of danger/ vulnerability/ fear
- Culture of humanitarian concern
- Culture of organizations/ institutions and their responses
- Culture of preventive actions to reduce risks, including the creation of buildings to resist extreme climatic forces
- Ways to create and maintain a 'Risk Management Culture' or a 'Safety Culture'.

In relation to our understanding of risk certain cultural issues need to be noted. Typical examples are cited below:

- *Ethnicity and Culture*. Deeply rooted cultural values are a dominant factor in whether or not communities adapt to climate change. For example recent research in Northern Burkina Faso, indicates that the level of adaptation to climate change is related to ethnicity and the issue of values and culture in adaptation and vulnerability to climate change. Two ethnic groups, were compared and it was shown that despite their presence in the same physical environment and their shared experience of climate change, the two groups have adapted very different strategies due to cultural values and historical relations. Neilson, et al (2008)
- *Locally Based Risk Management Culture*. Wisner (2003) has argued that the point in developing a 'culture of prevention' is to build networks at the neighbourhood level capable of ongoing hazard assessment and mitigation at the micro level. He has noted that while community based NGO's emerged to support recovery after the Mexico City and Northridge earthquakes, these were not sustained over time to promote risk reduction activities. This evidence confirms other widespread experience indicating that ways still need to found to extend the agenda of Community Based Organisations (CBO's) into effective action to reduce climate risks and promote adaptation to climate change.
- *Conflicting Cultures: who benefits, and who loses when risks are reduced?* A critical cultural conflict can arise when private actions to reduce disaster risks and by adapting to climate change by one party have negative consequences on another. This regularly applies in river flood hazard management where upstream measures to reduce risks can significantly increase downstream threats to persons and property. Neil Adger and his colleagues note that 'actions are likely to be undertaken by individuals or businesses if they perceive early rewards or benefits from their actions, such as reduced damages from extreme weather events or cheaper insurance.' Therefore, if risk reduction actions are to occur the key players must bear all the costs and receive all the benefits from their actions. Adger, (2009)

These examples are reminders that all actions to reduce risks, or adapt to them occur within a cultural context. Therefore, a key element in risk assessment is to review the likely cultural constraints on a proposed set of actions as well as their anticipated consequences on society, its citizens, and their deeply held values.

Traditional behaviours tied to local (and wider) tradition and cultural practices can increase vulnerability. For example, unequal gender norms (see above), traditional uses of the environment which have not adapted to changed environmental circumstances. However, local or indigenous knowledge can reduce vulnerabilities too (Gaillard).

Cultural dimensions to the perception of risk/hazard also create vulnerabilities. The early hazards paradigm literature (White, 1974; Burton, Kates and White, 1978) referred often to fatalistic attitudes, which resulted in inaction in the face of disaster risk but Schmuck-Widmann (2000), in her social anthropological studies of char dwellers in Bangladesh, noted how a belief that disaster occurrence and outcomes were in the hands of God did not preclude preparatory activities. Perception of risk depends on the cultural and social context (Slovic, 2000; Oppenheimer and Todorov, 2006; Schneider *et al.,* 2007).

Motivational and attitudinal factors which Anderson and Woodrow (1989) identify as important in determining vulnerabilities and capacities, are culturally specific.

Research on culture includes topics such as perceptions and risk (eg. Gaillard, 2007; de Silva, 2006), the role of faith in the recovery process following a disaster (eg. Massey and Sutton, 2007; Davis and Wall 1992), religious explanations of nature (eg. Orr, 2003; Peterson, 2001), and the role of religion in influencing positions on environment and climate change policy (eg. Kintisch, 2006; Hulme, 2009), as well as religion and vulnerability (Schipper, 2010; Chester, 2005; Elliott, 2006; Guth *et al.,* 1995). A key research area under this heading is cultural theory (closely associated with the work of Mary Douglas (1966)) which attempts to explain how people interpret their world and define risk according to their worldviews: hierarchical, fatalistic, individualistic, and egalitarian (Douglas and Wildavsky, 1982). While cultural theory has been criticized (lack of empirical testing,

Marris et al (1998) reinforce the importance of understanding differential risk perceptions in a cultural context. Too often policies and studies focus on 'the public' in the aggregate (p. 646) and too little on the needs and interests of different social groups. One aspect of vulnerability reduction is through individual risk perception and this demands recognition of diversity.

2.5.6. Institutional and Governance Dimensions

The institutional context of vulnerability to extreme events is a key determinant of vulnerability (Adger, 1999). Expanding the institutional domain to include political economy (Adger, 199) and different modes of production - feudal, capitalist, socialist (Wisner, 1978) –raises questions about the vulnerability *of* institutions and vulnerability caused *by* institutions (including government).

The institutional dimension includes the relationship between policy setting and policy implementation in risk and disaster management; top-down approaches assume policies are directly translated into action on the ground; bottom-up approaches recognise the importance of other actors in shaping policy implementation (Urwin and Jordan, 2008). Twigg's categorization of the characteristics of the ideal disaster resilient community (Twigg, 2007) identifies the important relations between the community and the enabling environment of governance at various scales in creating resilience, and by inference, reducing vulnerability. This set of characteristics also refers to institutional forms for, and processes of engagement with, risk assessment, risk management, and hazard and vulnerability mapping which have been championed by institutions working across scales to create the Hyogo Framework for Action (UNISDR, 2007a) and associated tools (UNISDR, 2007b; ProVention Consortium, 2009) with the goal to reduce disaster risk and vulnerability.

A lack of institutional interaction and integration between disaster risk reduction, climate change and development may mean policy responses are redundant or conflicting (Schipper and Pelling, 2006). And so the institutional model operational in a given place (and time) – more or less participatory, deliberative and democratic; integrated or disjointed - could be an important factor in vulnerability creation or reduction (Comfort *et al.,* 1999). However, further study of the role of institutions in influencing vulnerability is called for (O'Brien *et al.,* 2004).

Institutions have been defined in a broad sense to include "habitualized behaviour and rules and norms that govern society" (Adger, 2000) and not just the more typically understood formal institutions. This allows a discussion of institutional structures such as property rights and land tenure issues (Toni and Holanda 2008), which govern natural resource use and management. It forms a bridge between the social and the environmental/ecological dimensions and can create induce sustainable or unsustainable exploitation (Adger 2000). This broader understanding of the institutional dimension also takes us into a recognition of the role of social networks, community bonds and organizing structures and processes which can buffer the impacts of extreme events (Nakagawa and Shaw 2004) partly through increasing social cohesion but also recognizing ambiguous or negative forms (UNISDR 2004: 24). For example, social capital/assets (Putnam; Portes 1998) – "the norms and networks that enable people to act collectively" (Woolcock and Narayan 2000, 226) – have a role in vulnerability reduction (Pelling 1998). Social capital (or its lack) is both cause and effect of vulnerability (the conflation is regarded critically by Adger 2003: 390) and thus can be either positive benefit or negative impact; to be a part of a social group and accrue social assets is often to indicate others' exclusion.

_____ START BOX 2-1 HERE _____

Box 2-1. Cross-Cutting Dimensions and Intersectionality

Almost all of the dimensions discussed above generate differential effects. Indeed, research evidence of the differential vulnerability of social groups is extensive and raises concerns about the disproportionate effects of climate change on identifiable, marginalized populations (Kasperson and Kasperson 2001; Bohle *et al.,* 1994; Thomalla *et al.,* 2006). Particular groups and conditions have been identified for example race/ethnicity, socioeconomic class, gender, age (both the elderly and children), migration, and housing tenure (whether renter or owner) as among the most common social vulnerability characteristics (Cutter and Finch, 2008). Betty Hearn Morrow (1999) extends and refines this list to include: residents of group living facilities; ethnic minorities (by language); recent residents/immigrants/migrants; physically or mentally disabled; large households; renters; large concentrations of children/youth; poor households; the homeless (see also Wisner, 1998); women-headed households; tourists and transients. But as Adger and Kelly (1999) point out, the state of vulnerability is defined by a specific population at a particular scale and aggregations (and generalizations) are less meaningful and so such descriptors must be used with caution.

There is a literature on all these groups but one of the largest has been on gender and on women in particular (e.g., Enarson and Morrow, 1998). However, this body of literature is relatively recent, particularly in a developed world context, given the longer recognition of gender concerns in the development field (Fordham 1998). Additionally, the gender literature has led on the important acknowledgement of resilience/capacity/capability and not always a fixed vulnerability in these identified groups. The vulnerability label can reinforce notions of passivity and helplessness.

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[INSERT TABLE 2-3 HERE:
Table 2-3: Differential exposure and vulnerability of identified groups.]

2.5.7. Interactions and Integrations

This section began by breaking down the vulnerability concept into its constitutive parts with evidence derived from a number of discrete research and policy communities (e.g. disaster risk reduction; climate change adaptation; environmental management; and poverty reduction) that have largely worked independently (Thomalla *et al.,* 2006: 39). Increasingly it is recognized that collaboration and integration is necessary both to set appropriate policy agendas and to better understand the topic of interest. Although McLaughlin and Dietz (2008) make a critical analysis of the absence of an integrated perspective on the interrelated dynamics of social structure, human agency and the environment

Food security/vulnerability is a useful example of where reviewing singular dimensions of vulnerability will not provide an appropriate level of analysis (e.g. the early recognition that so-called natural disasters were not natural at all (O'Keefe *et al.,* 1976) and where crossing disciplinary boundaries (e.g. those separating disaster and development, or developed and developing countries) has been fruitful (see Hewitt, 1983). In analyzing the vulnerability of food systems (to put it broadly), we must note the combined contributions of inter alia: physical location in susceptible areas; political economy (Watts and Bohle, 1993); entitlements in access to resources (Sen, 1981); social capital and networks (Eriksen, Brown and Kelly, 2005); landscape ecology (Fraser, 2006); human ecology; political ecology (Pulwarty and Riebsame, 1997; Holling, 2001).

Coupled human/social–environment systems (Turner *et al.,* 2003; Holling, 2001)

While this section has identified a number of discrete dimensions of vulnerability that often arise out of focused research on singular elements, their application benefits from recognition of the dynamic nature of their interactions and in their necessary integration.

2.5.7.1. Migration and Displacement

Migration is both a condition of, and a response to, vulnerability – especially political vulnerability created through conflict, which can drive people from their homelands. Increasingly it relates to economic and environmental refugees and migrants but can also refer to those who do not cross international borders but become internally displaced persons as a result of extreme events in both developed and developing countries (e.g., Myers *et al.,* 2008).

Although data on climate change forced displacement is incomplete, it is fairly clear that the many outcomes of climate change processes will be seen and felt as disasters by the affected populations (Oliver-Smith 2009). For people affected by disasters, subsequent displacement and resettlement often constitute a second disaster in their lives. Cernea's well-known Impoverishment Risks and Reconstruction approach to understanding (and mitigating) the major adverse effects of displacement outlines the eight basic risks to which people are subjected by displacement as: landlessness, joblessness, homelessness, marginalization, food insecurity, increased morbidity, loss of access to common property resources, and social disarticulation (Cernea 1996). When people are forced from their known environments, they become separated from the material and cultural resource base upon which they have depended for life as individuals and as communities (Altman and Low 1992). The material losses most often associated with displacement and resettlement are losses of access to customary housing and resources. Displaced people are often distanced from their sources of livelihood, whether land, common property (water, forests, etc) or urban markets and clientele (Koenig 2009). Disasters and displacement may sever the identification with an environment that may once have been one of the principle features of cultural identity (Oliver-Smith 2006: 47-50). Displacement for any group can be a crushing blow, but for indigenous peoples it can prove mortal. The environment and ties to land are considered to be essential elements in the survival of indigenous societies and distinctive cultural identities (Colchester 2000). The displacement and resettlement process has been consistently shown to disrupt and destroy those networks of social relationships on which the poor depend for resource access, particularly in times of stress (Scudder 2005; Cernea 1996). Reconstruction and resettlement projects frequently stress efficiency and cost containment over restoration of community. Such top-down initiatives have a poor record of success because of a lack of regard for local community resources (de Wet 2006). Planners often perceive the culture of uprooted people as an obstacle to success, rather than as a resource.

2.5.8. Timing and Timescales

Two cross-cutting themes of particular importance for understanding the dynamic changes within exposure, vulnerability and risk are different time scales and different spatial and functional scales.

Timing and time scales are important cross-cutting themes that need more attention when dealing with the identification and management of extreme climate and weather events, disasters and adaptation strategies. The first key issue when dealing with timing and time scales is the fact that different hazards and their reoccurrence intervals might fundamentally change in terms of the time dimension. This implies that the identification and assessment of risk, exposure and vulnerability needs also to deal with different time scales and in some cases might need to consider various time scales. At present most of the climate change scenarios focus on climatic change within the next 100 or 200 years, while often the projections of vulnerability just use the present socio-economic data. However, a key challenge for enhancing our knowledge of exposure and vulnerability as key determinants of risk requires as well improved data and methods to project and identify directions in demographic, socio-economic and political trends that can adequately illustrate potential increases or decreases in vulnerability with the same time horizon as the biophysical projections (see Birkmann *et al.,* 2010).

Furthermore, it is important to consider the time dependency of risk analysis, particularly if the analysis is conducted at a specific point in time. Newer research underlines, that particularly exposure – especially the exposure of different social groups - is a very dynamic element that changes not only seasonal, but also during the day. A recent study of Setiadi et al. 2010 for the coastal city of Padang underlines, that a higher proportion of more vulnerable population groups is exposed in the high risk zone close to the sea due to the different mobility and activity patterns of female and male population during the day. The authors conclude that the major differences in the main activity profile of female and male population in the city of Padang has serious consequences in terms of the higher spatio-temporal exposure of female population to coastal hazards.

The analysis of the activity patterns showed that the majority of the female population are most likely to conduct their daily activities at home or in the neighbourhood. This situation is also strengthened by the fact that the female population work mainly in the service and trading sectors, of which about 30% are conducted at home. Thus the socio-demographic exposure within the city of Padang to coastal hazards various significantly between the morning-, afternoon- and night time (see Figure 2-3). The impacts of the 2004 Indian Ocean Tsunami also exemplify the differing spatial and temporal vulnerabilities of different social groups. Women located on the seashore preparing for the fish catch and in their homes rescuing children, died in greater numbers than men working out to sea in their boats (Doocy et al 2007). Consequently, time scales and dynamic changes over time have to be considered carefully when aiming at conducting risk and vulnerability assessments to extreme events and creeping changes in the context of climate change. Additionally, also changes in the hazard frequency and timing of hazard occurrence for example during the year will have a strong impact on the ability of societies and ecosystems to cope and adapt to these changes. These time scale related challenges and problems have been identified e.g. for ecosystems in the North of Peru under the influence of El Nino.

[INSERT FIGURE 2-3 HERE:
Figure 2-3: Difference between female-male population during morning, afternoon and night, for the coastal city of Padang, demonstrating differential exposure of women over time of day in the high risk zone close to the sea (Setiadi et al., 2010).]

Lastly, different time scales are also an important constrain when dealing with the link between disaster risk reduction and climate change adaptation. In many areas disaster risk reduction operates on different times scales compared to the strategies and measures of climate change adaptation and mitigation (see Birkmann/Teichman 2010 and Thomalla *et al.,* 2006: 41).

The timing of events may also create ‘windows of vulnerability,’ periods in which the hazards are greater because of the conjunction of circumstances" (Dow, 1992). Time is a cross cutting dimension that always needs to be considered but particularly so in the case of anthropogenic climate change, which may be projected some years into the future (Füssel, 2005). In fact, this time dimension is regarded (Thomalla *et al.,* 2006) as a key difference between the disaster management and climate change communities. To generalize somewhat, the former typically (with obvious exceptions such as slow onset disasters such as famine or desertification) must deal with fast onset events, in discrete, even if extensive, locations, requiring immediate action. The latter, however, occur in a dispersed form over lengthy time periods and are much more challenging in their identification and measurement (Thomalla *et al.,* 2006: 41). Risk perception may be reduced (Leiserowitz, 2006: 52) for events remote in time and/or space, such as some climate change impacts are perceived to be. Different time scales are also an important constraint when dealing with the link between disaster risk reduction and climate change adaptation. In many areas, disaster risk reduction operates on different times scales compared to the strategies and measures of climate change adaptation and mitigation (see Birkmann/Teichman 2010 and Thomalla *et al.,* 2006: 41). However, the affirmation that disaster risk management is short term and adaptation long term is a misconception and should be clarified. It appears to stem from disaster management considered narrowly as immediate response and coping but if we consider risk reduction more broadly then when we build a nuclear facility to resist 10000 year earthquakes flood barriers to resist 1000 year storm surges, we are not short-terming. All modern prospective risk management debates involve security considerations decades ahead for production, infrastructure, houses, hospitals etc.

“If the vulnerability of a system or its exposure to the hazard is expected to change significantly during the time period considered in an assessment, statements about vulnerability should specify a temporal reference, *i.e*., the point in time or period of time that they refer to. This is particularly relevant for vulnerability assessments addressing anthropogenic climate change, which may have a time horizon of several decades or longer.” (Fussell, 2005). Leiserowitz’ survey analysis (2006) concludes that, although many Americans believe climate change to be a real and serious problem, it lacks urgency because it is risk they believe “is more likely to impact people and places far distant in space and time”.

2.5.9. Spatial and Functional Scales

Spatial and functional scales are another cross cutting theme that is of particular relevance when dealing with the identification of exposure and vulnerability to extreme events and climate change. Leichenko and O'Brien (2002) conclude that in many areas of climate change and natural hazards societies are confronted with dynamic vulnerability, meaning that processes and factors that cause vulnerability operate simultaneously at multiple scales making traditional indicators insufficient (Leichenko and O'Brien 2002). Also Turner et al. (2003) stress that vulnerability and resilience assessments need to consider the influences on vulnerability from different scales, however, the practical application and analysis of these interacting influences on vulnerability from different spatial scales is a major challenge and in most cases not sufficiently understood. Furthermore, vulnerability analysis particularly linked to the identification of institutional vulnerability has also to take into account the various functions scales that climate change, natural hazards and vulnerability as well as administrative systems operate on. In most cases current disaster management instruments and measures of urban or spatial planning as well as water management tools (specific plans, zoning, norms) operate on different functional scales compared to climate change. Even the various hazards that climate change is likely to modify or to intensify encompass different functional scales that can not be sufficiently captured with one approach (see Birkmann/Teichman 2010). Consequently, functional and spatial scale mismatches might even be part of institutional vulnerabilities that limit the ability of governance system to adequately respond to hazards and changes induced by climate change.
[more literature references will be included]

_____ START BOX 2-2 HERE _____

Box 2-2. Cross-Cutting Dimensions and Intersectionality: the Garifuna Women of Honduras.

The Garifuna women of Honduras could be said to show multiple vulnerability characteristics: they are women – the gender often made vulnerable by patriarchal structures worldwide; they come from Honduras, a developing country at risk of many hazards; they belong to a marginalised ethnic group descended from African slaves; and they depend largely on a subsistence economy and a lack of education, health and other resources. However, despite these markers of vulnerability, there are examples of Garifuna women organizing to reduce their communities' risks of disasters and to protect and develop their livelihood opportunities (Fordham, Gupta, Shende, forthcoming).

_____ END BOX 2-1 HERE _____

2.6. Vulnerability Profiles

2.6.1. Introduction

Vulnerability profiles are a key input to risk assessments. A description of the vulnerable situation (who, what and where) is an important first step to avoid misunderstandings around vulnerability. Profiling is simply defined as a formal summary or analysis of data, often in the form of a graph, map or table, representing distinctive features or characteristics of the particular system being referred to.

Vulnerability depends critically on context, and the factors that make a system vulnerable to hazards will depend on the nature of the system and the type of hazard in question (Brooks, 2005). The term 'vulnerability' may refer to the vulnerable system itself, e.g., low-lying islands or coastal cities; the impact to this system, e.g., flooding of coastal cities and agricultural lands or forced migration; or the mechanism causing these impacts, e.g., disintegration of the West Antarctic ice sheet (IPCC, 2007). Many impacts, vulnerabilities and risks merit particular attention by policy-makers due to characteristics that might make them *key*. Key impacts that may be associated with key vulnerabilities are found in many social, economic, biological and geophysical systems, and are associated with many climate sensitive systems, including, for example, food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation, among others.

2.6.2. Agriculture and Food Security

Vulnerability in the agriculture sector can be indicated by combining elements of exposure, sensitivity, and adaptive capacity to climate change, variability and extremes. Exposure can be expressed in terms of the biophysical impacts of the hazards, which in this context would be the changing patterns of extreme events. These changes will affect agriculture and livestock production depending on several factors such as crop type, CO_2 fertilization, and other multiple stressors. Sensitivity to climate change and extreme weather events can be manifested in the presence of other external factors such as water stress, land degradation rates, and the dependency of the economies on agriculture. Other areas which are low-lying are more sensitive to the impacts of rising sea levels and storm surges. Socio-economic variables can also be used to assess the sensitivity of the agriculture sector to climate change, variability and extremes, such as rural population density, % of irrigated land, and agricultural employment (FAO 2004). Several indicators can be used to measure adaptive capacity, such as poverty rates, access to credit, literacy rates, farm income, and agricultural GDP.

Vulnerability also refers to the presence of factors that place people at risk of becoming food insecure. These factors can be external or internal (FAO, 2000). External factors have the nature of: (i) Trends, e.g. depletion of natural resources from which the population makes its living, food price inflation;(ii) Shocks, e.g. natural disasters, conflict; changing extremes due to climate change; (iii) Seasonality, e.g. seasonal employment opportunities, seasonal incidence of disease; and, (iv) Internal factors are the characteristics of people, the general conditions in which they live and the dynamics of the household that restrict their ability to avoid becoming food insecure in the future. The second and third factors are directly related to the changing risks due to extreme events, climate variability and change.

A typical two-step vulnerability assessment would include:

1) Analysis of factors and constraints that negatively affect the agriculture production and threaten food security situation
2) Evaluation of opportunities, which are the positive factors that exist internally in the system or in the external environment, that could potentially contribute to an improvement of the sector's performance or resilience.

In order to build resilience in the agriculture sector and on the people who depend on this sector, the actions must clearly work on the vulnerability components, for example as described schematically below (ADB, 2009) for agriculture sector.

[INSERT FIGURE 2-4 HERE:
Figure 2-4: Relation between vulnerability and building resilience in the agriculture sector (ADB, 2009).]

2.6.3. Human Health

In the context of health risks from extreme weather events, the National Research Council (2001) defines vulnerability as the "extent to which a population is liable to be harmed by a hazard event, and depends on the populations' exposure to the hazard and its capacity to adapt or otherwise mitigate adverse impacts". Nearly all the adverse environmental and social effects of climate change will ultimately threaten human health (physical, nutritional, microbiological, or mental). The dependence of human biology and of collective human ecology on the stability, productivity, and resilience of the natural environment is absolute. Food yields, water flows, air quality, fibre and timber supplies, natural medicinal substances, and climatic stability all underpin population health—and all are threatened by climate change.

Climate change will affect human health through complex systems involving changes in temperature, exposure to extreme events, access to nutrition, air quality and other vectors. Currently small health effects can be expected with very high confidence to progressively increase in all countries and regions, with the most adverse effects in low-income countries. Climate will interact with human health in diverse ways. Those least equipped to respond to changing health threats—predominantly poor people in poor countries—will bear the brunt of health setbacks. Ill-health is one of the most powerful forces holding back the human development potential of poor households. Changing risks from extreme events associated with climate change will intensify the problem (HDR, 2007).

Climate change, variability and extremes may affect health through a range of pathways—e.g., as a result of increased frequency and intensity of heat waves, reduction in cold-related deaths, increased floods and droughts, changes in the distribution of vector-borne diseases, and effects on the risk of disasters and malnutrition. The overall balance of effects on health is likely to be negative and populations in low-income countries are likely to be particularly vulnerable to the adverse effects. The experience of the 2003 heat wave in Europe shows that high-income countries might also be adversely affected. Adaptation to climate change requires public-health strategies and improved surveillance. Mitigation of climate change by reducing the use of fossil fuels and increasing the use of a number of renewable energy technologies should improve health in the near term by reducing exposure to air pollution (Haines, 2006).

The capacity to respond to the negative health effects of climate change relies on the generation of reliable, relevant, and up-to-date information. Strengthening informational, technological, and scientific capacity within developing countries is crucial for the success of a new public health movement. This capacity building will help to keep vulnerability to a minimum and build resilience in local, regional, and national infrastructures. Local and community voices are crucial in informing this process. Weak capacity for research to inform adaptation in poor countries is likely to deepen the social inequality in relation to health.

Policy responses to the public health implications of climate change will have to be formulated in conditions of uncertainty, which will exist about the scale and timing of the effects, as well as their nature, location, and intensity.

A key challenge is to improve surveillance and primary health information systems in the poorest countries, and to share the knowledge and adaptation strategies of local communities on a wide scale. Essential data need to include region-specific projections of changes in health-related exposures, projections of health outcomes under different future emissions and adaptation scenarios, crop yields, food prices, measures of household food security, local hydrological and climate data, estimates of the vulnerability of human settlements (e.g., in urban slums or communities close to coastal areas), risk factors, and response options for extreme climatic events, vulnerability to migration as a result of sea-level changes or storms, and key health, nutrition, and demographic indicators by country and locality.

2.6.4. Freshwater Resources

TBD

[INSERT TABLE 2-4 HERE:
Table 2-4: Vulnerability indicators used in Collins and Bolin (2007).]

2.6.5. Ecosystems

There is a high confidence probability that the resilience of many ecosystems will be undermined by climate change, with rising CO_2 levels reducing biodiversity, damaging ecosystems and compromising the services that they provide (IPCC, 2007).

2.6.6. Coastal Systems and Low-Lying Areas

Coastal vulnerability is a broad term that denotes the risk to various systems, such as human populations, natural ecosystems, managed land use, human habitations and infrastructure, which are exposed to a variety of external events, such as cyclones, storm surges and tsunamis. While most of them are natural events, their incidence is being affected by human induced changes. Climate change is one such process associated with human induced changes in global atmospheric environment which can result in widely varying impacts, such as sea level rise.

Indicators for coastal vulnerability can be grouped in vulnerability classes (Kaiser, 2006):

- Social vulnerability: demography, health, education and work, governance, culture or personal wealth, social networks
- Economic vulnerability: capital value at loss, land loss, labor force, economic information (e.g. GDP, buildings, unemployment rate, dependence on resources, tourism)
- Ecological vulnerability: ecological values and environmental pressure (e.g. protected area, unique ecosystems, managed land, tourism pressure).

Categories for resilience indicators can be grouped in ecological resilience and socio-economic resilience (preparedness, early warning capacity, coping capacity, adaptive capacity, recovery). An indicator system is indicated to provide decision-makers on local and national level with an effective tool, helping them to analyze and understand the risk a coastal area is exposed to. The choice of appropriate coastal vulnerability indicators depends on the type of coastal hazard, and especially social risk and vulnerability indicators may differ according to the development status or socio-cultural and economic state of a region.

In the real world, vulnerability assessment could be a part of a larger assessment activity on the ground such as environmental profiling, looking at factors affecting a system and the possible ways to reduce negative impacts and harness opportunities. For example in Box 2-3, a coastal environmental profiling that identified key values and management strategies in Bali. In the context of changing risks, the driving forces include the extreme climatic events and biophysical processes affecting the coastal environment. Aside from establishing qualitative and quantitative baseline information, an environmental profile identifies data gaps that require further research or monitoring. The environmental profiling activity also enhances the awareness of stakeholders. The environmental profile is essentially the basis for developing coastal strategy and conducting initial risk assessment. The data collected through environmental profiling are also useful inputs for the establishment of an integrated information management system.

_____ START BOX 2-3 HERE _____

Box 2-3. Coastal Environmental Profiling in Bali.

The environmental profiling and stakeholder consultation identified the key values, threats, and management strategies for the site. Aside from its historical and cultural values, Bali is critically important for coastal tourism, agriculture, capture fisheries and aquaculture, shipping, and human settlements. They described how the coastal habitats – particularly mangrove, seagrass beds and coral reefs – reduce the island's vulnerability to natural hazards and maintain essential ecological processes and biological diversity. The identified key threats to these values included beach erosion, destruction of coastal habitats, indiscriminate land conversion for commercial purposes, industrial and municipal wastes, multiple use conflicts, lack of interagency coordination, and weak environmental management capacity. There was a consensus that Integrated Coastal Management (ICM) is the best organizing framework to address such complex problems and issues. Some specific management recommendations relate to conservation of coastal habitats, integrated land and sea uses, establishing a waste management program, increasing the awareness level of the various stakeholders, and building the management capacity at the local level.

_____ END BOX 2-3 HERE _____

2.6.7. Industry and Settlements

Urban areas, cities and mega-cities as well as peri-urban areas are also highly vulnerable and at risk due to climate change and extreme events, although major attention has been given until now to rural areas and climate change. Vulnerability and risk in urban areas results from socio-economic transformations as well as from an increasing exposure of urban areas to the impacts of climate change (sources). One of the most vulnerable urban settings are informal settlements where marginalized population groups are living. These areas are increasing; they are in general characterized by a lack of access to basic services and a lack of political power as well as a high hazard exposure due to the necessity to settle in marginal areas.

Additionally, it is important to note that various cities depend on their hinterland and on functioning critical infrastructures in order to function and to provide basic functions such as housing, work and recreational services. Recent extreme weather events have showed that in both the South and North cities are particularly vulnerable due to the dependency on critical infrastructures, such as water supply, electricity, sewage sytems , transport and communication systems. A temporal or irreversible break down of critical infrastructures due to extreme events is therefore a key profile of the vulnerability and risks within urban areas. In general "critical infrastructures" are defined as organizations, institutions and services which are essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people. Their breakdown or malfunction can lead to severe supply shortfalls, substantial disruptions of the public safety and other serious consequences (see BMI 2005, European Commission 2008). The interdependency of various critical infrastructures (see Rinaldi et al. 2001), particularly the dependency on electricity for many services, is a serious threat for cities and in some cases increases their vulnerability to climate change related hazards. Risks in urban areas that are linked on the one hand to the dependency of urban societies on critical infrastructures and their functioning and on the other hand to the susceptibility and limited redundancy and replaceability of these critical infrastructures are a characteristic of new systemic risks that are closely embedded in specific development patterns of modern societies (IRGC 2009, Beck 2006).

2.7 Trends in Exposure and Vulnerability

2.7.1. Identifying Trends in Vulnerability and Exposure

As defined in Section 2.2 vulnerability is related to the degree to which human beings and their activity systems are damaged by natural or socio-natural events. Vulnerability then is very much associated with the level of exposure of society and the degree of sensitivity of a particular societal element at multiple scales (from the individual to the national).

In relation to climate, exposure has two broad meanings in the literature. How persons, property, infrastructure, goods and the environment itself come into contact with potentially damaging events matches the ideas surrounding exposure in the hazards, disasters and climate change literature. Exposure in this sense is very much dependent on location (direct or indirect proximity) and physical susceptibility or resistance to damage. From a poverty and development persepctive exposure relates to an aggregate measure of human welfare that integrates environmental or physical characteristics of where a person lives with social, economic and political factors that may work against protection from harm due to extreme climate events. Given these understandings, trends in exposure will be related to changes in the physical location and place and physical susceptibility along with alterations to a range of human welfare factors. Although exposure is complex, a consideration of trends in exposure factors whether they be physical or otherwise is necessary for a holistic understanding of vulnerability itself and trends in vulnerability.

As neither the environment (Ahmed et al., 2009; Ford et al., 2009) nor society are static (Jasparro and Taylor, 2008), then exposure and vulnerability are dynamic variables and accordingly will change both over time and space due to climatic variability and socio-economic and political-cultural changes. The dynamic nature of exposure and vulnerability will require that policy is flexible and able to cope with changing circumstances and "surprises" both in terms of changing environmental and societal conditions. This section therefore considers trends in environmental, economic, social and cultural factors that may alter the exposure and vulnerability profiles at a variety of scales.

2.7.2. Physical Dimensions

2.7.2.1. Geography, Location, and Place

TBD (from chapter 4)

2.7.2.2. Settlement Patterns and Development Trajectories

By 2030 it is estimated that at least 60 percent of the globe's population will be urbanised. In addition to the fact that the sheer numbers of urban dwellers will represent a large pool of potentially vulnerable individuals, concentrated into relatively small areas, the unintentional modification of environmental processes by urban areas may enhance the vulnerability of urban populations.

Adding to the vulnerability of urban areas is the fact that they are complex systems that pose management challenges in terms of the interplay between people, infrastructure, institutions and environmental processes (Matthias and Coelho, 2007). Alterations to any of these components of the urban system could bring about changes in vulnerability. In this respect, politico-economic factors may be extremely important such that politically motivated decisions to spread costs, concentrate economic benefits and hide the real risks could increase vulnerability to extreme climate events substantially (Freudenberg et al., 2008). Further many factors affect urban environmental quality, hence contrasting trends in water and air quality are found for many of the worlds major cities (Duhn et al., 2008).

In hydrological terms urban areas are impermeable, channelize water rapidly and are often the sites of devastating flash floods. As urban areas expand the percentage coverage of impervious surfaces will also increase thus increasing the likelihood of flood events, sewerage surcharging, basement flooding and combined sewer overflow due to rapid runoff response following intense rainfall events (Nie et al., 2009). The pressure for urban areas to also expand onto flood plains and coastal strips will also result in an increase in exposure of populations to riverine (Feyen et al., 2009) and coastal flood risk. In the case of riverine floods, or indeed any climate related hazard, a trend to anincreasing reliance on engineered protective measures may also amplify vulnerability leading to "floods of folly" (Freudenberg et al., 2008). Similarly the continued reliance on insurance products as an adaptive strategy for managing flood risk or any other climate related hazard for that matter, may lead to complacency amongst individuals and communities such that subsidised insurance may create a moral hazard in addition to that of the physical climate hazard resulting in a higher level of vulnerability than otherwise would exist. Consequently insurance related strategies put in place to increase adaptive capacity may be offset by behaviour that increases exposure (Lamond et al., 2009; McLemand and Smit, 2006).

During the day urban areas absorb a large amount of the incoming energy from the sun, which is stored in the urban fabric and in the evening released back into the atmosphere in the form of heat. The consequence of this is the development of the so- called urban heat island which manifests itself in terms of higher nocturnal urban compared to surrounding rural temperatures. In large cities the urban heat island effect can result in temperatures being as much as 7-10^{o}C higher than nearby rural areas. As urban areas expand and also increase in density over the coming decades, urban heat is likely to become a serious issue not only for human health but for urban based ecosystem services the consequence of which will be increases in vulnerability to heat related health problems, urban drought and subsidence and effects from pests and diseases. For a number of major cities there is strong observational evidence for increases in urban warming (Fujibe, 2009; Kataoka et al., 2009; Stone 2007) which makes some of the posited changes to urban environmental quality and thus vulnerability and exposure a real prospect. Loss of urban green space through the process of urbanisation may also increase vulnerability to climate change in urban areas through decreasing runoff amelioration, urban heat island mitigation effects and biodiversity (Wilby and Perry, 2006). For some cities there is clear evidence of a recent trend to a loss of green space (Boentje and Blinnikov, 2007; Rafiee et al., 2009; Sanli et al., 2008) for a variety of reasons including planned and unplanned urbanization with the latter driven by internal and external migration resulting in the expansion of informal settlements.

A further source of vulnerability for urban areas is that as attempts are made to localise global climate science to small-scale urban situations, potential misinterpretations or misapplications of climate science and therefore mal-formed policies could increase the vulnerability of urban areas to extreme climate events. The same of course applies to non-urban areas, however relatively speaking, because of the concentrations of people in urban areas the consequences of non-legitimate and –accountable decisions (Coburn, 2009) may have greater impacts on vulnerability in urban compared with non-urban areas.

Increases in the number and extent of informal settlements or slums (UN Habitat, 2003; Utzinger and Keiser, 2006) which are often located on land exposed to a variety of geophysical hazards within or on the edge of rapidly expanding cities, poses potential problems. This is because inhabitants of urban slums are often socio-economically marginalized and characterized by poor health (Sclar et al., 2005) and livelihood insecurity (Kantor and Nair, 2005) making them particularly vulnerable to extreme events

2.7.3. Environmental Dimensions

The environment provides a range of ecosystem services. These can be classed as provisioning (e.g. food and water), regulating (flood and disease control), supporting (e.g. biogeochemical cycling) and cultural (e.g. aesthetic, spiritual and recreational). Clearly environmental degradation will have a major impact on the quality and availability of such services the effects of which are likely to be fundamental changes in the components of vulnerability such as increases in exposure to hazards through for example changes in flood occurrence (loss of regulation services) and altering sensitivity of populations for example via soil nutrient loss (loss of support services) and associated impacts on food production (loss of provision services).

Because the environment provides a resource base for human development any degradation of that resource will inevitably have an impact on development trajectories and society's vulnerability to extreme climate events. As a large proportion of the world's population depends on forestry, fishing and agriculture as a source of income natural or anthropogenic related changes to water, forestry, land and fishery resources will have a fundamental impact on human livelihoods and economies at a range of scales which will in turn translate into fundamental shifts in the vulnerability profiles of those most affected.

There are a number of current environmental trends that threaten human well-being and thus by extension human vulnerability (UNEP, 2007). For example climate variability and change is having marked impacts on human health, food production, security and resource availability. Many communities have suffered considerable losses due to extreme weather events, which have rendered them even more vulnerable to future climatic and non-climatic extreme events. Deterioration in both indoor and outdoor air quality continues to bring about premature mortality in many of the worlds largest cities or where indoor cooking over open fires is still commonplace. Agricultural productivity, food security, livelihoods and health are being affected by land degradation which often starts with soil sealing, erosion, salinization, fire risk, over production, and land fragmentation resulting from both natural and human attributable changes in climate, soil, vegetation conditions and economic and population pressures (Salvati and Zitti, 2009). The inability of many to secure safe water supplies is having fundamental impacts on human health and economic activities. Reductions in fish stocks because of over exploitation and coastal and marine pollution are jeopardizing livelihoods and health in those communities heavily dependent on marine resources for development. Species extinctions and loss of biodiversity pose a threat to the diminution of genetic pools that represent possible sources for future advances in medicine and agricultural production.

Archetypes of vulnerability which are specific, representative patterns of the interaction between environmental change and human well-being (Wonink et al., 2005; UNEP, 2007) provide a useful framework for considering how changes in vulnerability may accrue from environmental degradation. A number of archetypes of vulnerability may be identified including contaminated sites, dry lands, global commons, securing energy, small island developing states, technological approaches to water problems and urbanisation of the coastal fringes (UNEP, 2007). The ways in which these archetypes of vulnerability can affect human well being is summarised in Table 2-5 along with possible policy responses for reducing vulnerability and the types of extreme climate events (ECE) which are likely to impact vulnerability in an acute (short-term) and possible chronic (long-term) sense.

[INSERT TABLE 2-5 HERE
Table 2-5: Vulnerability archetypes, human well-being issues, responses, and extreme climate events (modified from UNEP, 2007).]

From the above it is clear that environmental degradation and poorly planned development may well increase vulnerability to extreme climate events. Further as vulnerability is determined by multiple stresses and a lack of societal options at a variety of levels any changes in the natural resource base through environmental deterioration brought about by natural causes or inappropriate development will have fundamental impacts on societies that have little protection against extreme climate events. Future trends in vulnerability related to environmental quality will also depend on trends in exported or imported vulnerability. In the case of the former the consumption of high value products in the developed world, which have been produced from resources in the developing world, may have important impacts on environmental quality where resource extraction has occurred. Similarly the competition for resources between adjacent rural and urban communities can result in the export of vulnerability form large cities to their increasing resource depleted hinterlands as might come about from the transfer of water from rural to urban areas. Vulnerability may be imported either through the outsourcing of industrial production to developing nations for both environmental and economic reasons or because of the importation of hazardous material for processing or storage in developing countries.

2.7.4. Economic Dimensions

Poverty is arguably one of the most pressing social issues facing humanity. As a determinant of vulnerability to extreme events, upward changes in poverty levels or the growth of globe's population classed as in poverty may well have a fundamental impact on general levels of vulnerability. Added to this is the additional stress climate change may add to populations living in poverty.

As noted by Erikson and O'Brien (2007) poverty and climate change are interlinked yet distinct. Accordingly it is important to recognise that adaptation measures need to specifically target climate change – poverty linkages as not all poverty reduction measures reduce vulnerability to climate change and vice versa. Further, measures beyond the local scale may be required as the drivers of poverty may necessitate that political and economic issues at a larger scale are tackled (Erikson and O'Brien, 2007; O'Brien et al., 2008). Because the determinants and dimensions of poverty are complex as well as its association with climate change (Demetriades and Esplen, 2008; Khandlhela and May, 2006; Hope, 2009), poverty related increases in vulnerability to extreme climate events could theoretically be obtained through changes in economic development and openness, geographical and demographical disadvantages, political regime characteristics and war, and social policy and human capital enhancement (Tsai, 2006).

2.7.5. Social Dimensions

2.7.5.1. Demography

Population growth, composition and distribution are fundamental factors in determining vulnerability. Rarely does the preparedness and response to extreme events have anything to do with the event magnitude itself. More often than not it is factors such as social class, education, gender, ethnicity or race, cultural background and language status that are important in determining vulnerability (Donner and Rodriguez, 2008).

Certain population groups may, in a relative sense, be more vulnerable than others. For example the very young and old are more vulnerable to heat hazards than other population groups (Staffogia et al., 2006) and therefore an aging population or rising birth rates may increase the pool of susceptible individuals and therefore societal vulnerability. Population growth due to inward migration may also influence vulnerability especially in urban areas where the inflow of economically disadvantaged people results in urban migrant communities locating in unplanned housing areas on marginal land. Therefore communities living in physically marginal situations such as on unstable valley side slopes (Nathan, 2008), in flood prone areas (Aragon-Durand, 2007; Bertoni, 2006; Colten, 2006; Douglas et al., 2008; Zahran et al., 2008) or marginally productive land, because of their economic circumstances, are more vulnerable than those living in areas where the likelihood of slope failure, flooding and soil erosion respectively is much reduced.

Over the next 10-20 years it is likely that migration will contribute significantly to population growth in a number of countries. Because of their disadvantaged position, in terms of social, economic and cultural capital, migrants may be more vulnerable to extreme climate events. The inability to understand extreme event related information, prioritisation of finding employment and housing and distrust of authorities will all contribute to increased vulnerability amongst migrant groups (Donner and Rodriguez, 2008; Enarson and Morrow, 2000).

The role of gender, race and class in determining vulnerability is widely debated but in general it would appear that poor minority women experience higher vulnerability because of inequalities which restrict their access to resources that could help modify their risk (Enarson and Fordham, 2001; Rodriguez and Russell, 2006).

2.7.5.2. Education

Environmental education programmes have been shown to promote resilience building in socio-ecological systems because of their role in enhancing biological diversity and ecosystem services. They also provide the opportunity to integrate diverse forms of knowledge and participatory processes in resource management (Krasny and Tidball, 2009). Given this the support of environmental education programmes through government funding at a variety of levels may play a critical role in the development of public levels of environmental awareness affecting people's capability to take action towards sustainable development (Brieting and Wikenberg, 2010; Waktola, 2009). Because environmental education has clear benefits for increasing environmental awareness amongst children and adults (Kobori, 2009; Kuhar et al., 2010; Nomura, 2009; Patterson et al., 2009) support of this often funding sensitive aspect of education will be important for determining trends in the public understanding of some of the controlling factors of exposure and vulnerability related to extreme climate events.

2.7.5.3. Health and Well-Being

Individual and population health may determine broad levels of vulnerability and exposure to extreme events because good or poor health may influence the ability to respond to or cope with extreme events. Accordingly trends in the burden of disease and associated risk factors (Mather and Loncar, 2006) at a variety of geographical scales may affect local to global levels of vulnerability and exposure to extreme events. For example obesity, a risk factor for cardiovascular disease, has been noted to be on the increase in a number of countries (Skelton et al., 2009; Stamtakis et al., 2010). Such trends may well have an indirect impact on the vulnerability of people during periods of extreme events, as for example heat waves because pre-exisiting cardiovascular disease is a heat risk factor. Similarly observed and projected trends in major public health threats such as the infectious or communicable diseases HIV/AIDS, tuberculosis, and malaria could weaken the long term resilience of some populations. In addition to the diseases themselves, persistent and increasing obstacles to expanding or strengthening health systems such as inadequate human resources and poor hospital and laboratory infrastructure (Vitoria et al., 2009) may also contribute indirectly to increasing vulnerability and exposure in regions where for example malaria and HIV/Aids occasionally reach epidemic proportions.

Through its impact on key ecosystem services deteriorating environmental conditions (Tong et al., 2010) could exacerbate health related trends in vulnerability and exposure. For example land clearing and associated salinity increases could have implications for trends in wind-borne dust and respiratory health. However there is mixed evidence for trends in dust storm frequency (Goudie, 2009) and links between dust storm occurrence and respiratory health (Hong et al., 2009; Middelton et al., 2008). Altered ecology and increase in diseases may also follow land use change (Jardie et al., 2007) however the link between human induced changes to ecosystems and disease is complex (Ellis and Wilcox, 2009; Johnson et al., 2010; Ljung et al., 2009). Similarly the trends in the availability of clean drinking water, its impacts on the incidence of diarrhoeal disease (Clasen et al., 2007) and associated implications for health and resilience to other climate sensitive diseases may influence vulnerability and exposure.

2.7.6. Science and Technology

In many ways S&T is a double-edged sword in relation to vulnerability. It can help reduce vulnerability due to environmental and non-environmental change but on the other hand add to societal and environmental risk especially through contributing to environmental change.

Over the last few decades there have been rapid advancements in S&T especially in the agricultural sector. These have been functional in increasing food production, decreasing food prices and reducing famine. However a fundamental problem is that S&T developments and beneficiaries are unequal in distribution. This can lead to polarization of vulnerability over very short distances as for example brought about by the use of drought resistant crops in one area but not in a nearby area. To avoid such disparities clearly S&T transfer is required but the success of this will be very much dependent on the ability of the recipient community to apply the transferred S&T successfully. As opposed to complete reliance on technocratic solutions to vulnerability, blending western S&T with indigenous knowledge (Mercer et al., 2010) and ecological cautiousness offers opportunities for reducing vulnerability through the creation of eco-technologies with a pro-nature, pro-poor and pro-women orientation (Kesavan and Swaminathan, 2006).

Modern weather and forecasting techniques have helped reduce disaster risk and thus vulnerability through providing the basis for early warning for a range of ECE. Some forecasts are tailored for specific ECE such as hurricances or heat waves. However the efficacy of such early warning systems is very much dependent on the existence of well planned and thought through operationalisable response strategies. Notwithstanding this there is an increasing use of weather and climate information for planning and climate risk management (Changnon and Changnon, 2010) as well as the use of technology for the development of a range of decision support tools for climate related disaster management (van de Walle and Turoff, 2007).

Over reliance on S&T solutions as an adaptive option for coping with ECE and thus reducing vulnerability can in some cases be counterproductive (Marshall and Picou, 2008) as seen in the case of levee failure during Hurricane Katrina leading to what Freudenberg et al., (2008) have referred to as “floods of folly”. Further the persistent technocratic approach to hazards in general by the science and engineering community has tended to promulgate the view amongst the public and decision-makers that S&T solutions are the panacea for natural hazard management. This tends to stultify attempts to implement alternative approaches to vulnerability reduction through community empowerment to achieve hazard mitigation and the development of grass roots response strategies and coping mechanisms (Haque and Etkin, 2007).

2.7.7. Access to Information

Access to information related to early warnings, response strategies, coping mechanisms, S&T, human, social and financial capital is critical for reduction of vulnerability and increase resilience. A range of factors may control or influence the access to information including economic status, race (Spence et al., 2007), trust (Longstaff and Yang, 2008), belonging to a social network (Peguero, 2006) digital inequalities (Crutcher and Zook, 2009; Rideout, 2003). Further trends in the use of the internet for gathering information appear to be conditioned on a number of factors (Buente and Robbin, 2008).

Traditionally the approach to adaptation has been one focused on engineering or technology based solutions. However there is mounting evidence that non-structural interventions offer mutually beneficial interventions for adaptation. Integrating governance across all levels and sectors through for example incorporation of knowledge from the local to global in environment policies (Karlsson, 2007), co-management and involvement of stakeholders from all sectors in the management of natural resources (McConnell, 2008; Plummer 2006) and mainstreaming attention to vulnerability through policy can assist with understanding and addressing vulnerability. However the challenges associated with multi-level governance and co-management need to be recognized and can at times pose a barrier to achieving reduction in vulnerability (Armitage et al., 2007; Sandstrom, 2009). Environmental change and extreme events pose challenges to ecosystem services and thus human health. Accordingly prospective approaches to adaptation need to recognize the close association between environment and human well-being, as good levels of human health not only have implications for coping capacity and resilience but are crucial for development (Suhrcke et al., 2007).

Resolving conflict, though a challenge, could provide benefits for vulnerability reduction because war exacts a heavy toll on people thus affecting societal capacity to adapt and brings about damage to the environment. Although there are a variety of reasons for conflict, understanding the role of the competition for environmental resources and climate change in conflict generation (Barnett and Adger, 2007) could provide for developing policies for environmental cooperation that might facilitate vulnerability reduction, abatement of assaults on human well-being and create opportunities for development and poverty reduction.

Much environmental decision-making is non-inclusive especially as it relates to local resource users. This often generates tension between local and national level institutions because of contrasting visions of natural resource use. The inclusion of local concerns has the potential to transition local resource users from consumers of policies to agents in the making and shaping of the policies that affect their lives (Cornwall and Gaventa, 2000) leading to greater equity in financial and resource receipt (Leach et al., 2002) and thus reduced vulnerability due to marginalisation and social and economic disparity (Toni and Holanda, 2008).

Imperative for the attainment of sustainable livelihoods is the achievement of secure entitlements to natural resources (Whitford et al., 2010) as this can assist with poverty and thus vulnerability reduction. Further because of the role women play in managing natural resources in many countries addressing women's tenure rights can have positive effects in terms of ameliorating vulnerability (Flintan, 2010). Decision-making in the absence of knowledge can often lead to unfortunate outcomes. Accordingly building knowledge about environmental risk at a variety of levels, especially amongst vulnerable groups can assist with enhancing risk management and coping capacity. Also acknowledging reciprocity in knowledge generation and transfer is key to effective environmental decisionmaking as it relates to adaptation and coping strategies. Central is also the role of education in equipping the vulnerable with knowledge and actions that will assist with response and adaptation to extreme events (Cutter et al., 2006).

Although the potential exists for developments in science and technology, such as early warning systems, environmental monitoring and advances in risk assessment to reduce vulnerability, it is often difficult for those who stand to benefit most to access such developments. Localising S&T developments in terms of participation and relevance stands to enhance the achievement of the theoretical benefits of S&T. Globalisation, production and consumption often lead to the export or import of vulnerability. To manage such vulnerability institutions, sectors and individuals will need to develop cultures of responsibility and work to understand the chain of events that lead to vulnerability export/import with the result that actions can be taken and vulnerabilities of recipient communities can be reduced.

Without implementation, corrective and prospective plans of action for adaptation will remain as theoretical ideas at best. To achieve implementation the complexities underlying failure need to be understood so that these can be avoided. Building capacity for implementation by providing institutions with mandates and funding for action and monitoring the outcome of adaptation action plans will be critical if efficacy of corrective and prospective adaptation interventions is to be obtained at a variety of scales.

2.7.8. Influence of Gradual Climate Change

Climate change is expected to result in an increase in the climatology (timing, intensity, spatial extent) of extreme climate events and sea level rise. As outlined in Chapter 3 there has been an observed increase in the frequency of heat waves, intense rainfall, storminess, and storm surge for some regions of the world. Such observations are in line with climate change projections of extreme climate events. Observational evidence of increases in some extreme climate events however does not exist (e.g. tornadoes, thunderstorms, floods). Notwithstanding this climate change projections suggest that some events, such as heat waves and intense rainfall, will increase not only in their frequency but severity.

Following the definition of vulnerability adopted in this report, extreme climate events comprise an important element of exposure. Therefore current and predicted trends in extremes are likely to increase exposure and thus vulnerability in the absence of improvements in human well-being, investment in human and social capital and a reduction in human related environmental degradation. Exposure will not only potentially increase in endemic hazard areas and seasons but most likely in emerging climate hazard areas and seasons as a result of changes in storm tracks and the duration of storm seasons, the expansion of regions and periods of drought and extreme heat events, the intensification and alteration of the timing of hydrological cycle processes leading to intense rainfall events and changing periods of seasonal flood and low flow patterns. Observed and projected changes in the climatology of extreme events will therefore add to the changing spatial and temporal dynamics of exposure and thus vulnerability all other things being equal. Such changes through altering exposure will have a direct impact on vulnerability. Gradual climate change could also have a number of indirect impacts on vulnerability by altering the non-exposure terms of vulnerability. For example climate change may have a fundamental impact on the number of people in poverty or suffering from food and water insecurity, the social segregation of society, diminishing human and social capital, general health levels especially amongst the poor, where people live, conflict and governance. In short gradual climate change has the potential to add significantly to the multiple stressors that comprise vulnerability.

2.8. Risk Identification and Assessment

Risk accumulation, dynamic changes in vulnerabilities, and different phases of crises and disaster situations constitute a complex environment for identifying and assessing risks and vulnerabilities, risk reduction measures and adaptation strategies. In the context of climate change, risk identification, vulnerability assessment and improvement of our understanding of extreme events and disasters are pre-requisites for the development of adaptation strategies.

2.8.1. Risk Identification

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The modern vision of disaster risk management involves four distinct public policies or components:

- Risk identification (involving individual perception, social interpretation, and objective evaluation of risk)
- Risk reduction (which involves prevention or mitigation of physical and social vulnerability as such)
- Risk transfer (related to financial protection and in public investment)
- Disaster management (related to preparedness, warnings, response, rehabilitation and reconstruction after disasters).

It is easy to see from this perspective that the first three actions are *ex ante*; i.e. they take place in advance of disaster, and the fourth refers to *ex post* actions. At the same time, and inevitably, disaster risk management is transverse to development and a range of stakeholders and actors in society are necessarily involved in the process (Cardona 2004, 2010; IDB 2007). Clearly risk identification, through risk understanding by the stakeholders and actors and by vulnerability and risk assessment, is the first step for risk reduction, prevention and transfer, as well as climate adaptation in the context of extremes.

2.8.1. Risk Identification

Understanding risk factors and communicating risks, due to climate change, to decision makers and the general public are key challenges, especially for science. It requires, on the one hand, an improved understanding of risk factors, underlying vulnerabilities and societal coping and response capacities and, on the other hand, new formats of communication in terms of dealing with uncertainty and complexity – understood here as non-linearity, emergent structures and limits of knowledge (see e.g. ICSU-LAC, 2010, p. 15; Birkmann *et al*. 2009; Renn 2008, pp. 289; Bohle and Glade 2008, Patt *et al.,* 2005). The promotion of a higher level of risk awareness, regarding climate change-induced hazards and changes, also requires an improved understanding of the specific risk perceptions of different social groups, including those factors that influence and determine these risk perceptions, such as beliefs, values and norms.

Overall, essential pre-requisites for promoting a culture of adaptation and resilience are appropriate information and knowledge. Specific information and knowledge must first be collected on the dynamic interactions of exposed and vulnerable elements, e.g. persons, their livelihoods and critical infrastructures, and potentially damaging events, such as extreme weather events or potential irreversible changes as sea level rise. Based on the expertise of disaster risk research and findings in the climate change and climate change adaptation community, requirements for risk understanding related to climate change and extreme events particularly encompass:

- Knowledge of the processes by which persons, property, infrastructure, goods and the environment itself are exposed to potentially damaging events, e.g. understanding exposure in its spatial and temporal dimensions
- Knowledge of the factors and processes which determine or contribute to the vulnerability of persons and their livelihoods or of socio-ecological systems. Understanding increases or decreases in susceptibility and response capacity, including the distribution of socio- and economic resources that make people more vulnerable or that increase their level of resilience is also key
- Knowledge on how climate change impacts are transformed into hazards, particularly regarding processes by which human activities in the natural environment or changes in socio-ecological systems lead to the creation of new hazards (e.g. Natural-technical hazards, NaTech), irreversible changes or increasing probabilities of hazard events occurrence
- Knowledge regarding different tools, methodologies and sources of knowledge (e.g. expert knowledge / scientific knowledge, local or indigenous knowledge) that allow capturing new hazards, risk and vulnerability profiles, as well as risk perceptions. In this context, new tools and methodologies are also needed that allow for the evaluation e.g. of new risks (sea level rise) and of current adaptation strategies
- Knowledge on how risks and vulnerabilities can be modified and reconfigured through forms of governance, particularly risk governance – encompassing formal and informal rule systems and actor-networks at various levels. Furthermore, it is essential to improve knowledge on how to promote adaptive governance within the framework of risk assessment and risk management.

(ICSU-LAC, 2010, p. 15; Birkmann *et al*. 2009, Birkmann *et al*. 2008; Cutter and Finch 2008, Renn 2008, pp. 289; Bohle and Glade 2008; Biermann *et al*., 2007, Biermann *et al*. 2009, Füssel 2007; Renn and Graham 2006; Patt *et al.,* 2005; Cardona *et al*. 2005; and Kasperson *et al*. 2005)

Consequently, improving our understanding of disaster risk, in the context of climate change, and respective information needs for sustainable adaptation encompasses at least six knowledge demands:

- Identification of new hazards and irreversible changes
- Vulnerability patterns
- Risk perception and risk construction processes (particularly regarding 'unexperienced' hazards such as sea level rise)
- Evaluation and assessment methodologies and tools
- Risk communication
- Risk and adaptive governance.

If science is to help support the transition to a more sustainable and adaptive development in the light of climate change, with increasing frequency of extreme events and continuing creeping environmental degradation, risk identification and assessment are key activities. Climate change mitigation is a core task; however, it is increasingly evident that climate change can no longer be avoided and that existing green-house-gases in the atmosphere will imply a further increase in the probability of extreme weather events. Consequently, disaster risk understanding, communication and reduction in the context of climate change adaptation are crucial tasks (van Sluis and van Aalst 2006; ICSU-LAC 2010).

2.8.2. Vulnerability and Risk Assessment

Risk analysis and risk assessment were already issues of interest in Babylonian times. The development of modern risk analysis and assessments were closely linked to the establishment of scientific methodologies for identifying causal links between adverse health effects and different types of hazardous events and the mathematical theories of probability (Covello and Mumpower, 1985). Today, risk and vulnerability assessments encompass various approaches and disciplines and thus constitute a broad and multidisciplinary research field. In this regard, vulnerability and risk assessments can have different functions and goals.

Risk, as well as vulnerability assessment, is conducted from different angles depending on the underlying understanding of the terms. In this context, two main schools of thought can be differentiated. The first school of thought defines risk as a decision by an individual or a group to act in such a way that the outcome of these decisions can be harmful (Luhmann 2003; Dikau and Pohl 2007). In contrast, the disaster risk research community views risk as the product of the interaction of a potentially damaging event and the vulnerable conditions of a society or element exposed (UN/ISDR 2004).

Today, vulnerability and risk assessment encompass various approaches and techniques ranging from indicator-based global or national assessments to qualitative participatory approaches of vulnerability and risk assessment at the local level (see IDEA, 2005; Cardona, 2006; Birkmann, 2006a; Wisner, 2006a; IFRC, 2008; Dilley, 2006; and Peduzzi *et al.,* 2009).

In general terms, vulnerability and particularly risk assessment can be defined as a process to comprehend the nature of risk and to determine the level of risk (ISO 31000). Additionally, communication within the assessment and risk management are seen as key elements of the process (Renn, 2008). More specifically, vulnerability and risk assessment deal with the identification of different facets and factors of vulnerability and risk, by means of gathering and systematising data and information, in order to be able to identify and evaluate different levels of vulnerability and risk of societies -social groups and infrastructures- or coupled socio-ecological systems at risk. A common goal of vulnerability and risk assessment approaches is to provide information about profiles, patterns of and changes in risk and vulnerability (see e.g. IFRC, 2008; Birkmann, 2006a; IDEA, 2005; Cardona *et al.,* 2005), in order to define priorities, select alternative strategies or to formulate new response strategies. In this context, the Hyogo Framework for Action stresses that the starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge (UN, 2005).

One of the key strategic activities of disaster risk management and adaptation is the vulnerability and risk assessment, which requires the use of reliable methodologies that allow an adequate estimation and quantification of potential losses and consequences to the human systems in a given exposure time.

There are a wide range of approaches for integrating data and modelling risk and vulnerability. *Inductive* approaches model risk through weighting and combining different hazard, vulnerability and risk reduction variables. *Deductive* approaches are based on the modelling of historical patterns of materialized risk (i.e. disasters, or damage and loss that have already occurred). Other approaches combine the results of inductive and deductive modelling. An obstacle to inductive modelling is the lack of accepted procedures for assigning values and weights to the different vulnerability and hazard factors that contribute to risk. Deductive modelling will not accurately reflect risk in contexts where disasters occur infrequently or where historical data are not available. In spite of this weakness, deductive modelling offers a short cut to risk indexing in many contexts and can be used to validate the results from inductive models (Maskrey 1998).

Probabilistic estimations of risk attempt to predict damage or losses even where insufficient data are available on the system being analyzed. Failure and event trees are used for the analysis, and the probability of damage is evaluated in systematic fashion. This type of approach is useful for detecting deficiencies and for improving security levels in complex systems. The actuarial approach represents a classic example of *objectivist* approaches to the analysis of risk, where the base unit is an expected value that corresponds to the relative frequency of an average event in time (UNDRO, 1980; Fournier d'Albe, 1985; Petrovsky and Milutinoviç, 1986; Coburn and Spence, 1992; Woo, 1999; Grossi and Kunreuther, 2005; Cardona *et al.,* 2008a/b; Cardona 2010).

From an objectivist point of view, to achieve the overall goal of identifying and quantifying disaster risk, it is necessary to use and even develop a method that takes account the natural hazards in an integrated manner that includes the total and detailed exposure of assets with their main features. This in order to take into account the specific vulnerability of each component and to evaluate risk assessment using an appropriate technique that takes into account the uncertainty of the process, the inevitable limitations on information. In most cases it is necessary to use certain approaches and criteria for simplification and for aggregation of information due to a lack of data or the inherent low resolution of the information. This fact sometimes means sacrificing some scientific or technical and econometric characteristics, accuracy and completeness that are desirable features when the risk evaluation is the goal of the process (Cardona *et al.,* 2003).

The risk estimate must be prospective, anticipating scientifically possible hazard events that may occur in the future. For the case of hurricane-winds, the hydrometeorologic information available of the historic hurricanes that have affected the area of study is used and, jointly with engineering methodologies, the effects of these phenomena upon the exposed assets are estimated. Due to the high uncertainties inherent to the models of analysis regarding the severity and frequency of occurrence of the events, the risk model is based on probabilistic formulations incorporating said uncertainty in the risk evaluation. The steps of risk assessment from an objectivist point of view are can be described as follows:

- *Hazard assessment*: This means calculating the threat associated to all possible extreme events that could occur, to a group of selected events, or even to a single relevant event. For each type of extreme event it is possible to calculate the probable maximum value of the intensity that characterized for different rates of occurrence or return period.
- *Exposure modeling*: This is the description of the exposed elements or assets that may be affected by the extreme events or hazards.
- *Vulnerability evaluation*: The assignment of the vulnerability functions to each exposed element located in the hazard prone area.
- *Risk assessment*: It is the convolution of the hazard with the vulnerability of the exposed elements in order to assess the potential impact or consequences. Risk can be expressed in terms of damage or physical effects.

Once the expected physical damage has been estimated (average potential value and its dispersion) as a percentage for each of the assets or components included in the analysis, it is possible estimating various parameters or metrics as result of obtaining the Loss Exceedance Curve, such as the Probable Maximum Loss for different return periods and the Average Annual Loss or technical risk premium. These measures are of particular importance for the stratification of risk and the design of disaster risk intervention strategy considering risk reduction, prevention and transfer (Woo, 1999, Grossi and Kunreuther, 2005, Cardona *et al.,* 2008a/b).

At present probabilistic risk assessment is the result of the evolution from early days of insurance to computer-based catastrophe modelling using advanced information technology and geographic information systems (GIS) for mapping. With the ability to store and manage vast amount of information, GIS became an ideal environment for conducting easier and more cost-effective hazard and loss studies (Maskrey, 1998; Grossi and Kunreuther, 2005).

On the other hand, vulnerability and risk *indicators* or *indices* are feasible techniques for risk monitoring and may take into account both the harder aspects of risk as well as its softer aspects (Cardona *et al.,* 2003; Cardona, 2006;

IDEA, 2005). The usefulness of indicators depends on how they are employed. The way in which indicators are used to produce a diagnosis has various implications. The first relates to the structuring of the theoretical model. The second refers to the way risk management objectives and goals are decided on. This aspect is important given that it is preferable to promote an understanding of reality not in strict terms of the ends to be pursued, but, rather, in terms of the identification of a range of possibilities, information on which is critical to organize and orientate the praxis of effective intervention (Zemelman 1989). An appropriate technique based on indicators can be a rational benchmark or a common metric to rule the risk variables from a control point of view (Carreño *et al.,* 2007b, 2009). The goal in this case is not to reveal the truth, but rather to provide information and analyses that can improve decisions.

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Box 2-4. The Disaster Deficit Index: A Metric for Sovereign Fiscal Vulnerability Assessment.

Future disasters are contingency liabilities that must be included in the balance of each nation. As pension liabilities or guaranties that the government has to assume for the credit of territorial entities or due to grants, disaster reposition costs are liabilities that become materialized when the hazard events occur. By other way, extreme impacts can generate financial deficit due to sudden an elevated need of resources to restore affected inventories or capital stock (Cardona et al 2007, 2010; Carreño et al 2010). The Disaster Deficit Index (DDI) developed in the framework of the Program of Indicators of Disaster Risk and Risk Management for the Americas of the Inter-American Development Bank (Cardona 2005, 2010; IDEA, 2005) provides an estimation of the extreme impact (due to hurricane, floods, tsunami, earthquake, etc.) during a given exposure time and the financial ability to cope with such situation. The DDI captures the relationship between the loss that the country could experience when an extreme impact occurs (demand for contingent resources) and the public sector's economic resilience; that is, the availability of funds to address the situation (restoring affected inventories). This macroeconomic risk metric underscores the relationship between extreme impacts and the capacity to cope of the government. Figures 2-5 and 2-6 show the DDI for 2009 and for the last four periods.

[INSERT FIGURE 2-5 HERE:
Figure 2-5: Disaster Deficit Index (DDI) and Probable Maximum Loss in 500 Years for 2008.]

[INSERT FIGURE 2-6 HERE:
Figure 2-6: Disaster Deficit Index (DDI) (500 years) for 19 countries of the Americas.]

A DDI greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the DDI, the greater the gap between losses and the country's ability to face them. This disaster risk figure is interested and useful for a Ministry of Finance and Economics. It is related to the potential financial sustainability problem of the country regarding the potential disasters. On the other hand, the DDI gives a compressed picture of the fiscal vulnerability of the country due to extreme impacts. The DDI has been a guide for economic risk management; the results at national and subnational levels can be studied by economic, financial and planning analysts who can evaluate the budget problem and the need to take into account these figures in the financial planning.

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It is important to recognise that complex systems involve multiple facets (physical, social, cultural, economic and environmental) that are not likely to be measured in the same manner. Physical or material reality have a harder topology that allows the use of quantitative measure, whilst collective and historical reality have a softer topology in which the majority of the qualities are described in qualitative terms (Munda, 2000). These aspects indicate that a weighing or measurement of risk involves the integration of diverse disciplinary perspectives. An integrated and interdisciplinary focus can more consistently take into account the non-linear relations of the parameters, the context, complexity and dynamics of social and environmental systems, and contribute to more effective risk management by the different stakeholders involved in risk reduction decision-making. It permits the follow-up of the risk situation and the effectiveness of the prevention and mitigation measures can be easily achieved. Results can be verified and the mitigation priorities can be established with regard to the prevention and planning actions to modify those conditions having a greater influence on risk (Carreño *et al.,* 2007a, 2009).

In order to ensure that risk and vulnerability assessments are also understood, the key challenges for future vulnerability and risk assessments, in the context of climate change, are, in particular, the promotion of more integrative and holistic approaches, the improvement of assessment methodologies and the need to address the requirements of decision makers and the general public.

Many concepts and assessments still focus solely on one dimension, such as economic risk and vulnerability. Thus, they consider a very limited set of vulnerability factors and dimensions. Some approaches, for example, at the global level, view vulnerability primarily with regard to the degree of experienced loss of life and economic damage (see Dilley *et al*. 2005; and Dilley 2006). In contrast, approaches providing a more integrative and holistic perspective capture a greater range of dimensions and factors of vulnerability and disaster risk. Successful adaptation to climate change has been based on a multi-dimensional perspective, encompassing e.g. social, economic, environmental and institutional aspects. Hence, risk and vulnerability assessments – that intend to inform these adaptation strategies – require also a multi-dimensional perspective.

Assessment frameworks with an integrative and holistic perspective were developed by Turner *et al*. (2003) and Birkmann (2006b) – based on Bogardi/Birkmann (2004) and Cardona *et al*. (2005). Despite differences between the frameworks mentioned above, it is interesting to note that a common characteristic is the conceptualisation of vulnerability and risk within the context of general system theory, considering various linkages and feedback processes (feedback loops) between different factors or components of risk and vulnerability. Furthermore, integrative and holistic approaches disaggregate vulnerability into at least three factors: a) exposure, b) sensitivity, susceptibility or fragilities (inner conditions of the exposed elements) and c) response capacities (coping or adjustment) or the lack of it (lack of resilience) (see Cardona and Barbat, 2000; Turner *et al.,* 2003; Birkmann, 2006b; Carreño *et al.,* 2009).

Hence, the assessment of vulnerability and risk does not solely focus on the potential outcome, for example a certain level of risk, but rather helps to understand interlinkages between factors that might influence and determine the vulnerability and risk. Additionally, integrated assessment frameworks also take into account various thematic dimensions of vulnerability. These range from economic, socio-economic, environmental, cultural to institutional aspects. Thus these assessments require an interdisciplinary perspective that considers the broader context in which disaster risk is embedded.

Additionally, Turner *et al*. (2003) underline the need to focus on different scales simultaneously, in order to capture the interlinkages between different scales and their impact on the vulnerability of the exposed human-environmental system. However, the influences and interlinkages between different scales are still difficult to capture, especially due to their dynamic nature and their potential reconfiguration during and after disasters, for example, in form of external disaster aid.

Furthermore, integrative frameworks based on the notion of coupled systems and feedback loop systems also encompass the evaluation of response and feedback processes. Key elements of a more integrative and holistic view on risk and vulnerability are the identification of causal linkages between select factors of vulnerability and risk and the potential interventions that nations, societies or different social groups or individuals have to reduce their vulnerability or exposure to risks. The integration of these feedback processes and intervention tools within the assessment also promotes a problem solving perspective in the way that they put emphasis on the identification of policy responses (formal and informal responses) and options on how to reduce vulnerability and risk levels (Cardona, 1999; Cardona and Hurtado, 2000a/b; Cardona and Barbat, 2000; Turner *et al.,* 2003; IDEA 2005a/b; Birkmann, 2006b; Carreño *et al.,* 2005, 2009; ICSU-LAC 2010). Figure 2-1 contours a holistic and integrative perspective.

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Box 2-5. Measuring Vulnerability at National Level: The Prevalent Vulnerability Index.

Vulnerability is a key issue in understanding disaster risk. The Prevalent Vulnerability Index (PVI), developed in the framework of the Program of Indicators of Disaster Risk and Risk Management for the Americas of the Inter-American Development Bank (Cardona 2005, 2010; IDEA, 2005) provides a holistic approach to vulnerability assessment using social, economic and environmental indicators. The PVI depicts predominant vulnerability conditions. It provides a measure of direct effects (as result of exposure and susceptibility) as well as indirect and intangible effects of hazard events (as result of socioeconomic fragilities and lack of resilience). The indicators used are made up of a set of indicators that express situations, causes, susceptibilities, weaknesses or relative absences affecting the country, region or locality under study, and which would benefit from risk reduction actions. The indicators are identified based on figures, indices, existing rates or proportions derived from reliable databases available worldwide or in each country. These vulnerability conditions underscore the relationship between risk and development. Figures 2-7 and 2-8 show the aggregated PVI (Exposure, Social Fragility, Lack of Resilience) for 2007 and for the last four periods.

[INSERT FIGURE 2-7 HERE:
Figure 2-7: Aggregate Prevalent Vulnerability Index (PVI) for 2007.]

[INSERT FIGURE 2-8 HERE:
Figure 2-8: Prevalent Vulnerability Index (PVI) for 19 countries of the Americas.]

Vulnerability and therefore risk are the result of inadequate economic growth and deficiencies that may be corrected by means of adequate development processes. The information provided by an index such as the PVI should prove useful to ministries of housing and urban development, environment, agriculture, health and social welfare, economy and planning. The main advantage of PVI lies in its ability to disaggregate results and identify factors that should take priority in risk management actions as corrective and prospective measures or interventions of vulnerability from development point of view.

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Besides strengthening the integrative and holistic perspective within risk and vulnerability assessment, in the context of climate change, risk identification and vulnerability assessment has to be undertaken in different phases, e.g. before, during and even after disasters occur. Although risk and vulnerability reduction should be primarily conducted before potential disasters occur, it is important to acknowledge that ex-post and forensic studies of disasters provide a laboratory in which to study risk and disasters as well as vulnerabilities revealed (see ICSU-LAC, 2010; and Birkmann and Fernando, 2008). Disasters draw attention to how societies and socio-ecological processes are changing and acting in crises and catastrophic situations, particularly regarding the reconfiguration of access to different assets or the role of social networks and formal organisations (see Bohle, 2008). In this context, it is possible to evaluate actual disaster response processes and disaster relief and reconstruction activities and programmes, in terms of their contribution to medium- and long-term vulnerability and risk reduction as well as climate change adaptation. It is noteworthy that, until today, many post-disaster processes and strategies have failed to integrate aspects of climate change adaptation and long-term risk reduction (see Birkmann *et al.,* 2008, 2009).

In the broader context of the assessments and evaluations, it is also crucial to improve the different methodologies to measure and evaluate hazards, vulnerability and risks. The disaster risk research has paid more attention to sudden-onset hazards and disasters such as floods, droughts, storms, tsunamis, etc., and less on the measurement of creeping changes and integrating the issue of tipping points into these assessments. Therefore, the issue of measuring vulnerability and risk, in terms of quantitative and qualitative measures also remains a challenge. Lastly, the development of appropriate assessment indicators and evaluation criteria would also be strengthened, if respective goals for vulnerability reduction and climate change adaptation could be defined for specific regions, such as coastal, mountain or arid environments. Most assessments to-date have based their judgment and evaluation on a relative comparison of vulnerability levels between different social groups or regions.

The design of public policy on disaster risk management is very much related to the evaluation technique used to orient that policy. The quality of the evaluation technique, called by some as its scientific pedigree, has unsuspected influence on policy formulation. If the diagnosis invites action it is much more effective than where the results are limited to identifying the simple existence of weaknesses or failures.

The quality attributes of a risk model are represented by its *applicability*, *transparency*, *presentation,* and *legitimacy*. Respect for these attributes determines the *scientific pedigree* of a particular technique. Applicability refers to the way a model is adjusted to the evaluation problem at hand, to its reach and comprehensiveness, and the accessibility, aptitude, and level of confidence of the information required. Transparency is related to the way the problem is structured, facility of use, flexibility and adaptability, and to the level of intelligibility and comprehensiveness of the algorithm or model. Presentation relates to the transformation of the information, visualization, and understanding of the results. Finally, legitimacy is linked to the role of the analyst, control, comparison, the possibility of verification, and acceptance and consensus on the part of the evaluators and decision-makers.

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Box 2-6. Community-Based Climate Risk Assessment. [to be coordinated with chapter 5]

Examples of guidance on how to assess climate vulnerability at the community level, often with specific attention fo extreme weather and climate events, include Moench and Dixit, 2007; Van Aalst *et al.,* 2007; CARE, 2009; IISD *et al.*, 2009; Tearfund, 2009.

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Box 2-7. Risk Screening for Development Projects and Portfolios [to be coordinated with chapters 6 and 7]

A specific area of risk screening relates to development projects and portfolios. Several of these have paid specific attention to the risk of extremes (see e.g. Van Aalst and Burton, 1999, 2004; Klein, 2001; Klein *et al.,* 2007; Agrawala and van Aalst, 2008; Tanner, 2009).

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2.8.3. Risk Perception and Communication

Risk and vulnerability are preconditions for the occurrence of future disasters (Birkmann, 2006a/b). Thus risk perception and understanding the nature of disasters requires more information and communication about vulnerability factors, dynamic temporal and spatial changes of vulnerability and the coping and response capacities of societies or social-ecological systems at risk (see Turner *et al*. 2003; Cardona *et al*. 2005; Birkmann, 2006b/c; Cutter/Finch 2008 and ICSU-LAC, 2010).

What are the key factors that determine how people perceive and respond to a specific risk is a key issue for risk management and climate change adaptation effectiveness. This is the reason why it is necessary to address how people indentify and assess risk (perception of risk, whether it is real or not) – and then how to communicate this assessment to various audiences. Risk communication is a complex cross-disciplinary field that involves reaching different audiences to make a risk comprehensible, understanding and respecting audience values, predicting the audience's response to the communication, and improving awareness and collective and individual decision making. Effectiveness of risk management is based on how planners use data to design more effective risk communication programs and what theories, models, tools, and good practices exist to serve as resources for risk communication. Risk managers and practitioners must understand the affective/emotional/instinctive ways people interpret risk information in order to anticipate and account for human behaviours in planning for, responding to, or recovering from harmful events.

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Box 2-8. Lessons on Risk Perception and Communication from Early Warning Systems. [TBD]

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2.9. Risk Accumulation and the Nature of Disasters

2.9.1. Risk Accumulation

In a disaster risk context, the notion of risk accumulation describes a gradual build-up of disaster risk in specific locations, often due to a combination of processes, some persistent and/or gradual, others more erratic, often in a combination of exacerbation of inequality, marginalisation and disaster risk over time. Other underlying factors may include a decline in the regulatory services provided by ecosystems, inadequate water management, land-use changes, rural–urban migration, unplanned urban growth, the expansion of informal settlements in low- lying areas and an under-investment in drainage infrastructure. The classic example is disaster risk in urban areas in many rapidly growing cities in developing countries. In these areas, disaster risk is often very unequally distributed, with the poor facing the highest risk, for instance because they live in the most hazard-prone parts of the city, often in unplanned dense settlements with a lack of public services; lack of waste disposal may lead to blocking of drains and increases the risk of disease outbreaks when floods occur; with limited political influence to ensure government interventions to reduce risk. The accumulation of disaster risk over time may be partly caused by a string of smaller disasters due to continued exposure to small day-to-day risks in urban areas (e.g. Pelling and Wisner, 2009), aggravated by limited resources to cope and recover from disasters when they occur; clearly creating a vicious cycle of poverty and disaster risk. Analysis of disaster loss data suggests that frequent low intensity losses often highlight an accumulation of risks which will be realized when an extreme hazard event occurs (UNISDR, 2009a).

Such patterns of risk accumulation are often most effectively addressed based on a local understanding of risks of all scales. This may include better collection of sub-national disaster data that allows visualization of complex patterns of local risk (UNDP, 2004), as well as locally owned processes of risk identification and reduction. For instance, Bull-Kamanga et al. (2003) suggests that for urban disaster risk in Africa, perhaps the most important aspect of risk reduction is to support to community processes amongst most of the vulnerable populations that identify risks and set priorities – both for community action and for action by external agencies (including local governments). Such local risk assessment processes also avoid the pitfalls of planning based on government maps which rapidly going out of date due to unplanned construction.

*[***UNDP Living With Risk page 26: “Risk accumulates before being released in a disaster*
Everyday hazards and vulnerability form patterns of accumulating risk that can culminate in disaster triggered by an extreme natural hazard event. Achieving MDG 1 (to eradicate extreme poverty and hunger) and MDG 7 (to ensure environmental sustainability) will have a direct impact on reducing human vulnerability to everyday hazards and the accumulation of risk that prepares the way for disaster.”]

2.9.2. The Nature of Disasters and Barriers to Overcome

This chapter has highlighted how risk is determined not just by hazards, but importantly also by vulnerability and exposure. A better understanding of risk, including vulnerability and exposure, is essential for adaptation strategies and practices. That understanding must include not only the determinants of risk that define the nature of disasters, but also the barriers to overcome to better manage risk. These barriers are systematic and deeply engrained in the structure of society, and may include inequality, governance challenges, and adverse incentives.

Sometimes disasters themselves can be windows of opportunity for addressing the determinants of disaster risk. Physically, to not reconstruct the same exposure and vulnerability that existed before the hazard materialized, for instance in buildings and infrastructure, or the location of key settlements; and more broadly to address the underlying drivers of risk, building on the public awareness and political momentum for risk reduction to enhance community risk awareness and preparedness and increase accountability of public institutions for future disaster risk. The growing attention for adaptation as a component of development planning, including disaster risk as an integral component of the overall climate risk to be addressed, may offer an important opportunity to rationally assess and address these risks without waiting for a disaster to happen to justify appropriate investments in risk reduction.

2.10. Research Gaps

In a climate change context, analysis of exposure and vulnerability as drivers of climate risk remains an overall research gap. There has been a strong emphasis on changing climate phenomena, including hazards that may result in disasters, and to some extent in identification of actual and potential impacts. By comparison, the attention for exposure and vulnerability as drivers of changing climate risk has been very limited, especially given their importance in identifying and implementing appropriate intervention strategies.

Specifically, from a policy perspective there is strong interest in the quantification of the relative importance of trends in hazard intensity or frequency compared to trends in exposure and vulnerability as drivers of changes in risk. Beyond the general statement that trends in exposure and vulnerability are the main cause for the observed increases in disaster occurrence, this desire is likely to remain elusive for most hazards for most areas given limitation in climate information and disaster data. Another more specific interest is the quantification of the feedback loop, i.e. how strongly gradual climate change and/or the impacts of more frequent or intense disasters result in rising exposure and higher vulnerability to future hazards.

Shifting towards research gaps oriented towards risk management practice, one methodological gap is the development and application of appropriate climate risk assessment methodologies at the local level that can be rolled-out at scale and made available to a wide range of stakeholders at the local level, particularly in developing countries. In that context, a key challenge remains to couple information gathered in local risk assessments, often at the level of a specific city or even community, to national and international assessments of risk. This includes qualitative assessments to inform appropriate policy and practice, as well as quantitative assessments (including indicators) to set priorities and measure progress.

Another area of research that is underexplored in many aspects of climate risk management is decision analysis (including explicit account of different perspectives among different stakeholders). Many decision-models focus on optimizing decision-making given specific climate information, whereas there is a clear need to particularly develop approaches that focus on robust decisions given an explicit awareness of the inherent unknowns (e.g. Dessai et al., 2009). Such a perspective on risk assessment also requires new approaches for risk communication, and much research is needed to better assess effectiveness of interventions to reduce vulnerability and exposure.

Finally, a cross-cutting research gap relates to assessment of systemic risks. The rising interdependence of economies means that local disasters can have causes and implications far beyond their direct area of occurrence. A key example in a disaster context is the 2007-2008 food crisis, which was almost entirely unpredicted. It was created by a combination of many factors, including droughts and rising oil – and thus transport and fertilizer -- prices, as well as increasing use of biofuels and changing demand, especially in Asia. Supply and demand were further complicated by an international system affected by price supports and subsidies, as well as speculation. This also highlights the need for better understanding (and anticipation) of distributional effects (for instance, crop failures in one area may benefit farmers elsewhere). Assessment challenges include model limitations, especially the fact that models often record past experience rather than providing a true upstream evaluation of future risk; the fact that models often assume more or less linar relationships from hazards to outcomes and are thus inadequate to predict complex phenomena inherent in systemic risks; the fact that long-term consequences tend to be neglected; and the fact that human behavior is often the prevailing risk factor, but relatively difficult to evaluate for a wide range of possible futures (OECD, 2003). Note that systemic analysis challenges may particularly include the interaction of natural disasters with other systemic phenomena, such as pandemics (avian influenza), commodity price fluctuations, or the global financial crisis.

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Table 2-1: *Definitions of the term vulnerability as described in the literature reviewed.*

Domain	Definition of vulnerability	Author
Risk (physical)	Vulnerability is defined as the susceptibility to cause damage from an event and ability to recover from the impacts of it.	(Montz and Evans, 2001)
	Vulnerability measures the potential for damage or loss that may be inflicted to population, infrastructure and business (hazard community).	(Papathoma and Dominey-Howes, 2003)
	Vulnerability is considered to be the degree of loss from the occurrence of a hazard of a given magnitude (hazard community).	(Pielke *et al.,* 2003)
	In the context of risk management vulnerability refers to an internal risk factor for an element or group of elements that are exposed to a hazard. Vulnerability reflects the intrinsic physical, economic, social and political predisposition or susceptibility of a community to be affected by or suffer adverse effects when impacted by a dangerous physical phenomenon of natural, socio-natural or anthropogenic origin. It also signifies the lack of resilience or capacity of the community to anticipate, cope and recover.	(Cardona *et al.,* 2003)
	Vulnerability is the potential to experience adverse impacts, a measure of the damage suffered by an element at risk when affected by a hazardous process or event.	(Galli and Guzzetti, 2007)
Climate change	Vulnerability is defined here as the degree to which human and environmental systems are likely to experience harm due to a perturbation or stress.	(Luers *et al.,* 2003)
	Vulnerability as the potential for loss and distinguish between social and biophysical vulnerability.	(Brklacich and Bohle, 2006)
	Vulnerability, as defined by the IPCC, is the "degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change. It is a function of the climate-related stimuli to which a system is exposed, its sensitivity and its adaptive capacity".	(IPCC, 2007)
	Vulnerability is the likelihood that a specific coupled human–environment system will experience harm from exposure to stresses associated with alterations of societies and the environment, accounting for the process of adaptation.	(Schröter *et al.,* 2005)
Social/institutional vulnerability	Vulnerability is related to marginalisation and is described by variables such as: class, gender, age, ethnicity, access to livelihoods and resources.	(Wisner, 1993)
	Vulnerability is the result of a number of factors that increase the chance that a community will be unable to deal with an emergency. Not all sections of a community are vulnerable to hazards, but most are vulnerable to some degree.	(WHO, 1999)
	Vulnerability as a composition of lack of preparedness, weakness in coping capacity, and shortage of resilience.	(Alcantara-Ayala, 2002)
	Vulnerability as the characteristic of a person and a group and their condition that influence their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard.	(Wisner *et al.,* 2004)
	Vulnerability is a condition that depends on primarily upon a society's social order and the relative position of advantage or disadvantage that a particular group occupies within it.	(Bankoff, 2004b)
	Vulnerability describes the condition of a population that is inadequately prepared to face an extreme event and unable to	(Cannon, 2006)

	recover without external assistance.	
	Vulnerability is the pre-event, inherent characteristics or qualities of social systems that create the potential for harm.	(Cutter *et al.,* 2008b)
Integrated view	Vulnerability is the degree of susceptibility and resilience of the community and environment to hazards. The degree of loss to a given element at risk or set of such elements resulting from the occurrence of a phenomenon of a given magnitude an expressed on a scale of 0 (no damage) to 1 (total loss)	(Buckle *et al.,* 2001)
	Vulnerability as the degree of fragility of a person, a group, a community or an area towards defined hazards. Vulnerability is a set of conditions and processes resulting from physical, social, economic and environmental factors that increase the susceptibility of a community to the impact of hazards. Vulnerability also encompasses the idea of response and coping, since it is determined by the potential of a community to react and withstand a disaster.	(Kumpulainen, 2006)
	Vulnerability is a condition resulting from physical, social, economic and environmental factors or processes that increase the susceptibility of a community to the impact of a hazard.	(Arakida, 2006)
	Vulnerability is seen as the outcome of a mixture of environmental, social, cultural, institutional, and economic structures, and processes related to poverty and (health) risk, not a phenomenon related to environmental risk only.	(Brouwer *et al.,* 2007)

Table 2-2: *People exposed to and killed in disasters in low and high human development countries, respectively, as a percentage of total number of people exposed to and killed by disasters. Source: Birkmann, 2006: 174 (after Peduzzi, 2005).*

	Average exposed per year	**Average killed per year**
Low Human Development Countries	11%	53%
High Human Development Countries	15%	1.8%

Table 2-3: *Differential exposure and vulnerability of identified groups*

Dimensions	Characteristics	Sources
Gender	a) Unequal gender relations arising from patriarchal structures (xxx) can create new vulnerabilities or worsen existing ones for women and girls. b) Access to social capital is gendered (xxx) although not always suggesting a negative or limiting effect (xxx). c) Men and women have different entitlements (access to resources (Sen 1981) and abilities to reduce their vulnerability through various coping and adaption practices d) Men may be more mobile and have more opportunities to use large blocks of time on a single pursuit (perhaps livelihood activities) while women generally cannot because of their range of reproductive duties e) Women are a heterogeneous group and cannot be assumed to be equally vulnerable, everywhere and all of the time f) Gender is a cross cutting issue which can qualify all vulnerability dimensions. g) gender should be understood as an inclusive term and not simply a binary one. Groups defined/self-defining as transgender or non heterosexual are particularly invisible and under-researched and may be particularly vulnerable because of that alone	a) b) xxx c) Sen 1981 d) Eriksen, Brown and Kelly, 2005: 300-301 e) Fordham, 1998, 1999, Fordham, 2003: 64-65; Enarson and Fordham, 2001; Peacock *et al*. 1997; Fothergill, 1996 f) ISDR Words Into Action g) Wisner LA transsexuals; Pincha transgender; Gailliard xxx
Age Children	In terms of age, it is often those at the extreme ends of the age range who are identified as vulnerable (see heat/cold wave examples above). Children are often at or near the top of any list of vulnerable groups (data on why: stage of physical, intellectual and emotional development; greater surface area: body mass ratio; general lack of power and agency; but examples of their exercise of agency and risk reduction actions and potential must also be acknowledged In terms of risk groups, urban children in poverty face disproportionate risks from climate change. Children's vulnerability comes from their state of rapid development; their relative inability to deal with deprivation, stress and extreme events; their physiological immaturity; and their limited life experience. While urban children generally fare better than their rural children do, this is not the case for those living in extreme urban poverty. On the more positive side, children can also be very resilient to stresses and shocks but require adequate support and protection.	(Jabry, 2002; Wisner, 2006b). SHERIDAN BARTLETT Climate change and urban children: impacts and implications for adaptation in low- and middleincome countries Environment & Urbanization Vol 20(2): 501–519 2008
Race/Ethnicity/ Religious Associations (link to culture)	a) Hurricane Katrina – showing root causes of social vulnerability b) Evidence of differential access to relief (eg Moslems after Gujarat earthquake, other references)	a) references plus Cutter and Finch, 2008
Dis/ability		Mark Pelling contribution
Wealth/poverty	a) Vulnerability is not equal to poverty	a) Blaikie *et al*., 1994
Class/Caste	a) Guatemalan earthquake of 1976 termed a 'classquake'	a) O'Keefe *et al.,* 1976

Table 2-4: *Vulnerability indicators used in Collins and Bolin (2007)*

Indicator category	Indicator Type
Biophysical	
Groundwater access	Exempt wells overlying hard rock and outside of the basin-fill aquifer complex
Well spacing	Well density
Social	
Socio-demographic	
Population and structure	Total population Total housing units
Access to resources	Number of residents:owner/renters Number of female-headed households Number of people < age 18 Number of people > age 64
Socioeconomic status	Renter occupied housing units Mean housing unit value
Place dependency	Seasonal/recreational housing units
Water provider type	Proportion of housing units within municipal Proportion of housing units within private water provider service area Proportion of housing units with exempt wells

Indicator	Information Required	Methodologies
Exposure		
Dependence of population on groundwater	% of the population relying on groundwater for drinking and/or other purpose	Household interviews/ local statistics
Dependence of major economic sectors on groundwater	% of economic sectors in the study area relying on groundwater (e.g. agriculture, shrimp farming, bottling companies, tourism, etc.)	Desktop analysis, Interviews with land users
Ecological vulnerabilities	Major effects of groundwater depletion and pollution on natural ecosystems dependent on groundwater resources (e.g. oasis ecosystems, river basin flow systems etc.), such as change in flora and fauna, impacts on con	Literature review, Expert interviews
Well density	Location and density of groundwater wells per unit land indicate the pressure on aquifers.	Expert interviews, Desktop analysis, Household surveys
Hazard		
Groundwater quantity	Ratio of total groundwater abstraction to recharge	Secondary data; Expert interviews
Groundwater quality	Compared with country an / or WHO drinking water standards	
Sensitivity		
Groundwater vulnerability	Intrinsic vulnerability as a function of hydro-geological factors (e.g. net recharge, soil properties, topography, climate, unsaturated zone lithology and thickness, aquifer media, hydraulic conductivity and groundwater level below ground)	Secondary data; Literature review, Expert interviews
Population density	Historical data	National census data
Household structure	Number age and sex of family members and their relationships; characteristics of the household head	Household interviews/

Table 2-5: *Vulnerability archetypes, human well-being issues, responses and extreme climate events. (Modified from UNEP, 2007).*]

Archetype	**Extreme Climate Event**	**Human Well-Being Issues**	**Responses**
Contaminated Site (CS)	Impact on containment of hazardous materials by intense rainfall and floods; seepage during drought periods	Health hazards with impacts on communities living on or near CS or nations importing hazardous water for processing,	Improved laws and policies against special interests and increase participation of most vulnerable in decision making, relocation
Dry Lands	Drought	Decreasing supply of potable water, loss of productive land via desertirfication, environmental migration and ensuing conflict	Improvement of land tenure and management arrangements, provision of access to global markets.
Global commons	???	Decline or collapse of fisheries with partly gender specific poverty consequences; health consequences of air pollution and social and health consequences	Integrated regulations for fisheries, marine mammal exploitation and oil exploration; use of persistent organic compound policies for heavy metals
Securing Energy	Power outages due to heat waves, wind and ice storms, flooding of generator plants	Material well-being effects; marginalized affected by rising energy costs	Secure energy for the most vulnerable and encourage participation, foster decentralised and sustainable technology, invest in diversification of energy systems (renewables)
Small Island Developing States	Storm surge, wind storms, intense rainfall	Livelihoods of climate dependent natural resources most endangered; migration and conflict	Adapt by improving early warning; move to more climate independent economy; shift from controlling of to working with nature paradigm
Technology-centred approaches to water problems	Dam breaching by floods; drought and diversion of water to irrigation and non-domestic uses	Forced resettlement; uneven distribution of benefits from dam building; health hazards from water-borne vectors.	Stakeholder participation in decision making; dam alternatives such as small-scale solutions and green engineering
Urbanisation of the coastal fringe	Storm surge, intense rainfall and riverine/esturine flooding/landslides; heat and algal blooms	Lives and material assets endangered; poor sanitarty conditions and health impacts; unplanned coastal urbanisation in exposed areas	Implementation of Hyogo Framework of action on DRD; create opportunities for integrated coastal protection and livelihood options.

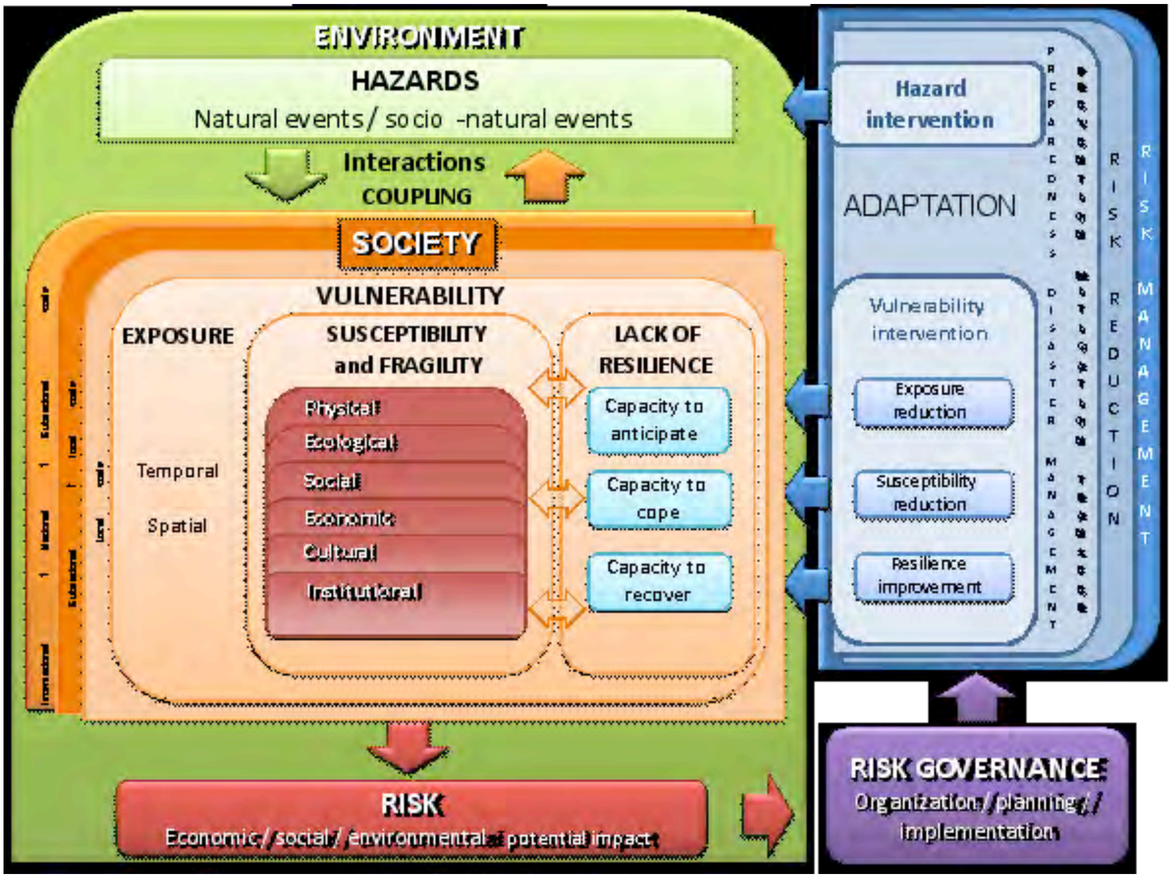

Figure 2-1: MOVE project framework on vulnerability and disaster risk assessment and management. Source: MOVE (2010).

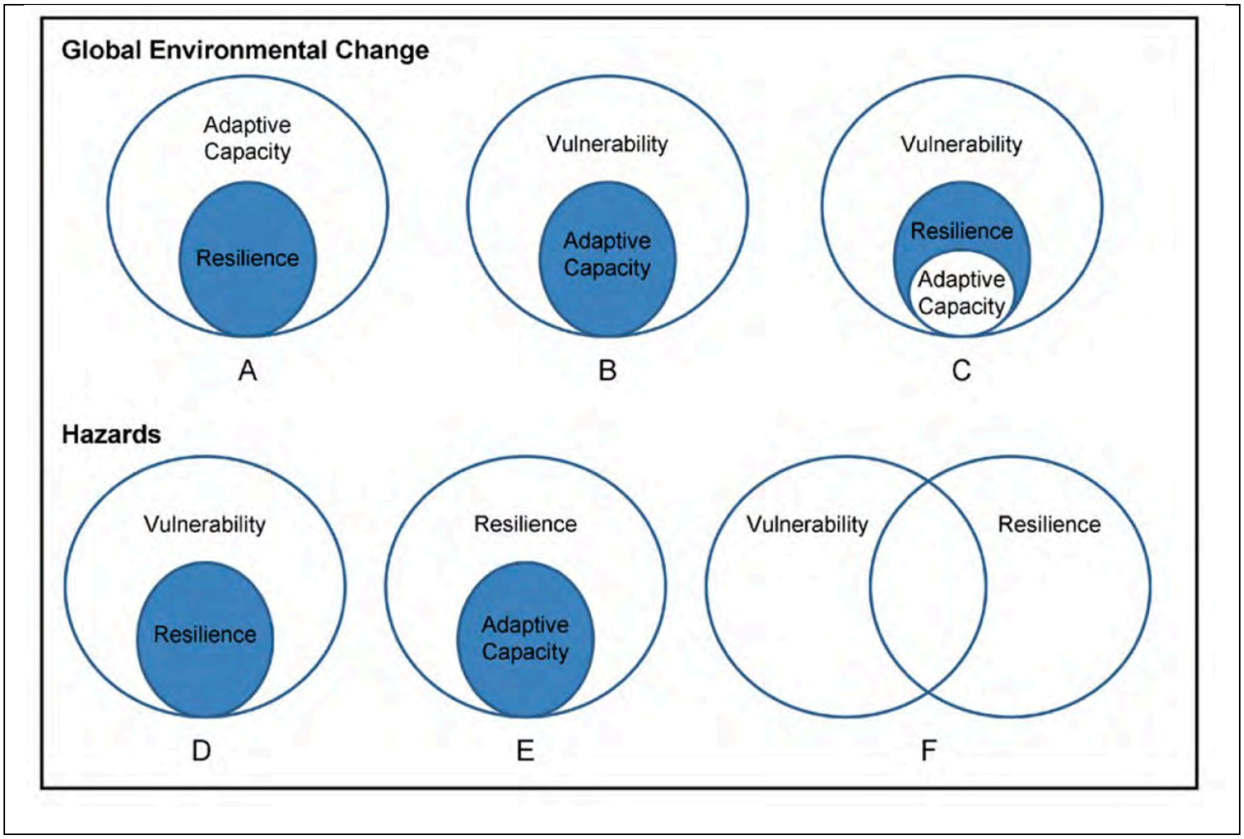

Figure 2-2: Conceptual framework relating adaptive capacity, resilience and vulnerability in the global environmental change and hazards communities of practice. Source: Cutter et al. (2008).

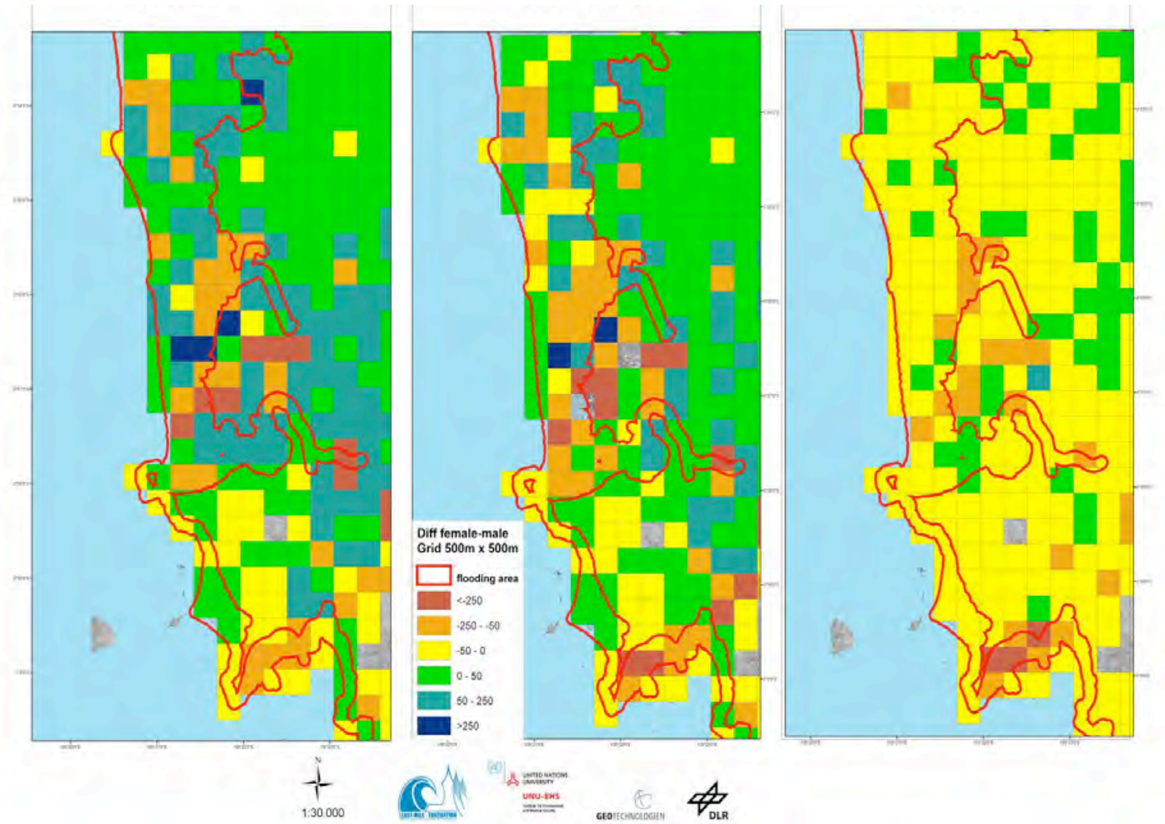

Figure 2-3: Difference between female-male population during morning, afternoon and night, for the coastal city of Padang, demonstrating differential exposure of women over time of day in the high risk zone close to the sea (Setiadi et al., 2010).

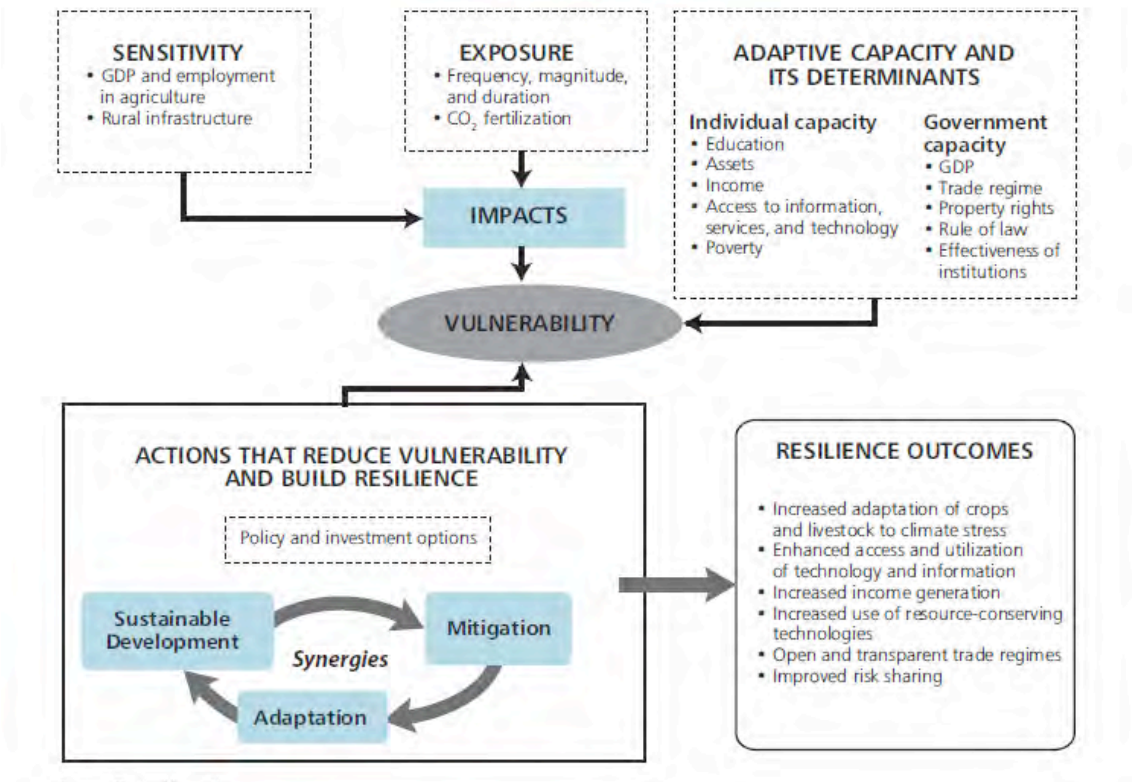

Figure 2-4: Relation between vulnerability and building resilience in the agriculture sector (ADB, 2009).

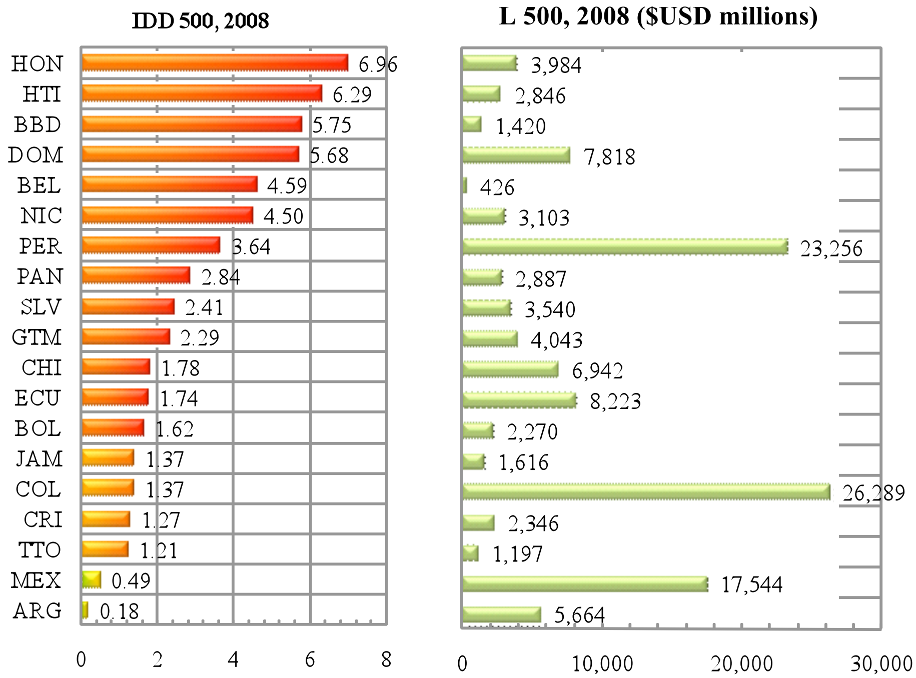

Figure 2-5: Disaster Deficit Index (DDI) and probable maximum loss in 500 years for 2008.

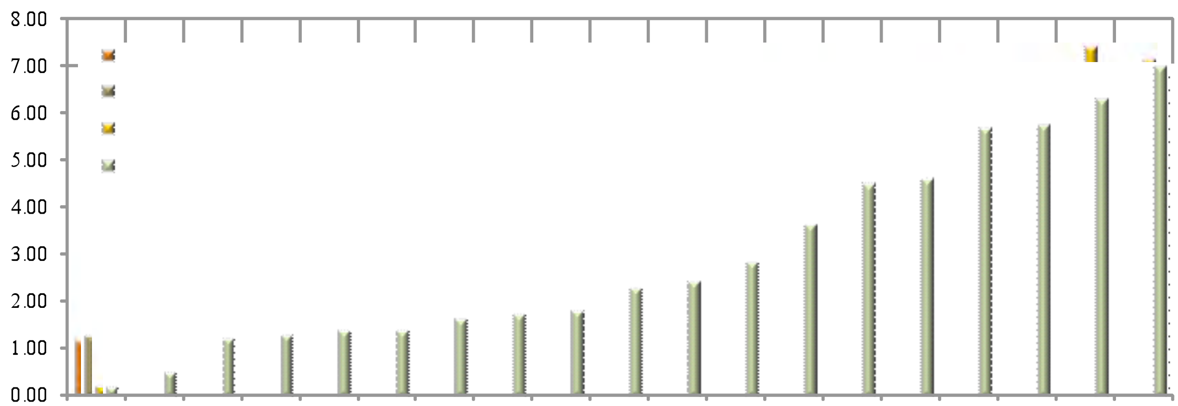

Figure 2-6: *Disaster Deficit Index (DDI) (500 years) for 19 countries of the Americas.*

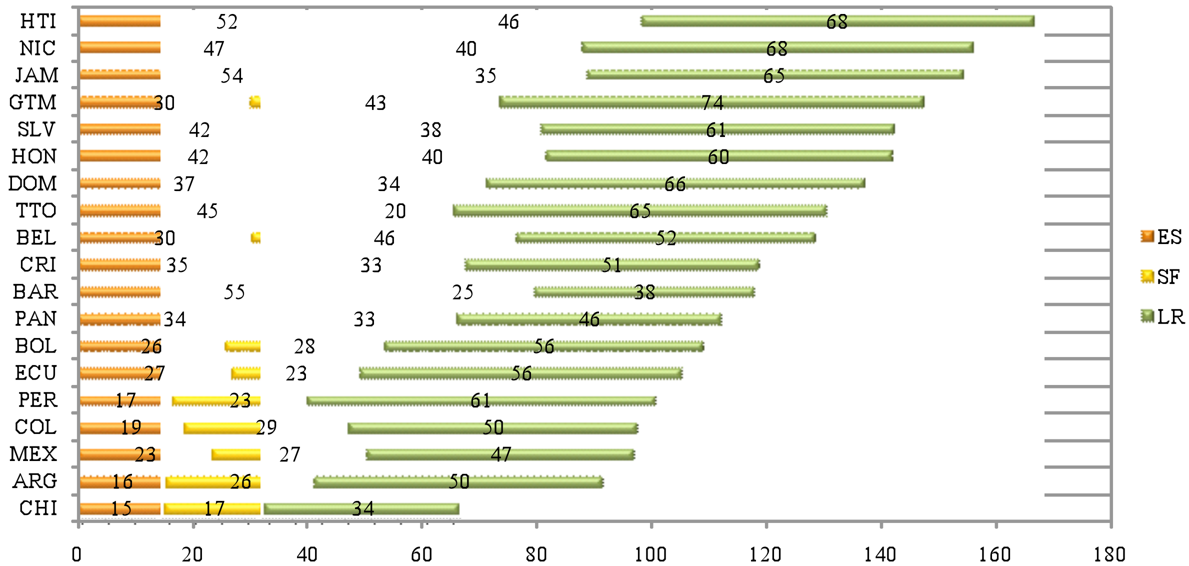

Figure 2-7: Aggregate Prevalent Vulnerability Index (PVI) for 2007.

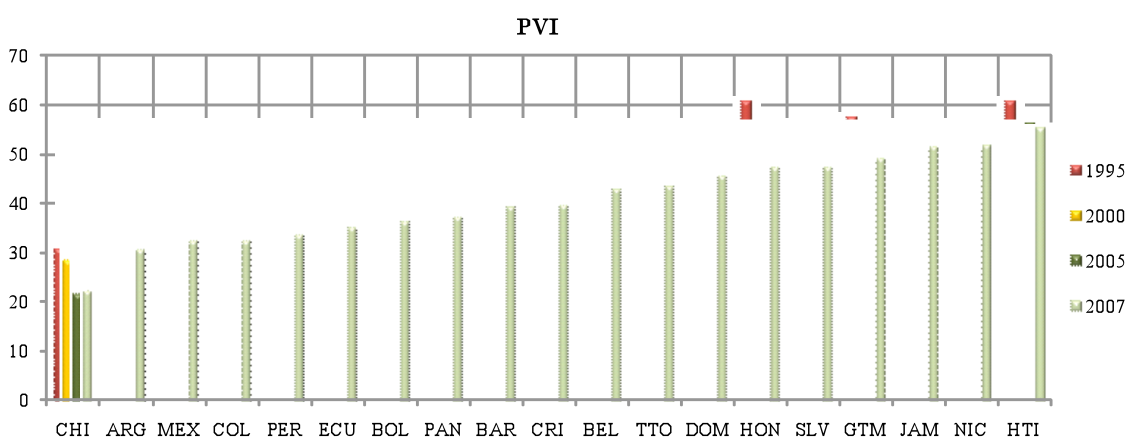

Figure 2-8: Prevalent Vulnerability Index (PVI) for 19 countries of the Americas.