Chapter 2. Determinants of Risk: Exposure and Vulnerability

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Executive Summary

Vulnerability and exposure are key determinants of disaster risk. A better understanding of risk, not only focusing on hazards but particularly also including vulnerability and exposure, is essential for the adaptation policy and practice [2.1, 2.2, 2.7, 2.8].

Adaptation and disaster risk management are rooted in the same understanding of vulnerability. Although different communities of practice and thinking on disaster risk management and adaptation to climate change label the concepts differently and emphasize different entry points for interventions, there is an agreement that causal factors of vulnerability fall into two broad categories: one focused on susceptibility/fragility to hazards and the other on lack of capacity/resilience [2.2, 2.3, 2.4].

Disaster risk is the result of the interactions of probable physical events with exposed vulnerable elements of social systems. Hazards arise when physical and biological processes interact with social processes. Manifestations of this interaction are disasters when losses of life and/or livelihoods transpire and damage to infrastructure occurs. [2.2, 2.3]

Disaster risk may be associated with differing levels of potential loss and damage, defined differently dependent on the context, e.g. the spatial scale of assessment**. Some events have limited human impact but very large financial costs or vice versa.** [2.2]

The accumulation of the effects of many small disasters may be as damaging or worse than one large disaster. Small events, often only registered at sub-national and local levels, can have chronic impacts on sustainable development, especially for the most fragile socio-economic groups. [2.9]

Vulnerability and exposure are highly context specific and dynamic, because they are driven by physical, environmental, economic, social, cultural, institutional and governance dimensions, which themselves are non-stationary. [2.2, 2.5, 2.7]

People are differently vulnerable and exposed according to characteristics such as wealth, gender, age, race/ethnicity/religion, disability and health status, and class/caste. Risk management policy and practice has often been ineffective in addressing this differential nature [2.5].

Lack of resilience and capacity to anticipate, cope with and adapt to shocks and change are important causal factors of vulnerability [2.4].

Vulnerability and exposure can be affected both positively and negatively by approaches taken to managing 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 and sustainable development. [2.2, 2.4]

There is high confidence that changes in exposure and vulnerability are the main drivers behind observed trends in disaster losses, and will be continue to be essential drivers of changes in risk patterns over the coming decades [2.1, 2.7].

Key drivers of these changes include population growth, changing demographics and health status, changing settlement patterns including urbanization, economic growth, environmental degradation, science and technology, gradual shifts in climate and its variability, as well as institutional and governance issues. Important complexities arise from feedbacks among these drivers, the accumulation and social amplification of risk, dynamic changes in vulnerabilities, and different phases of crises and disaster situations. [2.7, 2.9]

There is high confidence that climate change will affect disaster risk not only through changes in the frequency, intensity and duration of some extreme events (see chapter 3), but also through indirect effects on vulnerability and exposure, for instance through impacts on the number of people in poverty or suffering from food and water insecurity, changing disease patterns and general health levels and where people live. In some cases, these changes may be positive, but in many cases, they will be negative, especially for many groups and areas that are already among the most vulnerable. [2.7]

Comprehensive risk assessment is important for reducing vulnerability. However, there are methodological and data gaps in risk assessment that need to be filled to inform appropriate interventions (risk reduction/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, indices or probabilistic risk modelling are important tools for risk analysis and vulnerability assessment. However, no indicator or model fits all purposes, and improvements are needed to better capture dynamic aspects of vulnerability and risk, including societal response. [2.6, 2.8]

Effective disaster risk management and adaptation depends on appropriate risk communication. Impediments to information flow (bottom-up and top-down) are risk amplifiers. Effective communication of risks requires new formats of communication that deal appropriately with uncertainty and complexity. These uncertainties not only include the climate information, but particularly also current and future exposure and vulnerability. Bottom-up participatory assessment methods can help overcome some of these challenges. [2.8, 2.9]

Key research gaps include the lack of good information on vulnerability and exposure (at various scales), but also its proper use to inform robust decisions where uncertainties are high. Other areas that merit further attention include decision analysis and stakeholder engagement, characterization and quantification of indirect feedbacks between climate change and disaster risk, and assessment of systemic risks. [2.10]

2.1. Introduction and Scope

Many climate change adaptation efforts aim to address the implications of potential changes in the frequency, intensity and duration of "extreme events", with "extreme" usually defined by the nature of the impacts rather than the meteorological events themselves. To properly assess the implications of potential changes in such events, 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, there is high confidence that at least for those hazards where such analysis is available, changes in exposure and in some cases vulnerability have generally created larger and faster changes in risk than trends in climate and weather extremes due to anthropogenic climate change (e.g. Bouwer *et. al*., 2007; Pielke and Landsea, 1998; UNISDR 2009), although this comparative importance may change as climate change progresses, particularly if it reaches the upper ends of current projections for this century. However, even then, vulnerability and exposure will continue to be key determinants of aggregate risk. 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 changes in those dimensions. This chapter aims to provide that underpinning of the SREX, by further exploring the determinants of risk as presented in chapter 1, and thus demonstrating the fundamental entry points for disaster 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. 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). 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 risk management challenges 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.

Beyond analytical characterization of determinants risk, this chapter also highlights the essential role of risk perception and communication, and the importance of integration of bottom up and top down information, overcoming impediments to the flow of information across scales, and finally clarifying and communicating the risks of living in a particular location. Behind the 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.

The first sections of this chapter elucidate the concepts that help to define and understand 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 (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 more quantitative perspective on trends is provided in chapter 4). 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

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 that has not yet materialized. The social materialization of risk can be understood by thinking about risk in terms “a becoming-real” of a social construction (Beck, 2000, 2008; Adam and Van Loon, 2000). Risk can thus be defined as the possibility that an undesirable state of reality (adverse effects) will occur as a result of natural or socio-natural events (Luhmann, 1990). Hence, risk can be something measurable in probabilistic terms, what is useful for resource allocation. However, interventions can also be based on social values and preferences (Renn, 1992).

The conceptual frameworks used to understand and interpret risk as well as vulnerability and the associated terminologies have not only varied over time, but also differ according to the disciplinary perspective considered (see e.g. Cardona 2004, Birkmann 2006, Turner et al. 2003, Füssel and Klein 2006). Although researchers and professionals working on disaster risk and climate change adaptation 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 from the perspective of equity, legitimacy, sustainability, flexibility, etc. (Cardona, 2004).

Disaster risk refers to the probability of future damage and loss associated with the occurrence of hazard events (as defined in chapter 1). Risk may be associated with differing levels of potential loss and damage and may at times reach the level of a catastrophe or at others the level of a small disaster (defined differently dependent on the spatial scale); some have limited human impact but very large financial costs or vice versa (Alexander, 1993, 2000; Quarantelli, 1998; Birkmann 2006b; Marulanda *et al.,* 2008b, 2009, 2010; United Nations, 2009).

It is important to remark that the hazard event is not the sole driver of risk. The levels and types of loss are also determined by the exposure and vulnerability of society (UNDRO, 1980; Cardona, 1986, 1993; UNISDRa, 2004, 2009b; Birkmann, 2006a/b). Disaster risk is the result of the interactions in time and space of probable physical events with exposed vulnerable elements of social systems (Cuny, 1984; Davis and Wall, 1992). Through such interactions, physical events are transformed into hazards with the potential to generate future loss and damage. Disaster risk may be seen as a continuum in constant evolution and disaster one of its many “moments” or “materializations” (ICSU-LAC, 2010). Then, disasters reflect and signify unmanaged risks and may also be seen as representing unresolved development problems (Westgate *et al*., 1976; Wijkman and Timberlake, 1984).

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). Understanding disaster risk management as a social process that searches to forecast, control and reduce disaster risk drivers –such as hazard, exposure and vulnerability– in a development framework, by means of the design and implementation of appropriate policies, strategies, instruments and mechanisms (Cardona and Barbat, 2000), effective disaster risk reduction and adaptation require shift from focus on the disaster event towards understanding of disaster risk (Cardona *et al.,* 2003a). This understanding minimally requires knowledge about (ICSU-LAC, 2010):

- *Hazard*, 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.

Hazard was defined in chapter 1 and, in general, it refers 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). 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). 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 climate change are the most notable examples of socio-natural hazard phenomena (Lavell 1996, 1999a). Anthropogenic hazards include contamination of air, land and water; urban and rural fires; spills of toxic substances; rupture of dams and dykes etc. There are also biological hazards and cases of conjoint and concatenated hazards such as the NaTech events. The study of hazards typically involves the natural, earth- and applied sciences. Each hazard is characterised by its location, intensity, speed, onset and frequency.

At present the effects of climate change on frequencies and intensities of hazard events are key fields of research (ICSU-LAC, 2010). In this context hazards are related to the probability of extreme weather phenomena –such as intense tropical storms–, or of the physical impacts of climate extremes on the natural environment, especially through the local hydrology –such as a potential deficit or excess in rainfall that results in a drought or flood. Subsequently, these hazards may have impacts or adverse effects on human systems (socio-economic) or in ecosystems (environmental services) with negative implications for the society.

Exposure was also defined in chapter 1 making reference to the social and material context represented by persons, resources, infrastructure, production, goods, services and ecosystems that may be affected by a hazard event. Exposure is related to the inventory of components of society and environment that are exposed to the hazard from spatial and temporal point of view (Cardona 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, population dynamics, 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 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 (UNISDR, 2009a).

Now, as defined in chapter 1, *vulnerability* refers to the propensity of exposed elements such as human beings and their livelihoods and assets –such as buildings and infrastructure– to suffer damage and loss when impacted by single or diverse hazard events (UNDRO, 1980; Cardona, 1986, 1990, 1993; Maskrey, 1993b; Liverman, 1990; Cannon 1994, 2006; Blaikie *et al.,* 1996; Weichselgartner, 2001; UNISDR, 2004, 2009b; Birkmann, 2006b; Janssen *et al*., 2006; Thywissen, 2006). In the context of disaster risk management, the early view of vulnerability was related to the physical resistance of engineered structures (UNDHA, 1992), but at present, vulnerability is related also to other facets, factors and levels that are generally seen as a result of defined social and environmental processes. Vulnerability in the context of disaster risk management is the most palpable manifestation of the social construction of risk (Aysan, 1993; Blaikie *et al.,* 1996; Wisner *et al.,* 2004) and is related, such as in the context of climate change, to the susceptibility, sensitivity and the lack of capacities to cope and adaptation of the exposed system (Luers *et al.,* 2003; Schröter *et al.,* 2005; Brklacich and Bohle, 2006; IPCC 2001, 2007). 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 the society reactions, prioritization and decision making processes.

The term vulnerability has been employed by a large number of authors in other contexts, to make reference to the environmental fragility of ecosystems for example or by social sciences to refer to disadvantaged conditions and circumstances and drivers that make people vulnerable to natural and economic stressors (Wisner et al. 2004, Brklacich and Bohle 2006, Villagran 2006). 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 (Wisner, 1993; Bankoff 2004b). 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 (Cannon, 2006; Cutter *et al*. 2008b). 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 (Lavell, 2005). 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, ecology, poverty studies, etc). A population might be vulnerable to hurricanes, for example, but not to landslides 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*., 2003a; Lopez-Calva and Ortiz, 2008; UN, 2009). From climate change perspective basic environmental conditions are supposed to progressively change over time and then induce new conditions for societies. For example, more frequent and more intense events may induce that territories that are not for the moment at risk would be in the future, and then their respective vulnerabilities will be revealed; in fact, their future vulnerability features are embedded in present conditions of the future exposed communities (Patt *et al*., 2005; 2009). An extensive review of the terminology was carried put by Thywissen (2006) and includes a long list of definitions used for the term vulnerability.

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). This means evidence of disaster risk and the occurrence of disasters have been constantly on the rise over the last five decades. This trend could continue, may be exacerbated and be further enhanced in the future as a result of projected climate change, unless concerted actions to reduce vulnerability and adapt to the changing climate are not enacted, including corrective and prospective interventions to address disaster risks (Lavell, 1996, 1999a, 2005; see chapter 3). From the research angle, natural and applied sciences (such as engineering) provide a basic platform and understanding of environmental processes (in terms of climatology, 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).

2.3. Vulnerability from a Social Viewpoint: Causal Factors

Overall, 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 the intrinsic predisposition to being affected, as well as the lack of capacities; conditions that favour or facilitate damage and loss. Many believe that it is not possible to fully 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, 1996a/b, 2004, 2010a). 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).

Vulnerability describes a set of conditions of people that derives from the cultural, 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 (Watts and Bohle 1993, 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) 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). 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). The integration of the environmental dimension of vulnerability is other relevant issue related to causes, because considers the links between communities and specific services and the vulnerability of ecosystem components to hazards (Renaud, 2006). Lastly, from climate change point of view, 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.

Due to the diversity of approaches to address the causes of vulnerability Twigg (2001), Birkmann (2005, 2006) and Villagran (2006) give an overview of conceptual frameworks, definitions and methods to characterize 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). Füssel and Klein (2006) review the evolution of the concepts and methods of vulnerability assessment in the climate change community. 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.

In addition, Thomalla *et al.* (2006) and Mitchell and van Aalst (2009) examine commonalities and differences between the climate change adaptation and disaster risk management 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 and projected changes.

In summary, from the abovementioned efforts, four approaches to understand vulnerability and its causes can be distinguished between those that are rooted in: political economy, social-ecology, vulnerability and disaster risk assessment from a holistic view, and climate change systems science.

a) Pressure and release (PAR) model (Blaikie *et al.* 1994, 1996; Wisner *et al.* 2004) is common to social science related vulnerability research and makes emphasis on the social conditions of exposure and the root causes that generate unsafe conditions. This approach links vulnerability to unsafe conditions in a continuum of vulnerability that connects local vulnerability to wider national and global shifts in the political economy of resources and political power.
b) The social-ecology perspective emphasizes the need to focus on coupled human-environmental systems (Hewitt and Burton, 1971; Turner *et al.* 2003). This perspective stresses transformative qualities of society for nature – and also the effects of changes in the environment for social and economic systems. It argues that the exposure and susceptibility of a system can only be adequately understood if these coupling processes and interactions are addressed.
c) Holistic perspectives from vulnerability have tried to extend from technical modelling to embrace a wider and comprehensive explanation of vulnerability. These approaches differentiate as causes or factors of vulnerability the fact to be exposed, susceptibility and societal response capacities (see Cardona 1999a,b; 2001, 2010; Cardona and Hurtado 2000a,b; Cardona and Barbat 2000; Bogardi and Birkmann 2004; IDEA 2005; Birkmann 2006b; Carreño 2006; Carreño *et al.* 2007a,b, 2009; Birkmann and Fernando 2008). A core element of these approaches is the feedback-loop that underline that vulnerability is dynamic and is the main driver and determinant of current or future risk.
d) In the context of climate change adaptation vulnerability is understood as a function of exposure, sensitivity and adaptive capacities (McCarthy *et al.* 2001; Brooks, 2003; Füssel and Klein 2006; Füssel 2007; IPCC 2007; O'Brien *et al.* 2008a,b). These approaches differ from the understanding of vulnerability in the disaster risk management perspectives as the rate and magnitude of climate change is considered. The concept of vulnerability here includes external environmental factors of shock or stress. Therefore, in this view, the magnitude and frequency of potentially hazard events is to be considered in the vulnerability to climate change. This view also differs in its focus upon long-term trends and stresses rather than on current shock forecasting, something not explicitly excluded but rather rarely considered within the disaster risk management approaches.

Taking into account that the measurement of vulnerability is a challenge and using the more compatible approaches of the above mentioned frameworks the MOVE project (Methods for Improvement of Vulnerability Assessment in Europe) addresses vulnerability and disaster risk to natural and socio-natural hazards, emphasizing the association of risk assessment, risk reduction, adaptation and decisionmaking (see Figure 2-1). It provides a summary of the causal and intervention aspects associated with this holistic vision of risk and vulnerability including adaptation as a key component of disaster risk management (Birkmann et al. 2011).

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

Understanding vulnerability requires, hence, 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 also 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.

The degree of vulnerability of the society 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 specific 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 hurricane winds is not necessarily the same as in relation to 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.

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; Adger 2006, Cutter *et al.,* 2008a,b; Décamps, 2010). In any case it refers to susceptibilities or fragilities of the exposed elements; i.e. to the likelihood to be affected. Vulnerability is closely tied environmental degradation, in both urban and rural contexts. This degradation may include local effects of global climate change.

Some global processes are particularly significant drivers of risk and are particularly related to vulnerability. These include population growth, rapid and inappropriate urban development, international financial pressures, increase in socioeconomic inequalities, environmental degradation, and global warming. To take but a limited number of examples, urbanization of prone areas has been an important factor in damage; population growth 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, 1996; Glade, 2003; Wisner et al. 2004, Bradshaw et al, 2007).

At least the common causal factors of vulnerability, according to disaster risk management and climate change adaptation communities, have been differentiated as follows (Cardona, 1999a/b, 2001, 2010a; Cardona and Barbat, 2000; Cardona and Hurtado, 2000a/b; Gallopin 2006, Carreño *et al*., 2007a, 2009; McCarthy *et al.,* 2001; IPCC, 2007; ICSU-LAC, 2010; MOVE 2010):

- *Susceptibility (sensitivity)*: physical predisposition of human beings, infrastructure and environment to be affected by a dangerous phenomenon due to its lack of resistance and location (the fact to be exposed) in the area of influence of hazard.
- *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 and adaptive 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.

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 issues such as social inequalities regarding income, age or gender, as well as other characteristics of the society and the infrastructure, such as the level of urbanisation, growth rates, economic development, etc. (Cutter *et al.*, 2003).

In summary, risk understanding depends on the understanding of how vulnerability can be captured in its different dimensions and causes, and taking into account that vulnerability correlates with susceptibility (including the physical characteristics of the built environment) and the ecological, social-cultural and socio-economic fragilities. In addition, vulnerability is heavily influenced by 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 context of climate change 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 1993a; Lavell 2005, Birkmann 2006a/b).

2.4. Coping and Adaptive Capacities

Capacity is an important element in most conceptual frameworks of vulnerability and risk. It refers to the positive features of people's characteristics that may reduce the risk posed by a certain hazard. Improving capacity is often identified as the target of policies and projects, based on the notion that strengthening capacity will eventually lead to reduced risk. Capacity clearly also matters for reducing the impact of climate change (e.g., Sharma and Patwardhan, 2008).

This section discusses the role of capacity in managing and reducing risk. It introduces the different aspects of capacity, the drivers and barriers of capacity, and discusses how to move from building capacity to applying it in practice. IPCC AR4 covered elements of adaptive capacity, options and constraints (Adger et al., 2007). This section extends that discussion by focusing on the role of capacity in exposure and vulnerability reduction, and by comparing coping and adaptive capacity (as introduced in Section 1.4).

As presented in Chapter 1, coping is typically used to refer to *ex post* actions, while adaptation is normally associated with *ex ante* actions. This implies that coping capacity also refers to the ability to react to and reduce the adverse effects of experienced hazards, whereas adaptive capacity refers to the ability to anticipate and transform structure, functioning or organisation to better survive hazards (Saldaña-Zorrilla, 2007). Presence of capacity suggests that impacts will be less extreme and/or the recovery time will be shorter, but high capacity to recover does not guarantee equal levels of capacity to anticipate. In other words, the capacity to cope does not infer the capacity to adapt, although coping capacity is often considered to be part of adaptive capacity (Levina and Tirpak, 2006). This section discusses adaptive and coping capacity through this lens, to understand whether there are different requirements for enhancing each of these types of capacity.

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Box 2-1. Coping and Adaptive Capacity: Different Origins and Uses

As set out in Section 1.4, there is a difference in understanding and use of the terms coping and adapting. 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, which has a different meaning in the climate change discourse.

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. 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 (Anderson and Woodrow, 1989). 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 rather than to just overcome them. 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).

_____ END BOX 2-1 HERE _____

2.4.1. Capacity and Vulnerability

The generation of risk studies prevalent prior to the 1990s placed focus mainly on hazards, and 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 act *ex post* and *ex ante*.

Many approaches for assessing vulnerability rely on an assessment of 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 concept of capacity 'played a pivotal role in the progressive emergence of the vulnerability paradigm within the scientific realm'. On the whole, the literature describes the relationship between vulnerability and capacity in two ways, which are not mutually exclusive (Gaillard, 2010; Smit and Wandel, 2006; Brooks et al, 2005; Downing and Patwardhan, 2004; Yodmani, 2001; Moss et al 2001; IPCC TAR, 2001):

1) Vulnerability is, among other things, the result of lack of capacity; and
2) Vulnerability is the opposite of capacity, so that increasing capacity means reducing vulnerability, and high vulnerability means low capacity.

There is also the notion that there is no relationship between capacity and vulnerability. This can be explained if the factors that drive vulnerability are unrelated to the factors that drive capacity, and increasing capacity has no direct impact on vulnerability, or vulnerability can be reduced without any change in capacity.

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-capacity assessment approach (VCA) (Davis *et al*., 2004; Anderson and Woodrow, 1989). Weighing vulnerability and capacity against each other has not always been part of the process of response and recovery, however. Anderson and Woodrow (1989) 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.

2.4.2. Different Capacity Needs

Risk reduction initiatives are typically framed around using existing 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 the capacity needs for risk reduction. As the previous section has pointed out, there are *ex ante* and *ex post* capacity needs. The capacity necessary to anticipate and avoid being affected by an extreme event requires different assets, opportunities, social networks, local and external institutions from capacity to deal with impacts and recover from them (Lavell, 1994; Lavell and Franco, 1996; Cardona, 2001, 2010a; Carreño et al, 2007a/b; ICSU-LAC, 2010; MOVE 2010). Capacity to change relies on yet another set of factors. Importantly, however, these dimensions of capacity are not unrelated to each other: the ability to change is also necessary for risk reduction and response capacities.

Just like vulnerability, capacity is dynamic and will change depending on circumstances. 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 (e.g., Cutter *et al*., 2008; Marulanda *et al.,* 2008b, 2009, 2010).

The discussion in BOX 2-1 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 suggests that work done to understand the drivers of adaptive – *ex ante* – capacity (Magnan, 2010; Sharma and Patwardhan, 2008; Vincent, 2007; Yohe and Tol 2002; Brenkert and Malone 2005; Brooks et al. 2005; Haddad 2005; Leichenko and O'Brien 2002) may have little to offer regarding *ex post*. Notably, the body of literature on the drivers of coping capacity is much more limited. This section discusses capacity needs based on the differentiation made between coping and adaptive capacity, thus this section explores capacity needed to reduce risk, respond to impacts, and change. Many of these elements are reflected in local, national and international context in chapter 5, 6, and 7 of this Special Report.

2.4.2.1. Capacity to Anticipate and Reduce Risk

Having the capacity to reduce the risk posed by hazards and changes implies that people's ability to manage is not engulfed, so they are not left significantly worse off. Reducing risk means that people do not have to devote substantial resources to dealing with a hazard as it occurs, but instead have the capacity to anticipate this sort of event. This is the type of capacity that is necessary in order to adapt to climate change, and involves conscious, planned efforts to reduce risk. Anticipating hazards goes beyond warning and preparedness and includes other explicit *ex ante* risk prevention and reduction actions; i.e. daily decisions and actions to reduce both vulnerability and exposure to hazard events. The capacity to reduce risk also depends on *ex post* actions, which involve making choices after one event that reduce the impact of future events.

Risk and risk factors are always present and may be the subject of conscious human modification, reduction or control. Capacity for 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*, 2003a). This can range from guaranteeing survival to the ability to secure future livelihoods (Eriksen and Silva, 2009; Batterbury, 2001).

Development planning, including land-use and urban planning, river basin and land management, hazard-resistant building codes and landscape design are all activities that can reduce exposure and vulnerability to hazards and change (Cardona, 2001, 2010a). The ability to carry these out in an effective way is part of the capacity to reduce risk. Other activities include diversifying income sources, maintaining social networks, and collective action to avoid development that put people at higher risk (Maskrey, 1989, 1994b; Lavell, 1994, 1999b, 2005). Successful *ex ante* strategies are closely linked with sustainable development pathways that go beyond a focus on resilience and instead aim for transformation (Pelling, 2010).

Capacity to reduce risk also depends on capacity to prepare for an extreme event. This form of risk management differs from anticipatory risk prevention and reduction because it focuses on the occurrence of hazards of exceptional magnitude that are not expected on a daily basis. Preparedness includes monitoring of hazards and dissemination of information and warnings (including early warning), having emergency plans and accessible evacuation information (including maps, shelters, emergency supplies), that facilitate making rapid choices to reduce both short- and long-term impacts. Due to the uncertain nature of these events and the costs associated with *ex ante* actions, there are limits to the sort of preparedness that can be taken on the local level. In Bangladesh, for example, storm shelters have been widely successful for saving lives during cyclones, but this type of investment is not feasible for the household of village level (Cannon, 2008).

Up to the beginning of the 1990s, disaster preparedness and humanitarian response dominated disaster practice, and focus on capacity was limited to understanding inherent response capacity. Thus, emphasising capacity to reduce risk was not a priority. 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, there is an increasing recognition of the need to promote the capacity for 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 reduce 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

Capacity to respond is relevant both *ex post* and *ex ante*, since it encompasses everything necessary to be able to react once an extreme event takes place. Although response capacity is mostly used to refer to the ability of institutions to react following a natural hazard, in particular ex-post emergency response. However, effective response requires substantial ex-ante planning and investments in disaster preparedness and early warning (not only in terms of financial cost but particularly in terms of awareness raising and capacity building). Furthermore, there are also response phases for gradual changes in ecosystems or temperature regimes caused by climate change. These response phases may be longer, but still require the capacity to overcome something new, different and/or unexpected. The response phase is when people are reacting to the impacts of either a hazard event or a change in climate. During this time, people are either coping with the impacts or beginning to adjust to experienced changes, or both. In adaptation terms, this is when ‘reactive’ adaptation occurs (Smit *et al*, 2001) – both planned and spontaneous. Responding spans everything from people’s own initial reactions to a hazard upon its impact to actions to try to reduce secondary damage. It is worth noting that in climate change literature, anticipatory actions are often referred to as responses, which differs from the way this term is used in the context of disaster risk, where it only implies the actions taken once there has been an impact.

Since responding involves both affected people’s actions as well as external assistance, capacity to respond is driven by several different factors and actors, but 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 may even leave people worse off than before (DfID, 2004; Anderson and Woodrow, 1989; 1991).

Capacity to respond is not sufficient to reduce risk. Humanitarian aid and relief interventions have 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, 2006). This does not only have implications for the capacity to respond, but also for other aspects of capacity. 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 responding, rather than on the capacity to reduce risk and change. Response capacity is also differential (Chatterjee, 2010).

At the same time, optimal risk reduction will generally not eliminate risk completely (particularly for the tail end of the distribution of hazard events, where the cost of risk reduction may well be prohibitive), so the most effective ex-ante risk management strategies will often include a combination of risk reduction and enhanced capacity to respond to impacts (including smarter response by better preparedness and early warning, as well risk transfer such as insurance).

2.4.2.3. Capacity to Recover and Change

Having the capacity to change is a requirement in order to adapt to climate change. Viewing adaptation as requiring transformation, implies that it cannot be understood as only a set of actions that physically protect people from natural hazards (Pelling, 2010). In the context of natural hazards, the opportunity for changing is greatest during the recovery phase, when physical infrastructure has to be rebuilt and can be improved, and behavioural patterns and habits can be contemplated (Birkmann *et al*, 2008). This is an opportunity to rethink whether the crops planted are the most suited to the climate and whether it is worthwhile rebuilding hotels near the coast, taking into account what other sorts of environmental changes may occur in the area. The ability to recover in a more resilient way also requires capacity to recover.

Capacity to recover is not only dependent on the extent of a physical impact, but also on the extent to which society has been affected, including the ability to resume livelihood activities (Hutton and Haque, 2003). This capacity is driven by numerous factors, including mental and physical ability to recover, financial and environmental viability and political will. 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, which brings change – but not necessarily change that leads to sustainable development. 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, to markets or roads, to the sea (e.g. South and Southeast Asia after the 2004 tsunami). There are also social reasons why people return to the same location, even if they are aware of the risks. The poorer people become, the more likely that natural hazards have a lower priority than the threats of homelessness, lack of employment, illness and hunger (Hutton and Haque, 2003; Maskrey, 1994b).

Recovering to return to the conditions before a natural hazard occurs not only implies that the risk may be the same or greater, but also does not question whether the previous conditions were desirable. In fact, recovery processes are often are out of synch with the evolving process of development (Mitchell, 2008). 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). Pushing the recovery towards transformation and change requires taking a new approach rather than returning to 'normalcy'. 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, however undesirable.

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 long-term preparedness and change (Christoplos *et al*, 2010).

Traditional understandings of the capacity to recover do not implicitly or explicitly aim for change, and thus the capacity change is not an expected component of the recovery process. Recent work has shown that this paradigm needs to be rethought, because the very occurrence of a disaster shows that there are gaps in the development process (UNDP, 2005). Lessons learned from studying the impacts of the 2004 Indian Ocean tsumani (Thomalla *et al*, 2009; Thomalla *et al*, 2010) can be applied also to climate-related hazards. They 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 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.
- 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

When people repeatedly have to respond to natural hazards and changes, the capitals that sustain capacity are broken down, increasing vulnerability to hazards (Wisner and Adams, 2003; Marulanda *et al.*, 2008b, 2009, 2010; United Nations, 2009). Much work has gone into identifying what these factors of capacity are, to understand both what drives capacity as well as what acts as a barrier to it (Adger et al, 2004; Sharma and Padwardhan, 2008).

Drivers of capacity include: an integrated economy; urbanisation; information technology; attention to human rights; agricultural capacity; strong international institutions; access to insurance; class structure; life expectancy, health and well-being; 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 (Klein, 2001; Brooks et al, 2005; Barnett, 2005; Handmer et al, 1999; Cannon, 1994). Barriers to capacity include the lack of enabling drivers and determinants.

As a way of understanding the dimensions 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 it (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). Resources may be for enhancing 'the capacity and endurance of the affected people to cope with adversities' (Ahmed and Ahmad 2000: 100), but equating vulnerability with poverty creates a false association between lack of development and lack of capacity (Magnan, 2010).

Access to and the availability of financial, natural and social resources are 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 decision-making, and political feasibility.

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.

The capacity to respond through coping mechanisms may not enable adaptation, but there may be links between the factors that enable people to cope and those that allow them to adapt. While coping strategies such as selling off assets during drought can provide immediate relief – and this sense the ability to sell assets represents a degree of coping capacity – there is evidence that this will ultimately be damaging and increase vulnerability to future hazards for a number of reasons, (Corbett, 1988; Frankenberger and Golstein, 1990; Davies, 1996), thus decreasing adaptive capacity.

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. The definitions and applications of the, sometimes confounded, terms exposure and vulnerability, 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 but the distinction between them is often not made explicit.

O'Brien *et al*. (2008) contrast a hazard-centred, 'physical vulnerability' approach, emphasizing the bio-geo-physical and technological interpretations of vulnerability, with a complex interaction of biophysical, social, economic, political, institutional, technological and cultural conditions which is constitutive of a general 'social vulnerability' approach (2008: 13). 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 of conceptual obfuscation 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. Vulnerability is *implicit* in the conditions of "famine", "food insecurity" and "hunger". In these cases, vulnerability is inherent and not a predictor of a future situation; the predictors or stressors might be drought, undernutrition, or a number of other forms of deficit. The distinctions are important not only for conceptual clarity but for understanding the policy implications which otherwise may confuse a focus on symptoms with one on causes.

This section aims to be reasonably comprehensive without being exhaustive. The discussion is organized under the following main headings (with important sub-headings) to reflect major research foci but recognizing some significant overlaps:

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

The discussion begins with physical (and environmental) aspects because it is here that a major difference lies between those working primarily on climate change and those working from within the vulnerability paradigm of the disaster risk reduction community. Some in the latter group argue that it is only human beings that can be vulnerable; physical elements are simply exposed elements. For completeness, we include a discussion of the physical dimension and aim to bring out these distinctions in the process.

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 dimensions discussed here refer explicitly to a location-specific context for human–environment interaction (Smithers and Smit 1997, 131) in which 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) or exposure.

The physical *exposure* of human beings to hazards has been partly shaped by patterns of settlement on flood plains and other hazard-prone landscapes for the countervailing benefits they offer (UNISDR 2004). This does not make the inhabitants of such locations vulnerable per se because they may have capacities to resist the impacts of extreme events. 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). Physical vulnerability comprises aspects of geography, location, place (Wilbanks, 2003); settlement patterns; and physical structures (Shah, 1995; UNISDR, 2004) including infrastructure located in hazard prone areas or with deficiencies in resistance or susceptibility to damage (Wilches-Chaux 1989). 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.

2.5.1.1. 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, in the greatest number, who are 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 major distributional aspects of climate change. In a more targeted way, 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 at potential risk are threatened systems confined to narrow geographical ranges (McCarthy *et al.,* 2001) and less clearly delineated trade corridors (see the *economic* dimension below) which are extended, cross boundary regions vulnerable to the impacts of extreme events. Temperature and precipitation changes arising from climate change can be expected to have both positive and negative impacts on specific locations around the world. Such changes may lengthen the growing period (Menzel et al 2008; Christidis et al 2007) 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 developing the analysis of a generalised changed condition to a more specific 'vulnerability to hunger' in an African context.

Highly exposed 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; Nicholls 2004; Pelling and Uitto 2001). However, the point at which the disaster risk reduction literature can contribute to the understanding of the climate change adaptation community is in the recognition that the most biophysically exposed locations may not always intersect with the most vulnerable populations (Cutter *et al.,* 2000).

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; Scoones 1998).

Rapid urbanization processes have been shown to create vulnerability 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. Additionally, social isolation, especially as it intersects with individual characteristics (see Chapter 9, section 9.3.1, Case Study 9.2) and other social processes of marginalization (Duneier 2004), plays a significant role in vulnerability creation (or, conversely, reduction).

The built environment can be both protective of, and subject to, climate extremes. It is both vulnerability perpetrator and 'victim'. Inadequate structures make victims of their occupants but 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), 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 (and the wider supportive infrastructure necessary for their continued operation) 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). In a changing climate, more variable and with potentially more extreme events, old certainties about the protective ability of built structures are undermined.

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 may not be adequate for an existing rising trend in (particularly night-time) temperatures and thus will require recognition and attention in the context of longer term climate change adaptation (Shimoda, 2003). In a 1996 paper, Lavell identified eight contexts of cities that increased or contributed to disaster risk and vulnerability: the synergic nature of the city and the interdependency of its parts; the lack of redundancy in its transport, energy and drainage systems; territorial concentration of key functions and density of building and population; mislocation; social-spatial segregation; environmental degradation; lack of institutional coordination and the contrast between the city as a unified functioning system and its administrative boundaries that many times impede coordination of actions (Lavell 1996). There is utility in revisiting these in a context of climate change.

Many rural livelihoods are reliant to a considerable degree on the environment and natural resource base (Scoones 1998), and extreme climate events can impact severely on the agricultural sector (Saldaña-Zorrilla 2007). However, despite the separation here, the urban and the rural are inextricably linked. Inhabitants of rural areas are often dependent on cities for employment, as a migratory destination of last resort, and for health care and emergency services. Cities depend on rural areas for food, water, labour, ecosystem services 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). Furthermore, there is not a direct and inevitable link between disaster impact and increased impoverishment of a rural population. As Jakobsen found in Nicaragua (Jakobsen 2009), a household's probability of being poor in the years following Hurricane Mitch was not affected by whether it was living in an area struck by Mitch but by factors such as off-farm income, household size and access to credit. Successful coping post-Hurricane Mitch resulted in poor households regaining most of their assets and resisting a decline into a state of extreme poverty. However, longer-term adaptation strategies, which might have lifted them out of the poverty category, eluded the majority.

In assessing the material on exposure and vulnerability to climate extremes in urban and rural environments it is clear that there is no simple, deterministic relationship but one which is, or can be, either ameliorated or exacerbated by positive or negative adaptation processes.

2.5.2. Environmental Dimensions

The environmental dimension can include consideration of: 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); *impacts* to these systems (e.g. flooding of coastal cities and agricultural lands or forced migration); and/or the *mechanisms* causing impacts (e.g. disintegration of particular ice sheets) (Schneider *et al.,* 2007: 783; Füssel and Klein, 2006).

Maladaptive socio-ecological relations can expose people to hazards and increase their vulnerability to extreme events.

While there is valuable and necessary research on biophysical aspects alone, for the purposes of vulnerability analysis in the context of this special report, it is imperative to consider the mutuality between the environment and human beings; what has come to be called the socio-ecological system or SES (Gallopin et al 2001) approach. The SES approach grows out of a conception and an evidence base identifying fundamental errors in natural resource polices built on an assumption that human/social and environmental/ecological systems can be treated independently. This evidence base suggests that "natural and social systems behave in nonlinear ways, exhibit marked thresholds in their dynamics, and that social-ecological systems act as strongly coupled, complex and evolving integrated systems" (Folke et al 2002: 437). It points to the key links between property rights (Adger, 2000), development, environmental management, disaster reduction (e.g. Van Aalst and Burton, 2002) and climate adaptation.

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 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) (although Renaud (2006: 119-120) highlights the difficulty of accurately confirming attribution in some claims). Similarly, increasing location of housing in fire-prone areas is giving rise to greater human and property damage from San Francisco (Wisner, 1999) to Melbourne (see Box 4-2. Evolution of Climate, Exposure, and Vulnerability – The Melbourne Fires, 7 February 2009). Destruction of forest and other habitat on steep slopes exacerbates erosion of productive soils and amplifies exposure to landslide risks (Blaikie at al 1994; Glade, 2003; Wisner 2004, Bradshaw et al, 2007). The extent to which this exposure leads to or exacerbates vulnerability requires further analysis of local conditions in which some groups or locations are less able to anticipate, cope with or recover from disasters.

The vulnerabilities arising from floodplain encroachment and increased hazard exposure 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 and exposure in floodplains can put not only the lives and property of human beings at risk but can damage floodplain ecology and associated ecosystem services. Increased exposure of human beings comes about even in the face of actions designed to reduce the hazard. Structural responses and mitigation (e.g. provision of embankments, channel modification and other physical alterations 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 leads to increased flood risk and, ultimately, flood damages (see Figure 2-2). This maladaptive policy response to such exposure provides structural flood defences which encourage the belief that the flood risk has been removed. This then encourages more floodplain encroachment and a reiteration of the cycle as the flood defences (built to a lower design specification) are exceeded. This is typical of many maladaptive policy responses, which focus on the symptoms rather than the causes of poor environmental management. Any structural defence will have an exceedence probability, choices to provide protection for low consequence/return events will leave people and property at considerable risk of high consequence, extreme events.

[INSERT FIGURE 2-2 HERE:
Figure 2-2: Reactive and maladaptive policy responses: the ‘levee effect’ in floodplain hazard exposure.]

“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” (ICSU-LAC, 2009); see also Lavell, 1999a).

2.5.3. Economic Dimensions

This dimension includes economy as a *hazard* – a trigger for an extreme event (e.g. turbulence in (global) financial markets may lead to disaster for vulnerable groups); as an *outcome* of an extreme event (e.g. where an economy (at a particular scale) may be impacted by an event); and as a *condition* of vulnerability to an extreme event (e.g. where an economic system is such that it lacks resilience 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.

[INSERT TABLE 2-1 HERE:
Table 2-1: 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, 2004; Mechler, et al, 2010) and refers to the inability 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 (Mechler 2010). 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 hazards, 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 and social systems (Dudasik 1982) 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).

Paavola's (2008) analysis of livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania is indicative of the way extreme events impact livelihoods in specific ways. Here, rural households are found to be more vulnerable to climate variability and climate change than are those in urban environments. This is because rural incomes and consumption levels are significantly lower, there are greater levels of poverty, and more limited access to markets and other services. More specifically, women are made more vulnerable than men because they lack access to livelihoods other than climate-sensitive agriculture. Local people have employed a range of strategies (extensification, intensification, diversification and migration) to manage climate variability but these have sometimes had undesirable environmental outcomes, which have increased their vulnerability. In the absence of opportunities to fundamentally change their livelihood options, we see here an example of short term coping rather than long-term climate adaptation (page 651).

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 (in both wealthy and less wealthy countries) 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 often crosscutting. It encompasses aspects of several of the dimensions discussed above (e.g. that related to housing/built environment and work/livelihoods). 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 psychological trauma in and after disasters (e.g. Few, 2007), including that related to family breakdown and loss. The social dimension includes the following elements which will be elaborated below: education, health and well-being, culture, institutions, governance, including social networking and social capital/assets.

2.5.4.1. Education

The education dimension ranges across the vulnerability of educational building structures; issues related to access to education; and also sharing and access to information and knowledge (UNISDR 2006). 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 (UNDP 2004; UNICEF 2009). 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 of vulnerability includes differential health effects of extreme events 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, health service provision (e.g. environmental health and public health issues, infrastructure and conditions (Street et al., 2005)), which may be impacted by extreme events (e.g. failures in hospital/health centre building structures; inability to access health services because of storms and floods). Furthermore, mental health impacts of extreme events have been studied. For example, with flooding an association between increased risk of mental health problems has been shown in both adults and children (Aherne et al 2005, Department of Health 2009). In particular, a longitudinal study showed an eight fold increased risk of depression with pre-flood depression (Ginexi et al 2000) and a cohort study showed a four fold increased risk of psychological distress in adults at nine months post event (Reacher et al 2004). Other studies show that flooding is associated with increased rates of common mental disorders which may continue for a year or more post event (Tunstall et al, 2006, Carroll et al, 2006).

Health vulnerability is the sum of all the risk and protective factors that determine the degree to which individuals or communities could experience adverse impacts from extreme weather events (Balbus and Malina 2009). Vulnerabilities can arise from a wide range of institutional, geographic, environmental, socioeconomic, biological sensitivity, and other factors, which can vary spatially and temporally. Biological sensitivity can be associated with developmental stage (e.g. children are at increased mortality risk from diarrheal diseases); pre-existing chronic medical conditions (e.g. diabetics are at increased risk during heatwaves); acquired conditions (e.g. malaria immunity); and genetic factors (Balbus and Malina 2009). Vulnerability can be viewed from the perspective of the population groups more likely to experience adverse health outcomes, or from the perspective of the public health and health care services required to prevent adverse health impacts during and following an extreme event.

Demographic, medical, and social factors that increase vulnerability to heatwaves include age (infants, children, and older adults); gender; outdoor workers; presence of certain chronic diseases; use of particular medications; clothing choices; access to and use of cooling; urban and rural poor in developed countries; and socioeconomic factors (Basu and Ostro 2008; Bouchama et al. 2007; Kjellstrom et al. 2009; Kovats and Hajat 2008; Medina-Ramon et al. 2006; O'Neill et al. 2003; Staffoggia et al. 2006; Vandentorren et al. 2006). Heatwave vulnerability varies geographically within and between cities; key factors in one analysis that explained within city vulnerability were social and environmental vulnerability, social isolation, use of air conditioning, and proportion of the population that is elderly and/or diabetic (Reid et al. 2009). Vulnerability also varies temporally, as shown by the 2006 heatwave in Western

Europe that resulted in lower mortality than the 2003 heatwave; this difference was attributed to increased awareness, implementation of a heatwave early warning system, and better preparedness (Fouillet et al. 2008).

Population groups vulnerable to other extreme weather events depend on the adverse health outcome considered. For example, in flooding events, children are at greater risk for transmission of fecal-oral diseases, and those with mobility and cognitive constraints can be at increased risk of injuries and deaths (Ahearn et al. 2005).

Public health and health care services required for preventing adverse health impacts from an extreme weather event include surveillance and control activities for infectious diseases, access to safe water and improved sanitation, food security, maintenance of solid waste management and other critical infrastructure, maintenance of hospitals and other health care infrastructure, provision of mental health services, sufficient and safe shelter to prevent displacement, and effective early warning systems (Keim 2008). Lack of provision of these services increases population vulnerability, particularly in individuals with greater biological sensitivity to an adverse health outcome.

Extreme weather events also can result in short-term increases in population vulnerability by, for example, increasing common mental disorders and posttraumatic stress syndrome following a flooding event (Ahearn et al. 2005) – see Box 2-2 below. Flooding can also widen health and social inequalities because people on low incomes are less likely to be able to afford insurance against risks associated with flooding, such as storm and flood damage (Marmot, 2010). A UK study of over 1200 households affected by flooding suggested that there were greater impacts on physical and mental health among more vulnerable groups and poorer households and communities (Werrity et al 2007).

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.

___ START BOX 2-2 HERE _____

Box 2-2. Health Impacts Reported by Disaster Victims (Source: Norris, 2001)

Norris' 3-part review of 177 articles found a range of disaster impacts on mental health and wellbeing. The samples were coded for:
Disaster type: 62% natural disasters, 29% technological disasters, and 9% mass violence; and
Disaster location: 60% USA, 25% other developed country, 15% developing country.

Seventy-four percent of the samples showed specific psychological problems:
Posttraumatic stress or PTSD was found in 65%;
Depression or major depression disorder was found in 37%;
Anxiety or generalized anxiety disorder was found in 19%;
Non-specific distress was identified in 39%;
Health problems/concerns (e.g. self-reported somatic complaints, verified medical conditions, increased taking of sick leave, elevations in physiological indicators of stress, declines in immune functioning, sleep disruption, increased use of substances) were identified in 25%;

9% showed minimal impairment, meaning that the majority of the sample experienced only transient stress reactions;
52% showed moderate impairment (prolonged but subclinical distress);
23% showed severe impairment (25% to 49% of the sample suffered from criterion-level psychopathology); and
16% showed very severe impairment (50% or more of the sample suffered from criterion level psychopathology).

Source: Norris, F. H. 2001: 50*,000 Disaster Victims Speak: An Empirical Review of the Empirical Literature, 1981 – 2001*. Report for The National Center for PTSD and The Center for Mental Health Services (SAMHSA), September 2001. Executive Summary. http://www.dhss.mo.gov/SpecialNeedsToolkit/General/disaster-impact.pdf

____ END BOX 2-2 ___

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' a 'Safety Culture' or an "Adaptation 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. Adger has argued that if appropriate risk reduction actions are to occur the key players must bear all the costs and receive all the benefits from their actions (Adger, 2009).

Traditional behaviours tied to local (and wider) tradition and cultural practices can increase vulnerability. For example, unequal gender norms that put women and girls at greater risk or traditional uses of the environment that have not adapted (or cannot adapt) to changed environmental circumstances. On the other hand, local or indigenous knowledge can reduce vulnerabilities too (Gaillard et al 2010; Gaillard et al 2008). Furthermore, cultural practices are often subtle and may be opaque to outsiders. The early hazards paradigm literature (White, 1974; Burton, Kates and White, 1978) referred often to culturally-embedded fatalistic attitudes, which resulted in inaction in the face of disaster risk. However, Schmuck-Widmann (2000), in her social anthropological studies of char dwellers in Bangladesh, revealed how a belief that disaster occurrence and outcomes were in the hands of God did not preclude preparatory activities. Perceptions of risk (and their interpretation by others) depend on the cultural and social context (Slovic, 2000; Oppenheimer and Todorov, 2006; Schneider *et al.,* 2007).

While crude interpretations of behaviour and attitude as fatalistic have been challenged, fatalism as a social psychological construct continues to have a function. For example, empirically, in understanding risk reduction strategies by the urban poor (Wamsley 2007); methodologically, as needing to be overcome through Community Risk Assessments (van Aalst et al, 2008); and theoretically, in Cultural Theory, attempting to explain how people interpret their world and define risk according to their worldviews: hierarchical, fatalistic, individualistic, and egalitarian (Douglas and Wildavsky, 1982).

Research on culture also includes 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); the role of religion in influencing positions on environment and climate change policy (eg. Kintisch, 2006; Hulme, 2009); and religion and vulnerability (Schipper, 2010; Chester, 2005; Elliott, 2006; Guth *et al.,* 1995).

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, interests and attitudes of different social groups (see below, Cross-Cutting Dimensions and Intersectionality).

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.

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. However, as Adger and Kelly (1999) point out, the state of vulnerability is defined by a specific population at a particular scale; thus 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, and one which can be an exemplar for the way many other marginalized groups are differentially impacted or affected by extreme events, has been on gender, and on women in particular (e.g., Neal and Phillips, 1990; Enarson and Morrow, 1998; Neumayer and Plümper, 2007). 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). The specific gender and climate change link has been even more recent (e.g. Masika 2002 and see the other articles in this themed issue). The research evidence emphasises the social construction of gendered vulnerability in which women and girls are often, although not always, at greater risk of dying in disasters, typically marginalized from decision making fora, and discriminated against in post-disaster recovery and reconstruction efforts. However, 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 which obscures the very significant active contributions that women make for example. Box 2-3 provides an example of significant women-led disaster risk reduction and climate change adaptation.

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

_____ START BOX 2-3 HERE _____

Box 2-3. 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 exposed to many hazards; they belong to an ethnic group descended from African slaves which is socially, economically and politically marginalised; and they depend largely upon a subsistence economy, with a lack of education, health and other resources. However, despite these markers of vulnerability, the Garifuna women have organized to reduce their communities' exposure to hazards and vulnerability to disasters through the protection and development of their livelihood opportunities.

The women lead the Comité de Emergencia Garifuna de Honduras, which is a grassroots, community-based group of the Afro-Indigenous Garifuna that was developed in the wake of Hurricane Mitch in 1998. After Mitch, the Comité women repaired hundreds of houses, businesses and public buildings, in the process of which, women were empowered and trained in non-traditional work. They campaigned to buy land for relocating housing to safer areas, in which the poorest families participated in the reconstruction process. Since being trained themselves in vulnerability and capacity mapping by grassroots women in Jamaica, they have in turn trained 60 trainers in five Garifuna communities to carry out mapping exercises in their communities.

The Garifuna women have focused on livelihood-based activities to ensure food security by reviving and improving the production of traditional root crops, building up traditional methods of soil conservation, carrying out training in organic composting and pesticide use and creating the first Garifuna farmers' market. In collaborative efforts, sixteen towns now have established tool banks, and five have seed banks. Through reforestation, the cultivation of medicinal and artisanal plants, and the planting of wild fruit trees along the coast, they are helping to prevent erosion and reducing community vulnerability to hazards and the vagaries of climate.

The Garifuna women's approach, which combines livelihood-based recovery, disaster risk reduction and climate change adaptation, has had wide-ranging benefits. They have built up their asset base (human, social, physical, natural, financial and political), improving their communities' nutrition, incomes, natural resources, and risk management. They continue to partner with local, regional and international networks for advocacy and knowledge exchange.

_____ END BOX 2-3 HERE _____

2.5.7. Interactions and Integrations

This section began by breaking down the vulnerability concept into its constitutive dimensions, 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).]

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 group typically (with obvious exceptions such as slow onset hazards such as drought or desertification) deal with fast onset events, in discrete, even if extensive, locations, requiring immediate action. The latter group typically focuses on conditions which occur in a dispersed form over lengthy time periods and which are much more challenging in their identification and measurement (Thomalla *et al.,* 2006: 41). Risk perception may be reduced (Leiserowitz, 2006: 52) for such events remote in time and/or space, such as some climate change impacts are perceived to be. Thus, in this conceptualisation, different time scales are an important constraint when dealing with the link between disaster risk reduction and climate change adaptation (see Birkmann and 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 which 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 or 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]

2.6. Vulnerability Profiles

2.6.1 Introduction

This section looks at the characterization of vulnerability of selected sectors (using the classification in the Fourth Assessment Report, IPCC, 2007). These are intended as examples of how vulnerability, as defined by the dimensions listed in section 2.5, plays out in specific sector contexts and can be summarized in vulnerability profiles. These vulnerability profiles discussion is indicative and by no means exhaustive with regard to factors or indicators of the sectors. The section also discusses difficulties and problems with vulnerability profiling.

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 assessed. In defining such a profile, which is often applied for a specific location or issue being addressed, a description of the vulnerable situation (who, what and where) is an important first step, followed by an analysis of vulnerability factors and constraints, and finally an evaluation of opportunities, which are the positive factors that exist internally in the system or in the external environment, which could potentially contribute to an improvement in performance or resilience.

Vulnerability profiling, as part of a larger environmental profiling, thus identifies key threats and weaknesses in a sector or system. Aside from establishing qualitative and quantitative baseline information, a vulnerability profile identifies data gaps that require further research or monitoring and enhances the awareness of stakeholders. The profile is essentially the basis for developing sector strategy and conducting initial risk assessment. The data collected through profiling are also useful inputs for the establishment of an integrated information management system (KMI, 20010).

2.6.2. Agriculture and Food Security

The increases in mean temperature and a decline in precipitation rates changes, in conjunction with changes in land use that result from urbanization and agriculture, are likely to impact substantially on food production and food security (Tong, et al, 2010). The overall impact of climate change on food security will depend on the socio-economic status of each affected country and the extent of climate change in different regions.

Although the potential impacts of climate change on rainfed agriculture vis-à-vis irrigated systems are still not well understood, climate change is expected to change the pattern and quantity of rainfall; evapotranspiration, surface run-off and soil moisture storage; and water availability for irrigated agriculture and public use. These changes will affect agriculture and livestock production depending on several factors such as crop type, CO2 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 hazards, 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.

The components of vulnerability include exposure to climate change induced threats resulting to possible impacts of sea level rise and coastal flooding (e.g., saline intrusion due to sea level rise and storm surges, lowered freshwater availability, soil erosion, and land degradation); high intensity rainfall events (e.g., soil erosion, siltation and landslides); low rainfall (e.g., prolonged droughts); rise in temperature(e.g., crop heat stress and high incidence of pest and diseases). There are also vulnerability enhancing factors that may increase vulnerability to climate change such as: moving away from the use of traditional varieties of crops; loss of traditional knowledge in agriculture; loss of agricultural production due to land degradation and land use change; and threats from invasive species. Vulnerability of the agricultural community to climate change will be influenced by several socioeconomic factors, including status of poverty and food security; insecurity of land tenure; amount of resource endowed; education levels; dependency on agriculture for livelihood; availability of irrigation water; institutional supporting framework and government policies.

One way of mapping vulnerability is to use geographical information system (GIS) generated indices: exposure, sensitivity, adaptive capacity and combining them to create a composite sector-specific vulnerability index (O'Brien, 2004; Gov't of Sri Lanka, 2010)). In Box 2-4, a sector vulnerability profile for Agriculture and Fisheries sector is presented as prepared by Sri Lanka to provide additional inputs to its National Climate Change Adaptation Strategy for 2011 to 2016.

___ START BOX 2-4 HERE____

Box 2-4. Mapping Vulnerability of Agriculture and Fisheries in Sri Lanka

Exposure indices for floods, drought, and landslide) - developed based on historical data on the frequency and scale (i.e. assessed in terms of number of people affected). The index for sea level rise was based on a ratio of the area of land within 2 m above sea level as a percentage of total land area within 5 km from the coastline. Topography data was obtained from ASTER 30 m Digital Elevation Model. These exposure indices are common across all sectors. However only exposure types relevant to a given sector were analyzed and illustrated.

Examples of generated sensitivity and adaptive capacity indices, which are unique to each sector and the indicators used in their formulation, are shown below. It must be noted that the mapping exercise itself is preliminary and limited in scope, and should be refined on a periodic basis, based on detailed data which may become available from time to time from various sources.

[INSERT TABLE 2-4 HERE:
Table 2-4: Examples of generated sensitivity and adaptive capacity indices for agriculture and fisheries in Sri Lanka.]

____END BOX 2-4 HERE____

2.6.3. Human Health

Nearly all the adverse environmental and social effects of climate change will ultimately threaten human health (physical, nutritional, microbiological, or mental), as shown in Table 2-5 (Filiberto et al., 2010). Food yields, water flows, air quality, supplies of various other natural resources, and direct impacts of climate extremes all affect population health—and may all be affected by climate change.

[INSERT TABLE 2-5 HERE:
Table 2-5: Possible health threats from climate change.]

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, effects on malnutrition and air quality. 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. 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; WHO, 2010). It is projected that with climate change, the number of people suffering from death, disease and injury from heat waves, floods, storms, fires and droughts would increase (Confalonieri et al, 2007).

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 successful public health policy and practice. This capacity building will help to reduce vulnerability 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.

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. 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.

____START BOX 2-5 HERE____

Box 2-5. Vulnerability of Human Health to Climate Change and Extreme Events (Confalonieri et al., 2007)

Floods and weather disasters
Floods are low-probability, high-impact events that can overwhelm physical infrastructure and human communities. Major storm and flood disasters have occurred in the last two decades. Vulnerability to weather disasters depends on the attributes of the person at risk, including where they live and their age, as well as other social and environmental factors. High-density populations in low-lying coastal regions experience a high health burden from weather disasters.

Heatwaves
Hot days, hot nights and heatwaves have become more frequent. Heatwaves are associated with marked short-term increases in mortality. For example, in August 2003, a heatwave in Europe resulted in excess mortality in the range of 35,000 total deaths.
Heat-related morbidity and mortality is projected to increase. The health burden could be relatively small for moderate heatwaves in temperate regions, because deaths occur primarily in susceptible persons.

Drought

The effects of drought on health include deaths, malnutrition, infectious diseases and respiratory diseases. Countries within the "Meningitis Belt" in semi-arid sub-Saharan Africa experience the highest endemicity and epidemic frequency of meningococcal meningitis in Africa, although other areas in the Rift Valley, the Great Lakes, and southern Africa are also affected. The spatial distribution, intensity, and seasonality of the epidemic appear to be strongly linked to climate and environmental factors, particularly drought. The cause of this link is not fully understood.

Fires

In some regions, changes in temperature and precipitation are projected to increase the frequency and severity of fire Forest and bush fires cause burns, damage from smoke inhalation and other injuries.

____END BOX 2-5 HERE____

2.6.4. Freshwater Resources

Climate change has wide-ranging and complex impacts on water resources. These impacts have potentially huge implications on the agricultural, drinking water and energy sectors, public health, and ecosystem functionality. While this is particularly true in the regions of the world least able to cope with the impacts of climate change, the water management challenges posed by climate change will be universal. Water and how it is managed, presents one of the more significant opportunities to enhance resilience and adapt to present and future climate variability. Groundwater is one important source of freshwater and its vulnerability can be indicated in several ways as in Table 2-6.

[INSERT TABLE 2-6 HERE:
Table 2-6: Examples of vulnerability indicators for freshwater resources (Collins and Bolin, 2007).]

2.6.5. Ecosystems

Climate variability and change can directly impact on ecosystem functions and services, as already observed in the current climate regime (Tong, et al, 2010). There is a high confidence probability that the resilience of many ecosystems will be undermined by climate change, reducing biodiversity, damaging ecosystems and compromising the services that they provide (IPCC, 2007).

Climate change, variability and extremes could intensify significant influences on ecosystems and alter services (beneficial resources and processes) they provide (IPCC, 2007; MEA, 2005). While life forms have adapted to their regional climate over time, abrupt changes in climate modify the resources and processes that they provide to society, and potentially can act as a factor that affects ecosystems. For example, humans depend on ecosystems for the natural, cultural, spiritual, and recreational resources they provide. Global warming can affect biological and ecological components of the ecosystem and can create new environmental conditions for humans and other organisms by changing and disturbing ecosystem dynamics [Tong, et. al., 2010; Parmesan, et al., 2003).

The vulnerability of a specific ecosystem is a function of time and space. These are related both to different climate pressures and community responses. The ecosystems most vulnerable to climate change are likely those that are already near important thresholds due to other driving variables, which may lead 9o the so-called regime shifts (Biggs, et al., 2008). For example, the case where water use competition is already occurring, high summer water temperatures could be a limit for some species of concern; or the case where there are human-induced stressors together with climate change, such as such as limited water availability from available sources due to more urgent needs for human activities Slight shifts in climate can also alter the boundaries of terrestrial ecosystems, plant compositions, and the rate of supply of organic matter, with resulting impacts on the health of aquatic ecosystems. Marine species (individuals and populations) are affected either directly through metabolic and reproductive processes or indirectly through the ecosystem, including prey, predators, and competitors (Stenseth, et al., 2002).

Transition zones, where species compositions alter dramatically, may show the earliest evidence of change, and the changes may not be gradual. Better information is needed on which ecosystems change gradually and which may be subject to dramatic or sudden changes when a threshold is reached. Understanding these responses would enhance the detection and prediction of climate change, variability and extremes to these systems.

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.

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 neither the environment nor society are static, exposure and vulnerability vary over time, with the result that two very similar extreme weather or climate event may cause very different impacts. In some cases, this results in substantial changes in risk. In fact, there is high confidence for several hazards, changes in exposure and in some cases vulnerability are the main drivers behind observed trends in disaster losses, and will be continue to be essential drivers of changes in risk patterns over the coming decades (e.g. Bouwer *et. al.*, 2007; Pielke and Landsea, 1998; UNISDR 2009).

Chapter 4 presents detailed quantitative information about these patterns, in the context of observed and projected impacts of extreme events in light of climate change. Unfortunately, good data and analysis on observed changes in vulnerability are lacking, which complicates attribution of trends in impacts to specific underlying causes. However, there are several underlying drivers, partly along the lines of the dimensions of vulnerability and exposure discussed in section 2.5, which clearly play a role in trends in disaster risk, although differently in different places and for different levels of spatial aggregation.

This section assesses the potential for, and presents where possible, the limited evidence for secular changes in factors related to the physical, economic social, science and technology and governance dimensions of exposure and vulnerability.

2.7.2. Physical Dimensions, Settlement Patterns, and Development Trajectories

The characteristics of the places where people live and where assets are located are key attributes in the vulnerability and exposure patterns that determine disaster risk. A full treatment of aggregate trends in the environmental dimensions of exposure and vulnerability as they related to geography, location and place are given in Chapters 3 and 4. This section discussed the related underlying changes in in settlement patterns and development trajectories that drive many changes in exposure and vulnerability at local, national and global scales.

Settlements are where people gather in varying densities to live. Urbanization has been an imporatnt trend in human settlement over the last five decades. For example the percentage urban population increased in Africa and Asia from 14 to 39 and 16 to 41 percent respectively over the period 1950 to 2009. While North America and Europe was already moderately urbanised in 1950, with an urban populations of 63 and 50 percent, by 2009 this had increased to 82 and 72 percent respectively. Globally the end of the first decade of the 21st century represents an important watershed for human settlement, as in 2008 just over 50 percent of the world's population lived in urban areas. By 2050 it is predicted that the world's urban population will reach 69 percent and that most of the growth will be concentrated in urban areas in less developed regions with Asia and Africa expected to have urban dwellers making up 61 and 64 percent of their region's total population respectively. Latin America and the Caribbean already have a highly urbanised population of 79 percent but by 2050 this region is expected to reach 89 percent, comparable to the 90 percent urban population expected for North America (United Nations, 2010).

Urbanization is of concern to disaster risk management and adaptation because of its implications for exposure and vulnerability. For a variety of reasons, extreme events can cause a large loss of life or livelihoods when these events occur in places with high concentrations of people (Guha-Sapir, D. et al., 2004). The devastating impacts of Hurricane Mitch in Central America in 1998 and Hurricane Katrina in 2005 are clear demonstrations of how settlements in developing and developed countries located in hazardous locations are highly vulnerable to acute extreme storm and flood events (Fungfeld, 2010). The 2009 Melbourne heat wave provides a lucid example of how a pervasive meteorological event can impact a heavy toll on life and infrastructure in a large city which was thought to have a relatively good level of preparedness for extreme climate events (QUT, 2010).

On the other hand, the spatial concentration of people might also allow for improved capacities to cope and to adapt. Cross (2001) argues that small cities and rural communities are more vulnerable to disasters than big cities or megacities, since megacities have considerable resources for dealing with hazards and disasters. For that reason, contrary to what is often assumed, urbanization is not always a driver for increased vulnerability. Instead, the type of urbanization and the context in which urbanization is embedded defines whether these processes contribute to an increase or decrease in people's vulnerability to natural hazards and changing environmental conditions.

In particular, vulnerability often increases in the case of informal urban settlements where poor people are concentrated and do not get access to service provision and basic needs, such as clean water. Also settlements that are located in areas prone to hydrometeorological hazards such as flood plains, low lying coastal zones and steep slopes are highly exposed and often a point where marginalized groups have to migrate to due to a lack of alternative locations or the fact that areas close to river systems or areas at the coast line are often state land that can be accessed compared to private land.

In addition, the rapid growth and expansion in those cities often leads to a loss of governability and a reduction in the capacity of formal players to steer developments and adaptation initiatives in a comprehensive, preventive and inclusive way. Particularly, the lack of service provision with respect, for example, sewage systems or effective transportation means for emergency response contribute among other factors to an increasing vulnerability to climate change impacts (see Birkmann et al. 2010)

Furthermore, in some regions the population that determines the major increase in urban population appears to be refugee populations. In 2009 the percentage of urban based refugees had reached 58 percent almost twice that living in camps and 8 percent higher than 2007 when for the first time refugees living in urban centres outnumbered those in non-urban areas (UNHCR, 2009).

While the rates of urbanisation are expected to slow in the developed world over the next 40 years, in the developing world total population growth will become largely an urban phenomenon (Satterthwaite, 2007). This has implications for possible trends in vulnerability and exposure as increasing numbers of people concentrate in existing urban centres built on flood plains and low coastal zones and marginal land where good land and infrastructure availability is restricted. Rapidly growing urban populations may also affect the capacity of developing countries to cope with the effects of extreme events because of the ability of governments to provide the requisite urban infrastructure and for citizens to pay for essential services (UN Habitat, 2009). This may be especially so for urban centres with less than one million population as these are expected to account for 63 and 54 percent of the increase in urban population between 2009 and 2025 in more developed and less developed regions respectively and are often of lower priority for government spending. This contrasts with mega-cities as between 2009 and 2025 they are expected to account for only 3 and 14 percent of the total urban population growth in more developed and less developed regions receptively (United Nations, 2010).

Associated with burgeoning urban populations are changes in urban form. As yet there has not been a systematic empirically based assessment of the implications of rapidly changing urban form for trends in exposure and vulnerability. However the potential for the disproportionate concentration of people in the region's largest cities and the trend to increasing levels of informal, unserviced and unregulated peri-urbanisation as found for Sub-Saharan urban centres and the relocation of people, industry and services to the urban periphery and associated rising cost of infrastructure and service delivery as found in many Latin Amercan cities (UN Habitat, 2010) might lead to temporal and spatial trends in exposure and vulnerability. Such trends may emerge due to highly differentiated urban landscapes in terms of exposure because of the location of dwellings/settlements in hazardous locations and the loss of ecosystems services arising from land use change and vulnerability due to social inequalities because of highly spatially differentiated infrastructure and service delivery all of which coalesce to raise the level of risk due to extreme climate events.

A number of country development trajectories have been identified (United Nations, 2009), namely high economic growth and high human development, neither high economic growth nor high human development and high growth in either economic or human development terms but not the other. The extent to which such trajectories have influenced historical trends in exposure and vulnerability have as yet not been assessed and room remains for a systematic research agenda on this potential association.

Globally the pressure for urban areas to expand onto flood plains and coastal strips has resulted in an increase in exposure of populations to riverine and coastal flood risk (Feyen et al., 2009; McGanathan et al., 2007; Nichols et al., 2008). For example intensive and unplanned human settlements in flood-prone areas appear to have played a major role in increasing flood risk in Africa over the last few decades (Di Baldassarre et al., 2010). As urban areas have expanded urban heat has become a management and health issue (see heat wave case study Chapter 9). There is strong observational evidence for increases in urban warming for some major cities and thus exposure of populations to extreme urban heat events (Fujibe, 2009; Kataoka et al., 2009; Stone 2007). 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) due to 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. Such changes in green space may increase exposure to extreme climate events in urban areas through decreasing runoff amelioration and urban heat island mitigation effects and alterations in biodiversity (Wilby and Perry, 2006).

Associated with rapid urbanisation are increases in the number and extent of informal settlements or slums (UN Habitat, 2003; Utzinger and Keiser, 2006) which are often located on marginal land within cities or on the periphery. Because of their location, slums are often exposed to hydrometeorological related hazards such as landslides (Nathan, 2008) and floods (Aragon-Durand, 2007; Bertoni, 2006; Colten, 2006; Douglas et al., 2008; Zahran et al., 2008). Vulnerability in informal settlements can also be elevated because of poor health (Sclar et al., 2005) and livelihood insecurity (Kantor and Nair, 2005). Lagos Nigeria (Adelekan, 2010) and Chittagong, Bangladesh (Rahman et al., 2010) serve as clear examples of where an upward trend in the area of slums has resulted in an increase in the exposure of slum dwellers to flooding. Despite the fact that rapid growing informal and poor urban areas are hotspots of vulnerability, it has to be acknowledged that also various urban poor have developed more or less successful coping and adaptation strategies to deal with changing environmental conditions (see e.g. Birkmann et al. 2010).

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 (Roth and Coelho, 2007). Alterations or trends in any of these components of the urban system, such as environmental governance or the percentage of people living in the low elevation coastal zone, could bring about changes in vulnerability and exposure. 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 exposure and vulnerability to extreme climate events substantially (Freudenberg et al., 2008). Similarly the continued reliance on insurance products as an adaptive strategy for managing urban flood risk 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).

2.7.3. 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).

Generally positive drivers are decreasing reliance of many developing economies on agriculture, which tends to be most sensitive to the impacts of extremes. However, narrow economic development paths focusing on a relatively limited range of economic activities may continue to result in relatively high vulnerability to shocks.

Finally, it should be noted that economic development is often resulting in an increasing reliance on critical infrastructure, such as power supply. Where this infrastructure is at risk of natural hazards, it may have large impacts on the functioning of economies as a whole.

2.7.4. Social Dimensions

2.7.4.1. Demography

Certain population groups may, in a relative sense, be more vulnerable than others to extreme climate events. For example, the very young and old are more vulnerable to heat than other population groups (Staffogia et al., 2006). Europe, where heat waves are a characteristic of the climate and the majority of heat related deaths occur amongst the elderly (Gosling et al., 2009), posseses one of the most rapidly aging populations with 16 percent of the population 65 or over in 2009 with this projected to increase to 37 percent in 2050 (United Nations, 2009b). Such a trend might lead to an increase in the pool of individuals susceptible to heat. The trend to an aging population is not restricted to Europe as the population of most countries is aging, Currently the percentage of people more than 60 years is higher in more developed compared to less developed countries; 20 compared with 8 percent. By 2050 it is expected that the percentage of older people will increase to 33 and 20 percent in more developed and less developed countries respectively. Although there is little evidence in the literature of concomitant secular changes in aging and vulnerability a rapidly aging population at the community to country scale bears implications for health, social isolation, economic growth, family composition and mobility all of which are social determinants of vulnerability.

Conceptually, trends in migration as a component of changing population dynamics could arise because of alterations in extreme climate event frequency. However because of the multi-causal nature of migration the role of climatic variability and change in migration is often contested (Black, 2001) as are the terms environmental refugee and climate refuges (Myers, 1993; Castles 2002, IOM, 2009). The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and the Internal Displacement Monitoring Centre (IDMC) have estimated that 20,293,413 people were displaced or evacuated in 2008 because of climate-related disasters. (OCHA/IDMC, 2009). Further over the last 30 years, twice as many people have been affected by droughts as by storms (1.6 billion compared with approximately 718 million) (IOM, 2009). Despite an increase in the number of hydrometeorological disasters between 1990 and 2009, the International Organisation on Migration reports no major impact on international migratory flows because displacement is temporary and often confined within a region, plus displaced individuals do not possess the financial resources to migrate (IOM, 2009). Although there is also a lack of clear evidence for a systematic concomitant trend in extreme climate events and migration, there are clear instances of the impact of extreme hydrometerological events on displacement. For example floods in Mozambique displaced 200,000 people in 2001, 163,000 people in 2007 and 102,000 more in 2008 (INGC, 2009; IOM, 2009), in Niger large internal movements of people are due to pervasive changes related to drought and desertification trends (Afifi, 2010), in the Mekong River Delta region changing flood patterns appear to be associated with migratory movements (IOM, 2009; White, 2002) and Hurricane Katrina for which social vulnerability, race and class played an important role in outward and returning migration (Elliot and Pais, 2006; Landry et al., 2007; Meyers et al., 2008) resulted in the displacement of in excess of one million people. As well as the displacement effect there appears to be evidence for increased vulnerability to extreme events amongst migrant groups because of an inability to understand extreme event related information due to language problems, prioritisation of finding employment and housing and distrust of authorities tends (Donner and Rodriguez, 2008; Enarson and Morrow, 2000).

Although gender, race and class have been found to be important in determining vulnerability and the modification of risk to extreme climate events (Enarson and Fordham, 2001; Rodriguez and Russell, 2006), there is little evidence in the literature for secular vulnerability trends related to these social factors.

2.7.4.2. Education

As outlined in Section 2.5.4.1 the education dimension refers to educational building structures, access to education, natural hazards in the education curriculum and access to information and knowledge. In many disasters due to extreme events a major component that constituted the disaster was a lack of appropriate information and education. Where flooding is a recurrent phenomenon schools can be at risk to exposure to floods. For example a survey of primary schools' flood vulnerability in the Nyando River catchment western Kenya, revealed that 40% were vulnerable, 48% were marginally vulnerable and 12% were not vulnerable with vulnerability due to a lack of funds, poor building standards, local topography, soil types and inadequate drainage (Ocola et al., 2010). Although this study does not provide an assessment of trends in exposure or vulnerability, by considering changing flood frequency or the historical deterioration of buildings, in terms of the published peer reviewed literature, it is quite rare. This is indicative of the lack of information on trends in exposure and vulnerability of educational structures. The same applies to trends in access to education as might arise from school closures related to any observed increase in extreme weather event frequency.

Over the last 20 to 30 years there has been a trend in some countries towards incorporating environmental education into educational curricular at a variety of levels (Filho, 1996). Although the curricular content may not explicitly relate to extreme climate events, vulnerability and exposure 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.

Access to information related to early warnings, response strategies, coping mechanisms, science and technology, human, social and financial capital is critical for reduction of vulnerability and increasing 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) and belonging to a social network (Peguero, 2006). However there are no systematic studies on how these factors may have varied historically and thus given rise to any trends in exposure and vulnerability. Some evidence exists that people who have experiences natural hazards before are in general better prepared than those who have not. Thus information and experiences of hazards are a key factor that differenciates vulnerability in developing and developed countries. Furthermore, there is emerging evidence of a growing digital divide (Critcuer and Zook, 2009; Rideout, 2003) which may influence trends in vulnerability as an increasing amount of information about extreme event preparedness and response is often made available via the internet.

2.7.4.3. 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) may affect vulnerability and exposure to extreme events. Although there is little evidence for trends in the exposure or vulnerability of public health infrastructure the imperative for a resilient health infrastructure is widely recognised in the context of extreme climate events (Burkle and Greenough, 2008; De Salvo et al., 2008).

For some health outcomes, which have direct or indirect implications for vulnerability to extreme climate events, there is evidence of trends. For example obesity, a risk factor for cardiovascular disease, which in turn is a heat risk factor, has been noted to be on the increase in a number of developed countries (Skelton et al., 2009; Stamtakis et al., 2010). Observed trends in major public health threats such as the infectious or communicable diseases HIV/AIDS, tuberculosis and malaria, although not directly linked to the diminution of long term resilience of some populations, have been identified as having the potential to do so (IFRC, 2008). 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 as observed in some countries (Vitoria et al., 2009) may also contribute indirectly to increasing vulnerability and exposure 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; see also chapter 3) 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. Additionally, deteriorating environmental conditions and the degradation of environmental services and goods is particularly problematic for rural poor and rural communities which have often a direct dependency on ecological resources, such as clean water for drinking and farming (see Renaud 2006). Globally, particularly communities in low-laying coastal areas will suffer from salinization processes that will affect the availability or degradation of the access to clean water for drinking and farming. These trends are already observable e.g. in the Mekong Delta. Furthermore, the salinization has also a direct negative effect on the productive function of soils, thus ecosystem services are vulnerable to climate change.

2.7.5. Science and Technology

Over the last few decades there have been rapid advancements in science and technology especially in the agricultural sector. These have been functional in increasing food production, decreasing food prices and reducing famine. However a the beneficiaries of science and technology development are often unequally in distributed 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 science and technology transfer is required, the success of which will dependent on the ability of the recipient community to apply the transferred science and technology (Gisselquist et al., 2002; (IAASTD, 2009).

Although approaches alternative to pure science and technology based ones have been suggested for decreasing vulnerability (Haque and Etkin, 2007; Marshall and Picou, 2008), such as blending western science and technology with indigenous knowledge (Mercer et al., 2010) and ecological cautiousness and the creation of eco-technologies with a pro-nature, pro-poor and pro-women orientation (Kesavan and Swaminathan, 2006) there has not been any systematic scientific assessment of their efficacy to date.

The increasing integration of a range of emerging weather and climate forecasting products into early warning systems has helped reduce exposure to extreme climate events because of an increasing improvement of forecast skill over a range of time scales (Barnston et al., 2010; Goddard et al., 2009; Stockdale et al., 2009; van Aalst, 2009). Moreover, there is an increasing use of weather and climate information for planning and climate risk management in business (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).

2.7.6. Governance

Governance is also a key topic for vulnerability and exposure. Governance is broader than governmental actions, governance can be understood as the structures of common governance arrangements and processes of steering and coordination – including markets, hierarchies, networks and communities (Pierre and Peters 2000). Institutionalized rule systems and habitulized behaviour and norms that govern society and guide actors are representing governance structures (Ostrom 2005, Adger 2000, Biermann et al. 2009). These formal and informal governance structures are also determine vulnerability, since they influence power relations, risk perceptions and constitute the context in which vulnerability, risk reduction and adaptation are managed.

Particularly conflicts between formal and informal governance strategies and norms can generate additional vulnerabilities for communities exposed to environmental change. An example of these conflicts of formal and informal strategies is linked to flood protection measures. While local people might spend various resources to deal with increasing flood events in terms of adapting their livelihoods and production patterns to changing flood regimes, formal adaptation strategies in some countries particularly in so called developing countries are prioritizing structural measures, such as dyke systems or relocation strategies, that have severe consequences for the vulnerability of local communities depending on local ecosystem services, such as fishing and framing systems (see Birkmann 2011). These conflicts between formal and informal management and norm systems are an important factor that increases vulnerability and reduces adaptive capacity of the overall system (see e.g. Birkmann et al. 2010).

Increases in state governance deficits and respective implications for the vulnerability of people in these countries can also be assessed using performance indicators for governance policies and governance issues linked to the social, political and economic dimension of governance. At the international level governance issues can be described and measures examining governance problems, such as corruption or the progressive deterioration of public service provision or the widespread violation of human rights.

Countries classified as failed or fragile states often lack the capacity to deal with emergencies and disasters effectively due to governance problems. The recent disaster and problems in coping and recovery in the aftermath of the Earthquake in Haiti or the problems in terms of managing recovery and emergency management after the Pakistan floods are examples that illustrate the importance of governance as a subject of vulnerability.

Although it is still difficult to evaluate governance deficits at the international level, recent studies such as the Corruption Perception Index (CPI) published by Transparency International or the Failed States Index (FSI) published by Foreign Policy and Fund for Peace underline that in many countries heavily affected by natural hazards governance problems are likely to increase the vulnerability of people at risk. Despite the fact that trends are difficult to analyze, the examination of governance problems, linked to social indicators, such as mounting demographic pressures, massive movement of refugees or IDPs creating complex humanitarian emergencies, legacy of vengeance-seeking group grievance or group paranoia, chronic and sustained human flight, and secondly economic indicators, such as uneven economic development along group lines, sharp and/or severe economic decline and thirdly political indicators such as criminalization and/or delegitimization of the State, progressive deterioration of public services, suspension or arbitrary application of the rule of law and widespread violation of human rights are key factors that show the context in which the vulnerability of individuals is embedded and underlines the lack of these countries to provide services that can help to reduce vulnerability and increase resilience, particularly of the poorest communities and groups.

Moreover, the World Bank has been issuing Worldwide Governance Indicators on an annual basis since 1996 distinguishing six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption all of which are "useful for broad cross-country and over-time comparisons of governance"(Kaufmann et al. 2009). These indicators show for example a significant decline comparing voice and accountability and political stability of 1998 and 2008 in Thailand, whereas most of the Eastern European States show a positive development. That means positive and negative trends in governance at state level can be measured and assess. The Index shows for example for the dimension "Political Stability/ Absence of Violence" that the trends in Nepal, Pakistan, Zimbabwe, Philipines and Nigeria are rather showing an increase in problems linked to political stability and violence, while in countries such as Angola, South Africa and Armenia these trends have taken a more positive development towards an improved level of political stability and absence of violence. However, it has also to be noted that the absolute values are important for the interpretation, that means countries which has a significant deficit in political stability in 1998 – such as Angola – increase their performance, however, they are still on a low level of political stability and still need to improve on problems related to violence (see Kaufmann et al. 2009., p. 33).

In some developed countries, the last 30 years have witnessed a shift in environmental governance practices towards more integrated approaches. For example EU environmental policy has transitioned from the use of remedial measures in the 1970s, to end of pipe pollution reduction strategies in the 1980s followed by integrated pollution prevention and control in the 1990s. With the turn of the century there has been recognition of the need to move beyond technical solutions and to deal with the patterns and drivers of unsustainable demand and consumption. This has resulted in the emergence of a more integrated approach to environmental management, a focus on prevention (UNEP, 2007), the incorporation of knowledge from the local to global in environment policies (Karlsson, 2007) and co-management and involvement of stakeholders from all sectors in the management of natural resources (McConnell, 2008; Plummer 2006) although some issues associated with the efficacy of this new paradigm have been identified (Armitage et al., 2007; Sandstrom, 2009).

In the specific areas of environmental health and water there are clear indications in some countries of a transition to more integrated, differentiated and collaborative approaches to environmental health risk and water resource management (Memon et al., 2010; Runhaar et al., 2010). As a response to changes in ecological systems there also appears to be evidence for the development of new governance structures for tackling global pandemic diseases, the management of marine resources and the possible advent of migration related to environmental changes (Duit et al., 2010) as well as a the recognition that socio-ecological changes require long-term policy solutions, are embedded in complex systems and require more than single best effort solutions because they are linked to a wide range of human activities (Underdal, 2010). Despite the potential for such trends in governance to moderate environmental risk, empirical analyses and evaluations of the impacts of environmental governance changes on bringing about historical changes in exposure and vulnerability to extreme climate events is scarce, although there are local highly specific success stories (see Section 2.4). This may well be due to the time lag between policy implementation and effect which often extends beyond one human generation (Underdal, 2010).

2.7.7. Influence of Gradual Climate Change

There is high confidence that climate change will affect disaster risk not only through changes in the frequency, intensity and duration of some extreme events (see chapter 3), but also through indirect effects on vulnerability and exposure. In most cases, it will do so not in isolation but as one of many sources of possible stress, for instance through impacts on the number of people in poverty or suffering from food and water insecurity, changing disease patterns and general health levels and where people live. In some cases, these changes may be positive, but in many cases, they will be negative, especially for many groups and areas that are already among the most vulnerable. While there is high confidence that these connections exist, current knowledge does not allow us to provide specific quantifications.

Table 2-7 identifies several observed and projected climate change impacts identified in the Fourth Assessment Report (AR4) (IPCC, 2007) that affect vulnerability and exposure. Given the highly differential nature of vulnerability and exposure, these effects will be different from place to place and person to person. However, as pointed out in the AR4, the most vulnerable groups are likely to be affected the worst by these changes, and consequently suffer the largest increases in exposure and vulnerability to extreme events.

[INSERT TABLE 2-7 HERE:
Table 2-7: Examples of observed and projected climate change impacts identified in the Fourth Assessment Report (AR4) (IPCC, 2007) that affect vulnerability and exposure.]

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.

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

- Risk identification (involving individual perception, social interpretation, and evaluation of risk)
- Risk reduction (which involves prevention and mitigation –of hazard or 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).

For all interventions, these should be followed by a final assessment step of continuous evaluation of actions taken to manage the risks.

The first three actions are mainly *ex ante*; i.e. they take place in advance of disaster, and the fourth refers mainly to *ex post* actions, although preparedness and early warning do require *ex-ante* planning. 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; 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 more risk-aware behavior and decisions 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.
- Knowledge of adaptive capacity status and limitations

(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 2005; and Kasperson *et al*. 2005)

In addition, in order to arrive at appropriate risk governance, especially in context of changing risks, effective communication about risk is essential (van Sluis and van Aalst 2006; ICSU-LAC 2010). 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.

2.8.2. Vulnerability and Risk Assessment

Risk analysis was an issue of interest in Babylonian times already. 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 (as discussed in Box 2-6) (see IDEA, 2005; Cardona, 2006; Birkmann, 2006a; Wisner, 2006a; IFRC, 2008; Dilley, 2006; and Peduzzi *et al.,* 2009).

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Box 2-6. Community-Based Participatory Climate Risk Assessment

Risk assessment at the local level presents specific challenges related to a lack of data (including climate data at sufficient resolution, but also socio-economic data at the lowest levels of aggregation) but also the highly complex and dynamic interplay between the capacities of the communities (and the way they are distributed among community members, including their power relationships) and the challenges they face (including both persistent and acute aspects of vulnerability).

Local people often have a much more sophisticated insight into many of these determinants of risk than outsiders, even when those outsiders have access to much more advanced modelling tools that allow deeper insight into the hazards facing the location. For effective risk management, risk assessment must be locally-based and lead to not only understanding but also a sense of local ownership of the diagnosis and the options that may be employed to address the risks. Several participatory risk assessment methods, often based on participatory rural appraisal methods, have been adjusted to explicitly address changing risks in a changing climate. Examples of such guidance on how to assess climate vulnerability at the community level include Willows and Connell, 2003; Moench and Dixit, 2007; Van Aalst *et al.,* 2007; CARE, 2009; IISD *et al*., 2009; Tearfund, 2009. In integrating climate change, a balance needs to be struck between the desire for a sophisticated assessment that includes high-quality scientific inputs as well as rigorous analysis of the participatory findings, and the need to keep the process simple, participatory and implementable at scale.

For more details on the implementation of risk management at the local level, see chapter 5.

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In general terms, according to the International Standards Organization risk assessment can be defined as a process to comprehend the nature of risk and to determine the level of risk (ISO, 2009a/b). 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., 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 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.

Usually risk has been associated to probabilities, but in general taking into account epistemic and aleatory uncertainties the *probabilistic estimations* of risk attempt to forcast damage or losses even where insufficient data are available on the hazards and 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 risk assessment based on probability, 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; Spence and Coburn 1987;Coburn and Spence, 1992; Woo, 1999; Grossi and Kunreuther, 2005; Cardona *et al.,* 2008a/b; Cardona 2010a).

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 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.,* 2003b).

The risk estimate must be prospective, anticipating scientifically possible hazard events that may occur in the future. For instance, for the case of hurricane-winds, the hydrometeorologic information available of the historic or future hurricanes –using climate change models or simulations– that have or may affected the area of study is used and, jointly with engineering methodologies, the effects of these phenomena upon the exposed current or future 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 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. Note that each of these factors may be subject to change in a changing climate (including consideration of uncertainty ranges).

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. The usefulness of indicators depends on how they are employed (Cardona et al., 2003; IDEA 2005; Cardona, 2006). The way in which indicators are used to produce a diagnosis has at least two implications: The first is related to the structuring of the theoretical model. The second relates to the way risk management objectives and goals are decided on. These aspects are relevant 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 alternatives, information on which is critical to organize and orientate the praxis of effective intervention (IDEA 2005). An appropriate technique based on indicators or composite indices can be a rational benchmark or a common metric to rule the risk variables from a control point of view; the goal in this case is not to reveal the truth, but rather to provide information and analyses that can improve decisions (Cardona, 2005; Carreño *et al.,* 2007b, 2009). Box 2-7 illustrates how with a particular indicator it is possible to communicate disaster risk to country's financial authorities in their own financial language.

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Box 2-7. The Disaster Deficit Index: A Metric for Sovereign Fiscal Vulnerability Assessment

Future disasters have been identified as contingency liabilities and could 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. 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, 2010b; 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. Figure 2-4 shows the DDI for 2008.

[INSERT FIGURE 2-4 HERE:
Figure 2-4: Disaster Deficit Index (DDI) and Probable Maximum Loss in 500 Years for 19 countries of the Americas for 2008. Source: Cardona, 2010b]

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. [add discussion on applications]

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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 or adaptation decision-making. Results can be verified and risk management/adaptation priorities can be established (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 and Birkmann (2004) and Cardona, (2001). 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. Similar frameworks have been developed from an adaptation perspective (insert refs).

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 specific options (technical and structural as well as non-technical and non-structural) on how to reduce vulnerability and risk levels, which can then be appraised against identified criteria. (Cardona, 1999; Cardona and Hurtado, 2000a/b; Cardona and Barbat, 2000; Turner *et al.,* 2003; IDEA 2005; Birkmann, 2006b; Carreño *et al.,* 2005, 2007a, 2009; ICSU-LAC 2010). Figure 2-1 contours a holistic and integrative perspective.

Several methods have been proposed to measure vulnerability from a comprehensive and multidisciplinary perspective. In some cases composite indices or indicators intend to capture favourable conditions for direct physical impacts –such as exposure and susceptibility– as well as indirect or intangible impacts of hazard events –such as socio-ecological fragilities or lack of resilience– (IDEA, 2005; Cardona, 2006; Carreño *et al.,* 2007a). In these holistic approaches, exposure and physical susceptibility are representing the 'hard' and hazard dependent conditions of vulnerability. On the other hand, the propensity to suffer negative impacts as a result of the socio-ecological fragilities and not being able to adequately cope and anticipate disasters, can be considered 'soft' and usually non-hazard dependent conditions, that aggravate the impact. Box 2-8 describes one of these approaches based on relative indicators useful for monitoring vulnerability of countries over time.

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Box 2-8. 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, 2010b; IDEA, 2005) provides a holistic approach to relative vulnerability assessment using social, economic and environmental indicators. The PVI depicts predominant vulnerability conditions of the countries over time to identify progresses and regressions. 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 demographic, socio-economic, and environmental national indicators that reflect situations, causes, susceptibilities, weaknesses or relative absences of development affecting the country under study. The indicators are selected based on existing indices, figures or rates available from reliable worldwide databases or data provided by each country. These vulnerability conditions underscore the relationship between risk and development. Figure 2-6 shows the aggregated PVI (Exposure, Social Fragility, Lack of Resilience) for 2007 and for the last four periods.

[INSERT FIGURE 2-5 HERE:
Figure 2-5: Aggregate Prevalent Vulnerability Index (PVI) for 19 countries of the Americas for 2007. Source: Cardona, 2010b]

Vulnerability and therefore risk are the result of inadequate economic growth and deficiencies that may be corrected by means of adequate development processes, reducing susceptibility of exposed assets, socio-economic fragilities, and improving capacities and resilience of society (IDB, 2007). 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. The PVI can be used at different territorial levels, however often the indicators used by the PVI are only available at national level; this is a limitation for its application in other subnational scales.

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To enhance disaster risk management and climate change adaptation, besides strengthening the integrative and holistic perspective within risk and vulnerability assessment, risk identification and vulnerability assessment has to be undertaken in different phases, i.e. before, during and even after disasters occur. Particular attention should be given to the evaluation of the continued viability of measures taken and/or identifying the need for further or different adaptation/risk management measures. 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, 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 main 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 (Corral, 2000). Applicability is related 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 method or algorithm. Presentation refers to the transformation of the information, visualization, and understanding of the outcomes. Finally, legitimacy is linked to the role of the analyst, control, comparison, the possibility of validation, and acceptance and consensus of the evaluators and decision-makers (Cardona, 2003b; Cardona, 2010a).

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Box 2-9. Climate Risk Assessment and Screening for Development Projects and Portfolios

A specific area of risk screening for risks related to climate change relates to development projects financed by international donor agencies and development banks, and their overall portfolios of development projects and loans. As part of their standard operations, they have traditionally assessed the risk that their projects could pose to the environment, specifically using instruments such as environmental impact assessments. In light of climate change, these questions have expanded to include (a) the risk that climate change could pose to the project itself (for instance in the case of infrastructure collapse); (b) the risk that climate change could pose to the project's intended outcomes (for instance when investments would not pay off as expected); (c) the risk that the project could generate to the vulnerability of its surroundings (for instance when a project generates employment in an unsuitable area so that it increases exposure to future hazards). Initial risk assessment for such risks has a dual role of technical screening and awareness raising of project managers of potential issues to be addressed. It is often accomplished through a very simple set of questions. Follow-up risk assessment would be much more in-depth and conducted by expert consultants. At portfolio level,

Given their focus on the near future (planning horizons of most development projects are typically up to about 20 years, even if the physical lifetime of the investment may be much longer) and need to combine attention for current and future risks, several of these risk assessment methods for development agencies have paid specific attention to the risk of variability and extremes, and thus offer significant win-wins between adaptation to climate change and enhanced disaster risk management even in light of current hazards (see e.g. Van Aalst and Burton, 1999, 2004; Klein, 2001; Klein *et al.,* 2007; Agrawala and van Aalst, 2008; and Tanner, 2009).

For more details on the implementation of risk management at the national level, see chapter 6.

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2.8.3. Risk Communication

Risk assessments and risk identification have to be linked to different types and strategies of risk communication. Risk communication or the failure of effective and people centred risk communication is often contributing to an increasing vulnerability and disaster risk. Knowledge on factors that determine how people perceive and respond to a specific risk or a set of multi-hazard risks is key for risk management and climate change adaptation (see van Aalst et al. 2008; Grothmann/Patt 2005).

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, 2005; Birkmann, 2006a/b/c; Cutter/Finch 2008 and ICSU-LAC, 2010). In this regard, risk communication is not solely linked to a top-down communication process, rather effective risk communication requires that communication is a dialog meaning that risk communication also deals with local risk perceptions and local definitions of risk. Risk communication thus functions also as a tool to up-scale local knowledge and needs (bottom-up approach). Therefore, modern risk communication is about both an improved way to inform people at risk about the key determinants of risk or acute disaster risk (early warning), but also a way on how to engage different stakeholders in the definition of a problem and the identification of respective solutions (see van Aalst et al. 2008, p. 177; DKKV et al. 2010 [note: title: emerging challenges for early warning systems in the context of climate change and urbanization (study)].

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 identify and evaluate 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. The failure of risk communication has been revealed in past disasters, such as Hurricane Katrina in 2005 or the Pakistan Floods in 2010. Particularly, the loss of trust in official institutions, responsible for early warning and disaster management were a key factor that contributed to the increasing disaster risk. Effective and people centred risk communication is therefore a key to improve vulnerability and risk reduction. In contrast, weak and insufficient risk communication as well as the loss of trust in governmental institutions in the context of early warning or climate change adaptation can be seen as a core component of institutional vulnerability.

Climate change adaptation strategies as well as disaster risk reduction approaches need public interest and acceptance. In this context the role of mass media becomes increasingly important (see e.g. the case of Japan shown in Sampei/Aoyagi-Usui 2009). Communication within society is more and more organized according to the rules of the mass media. Mass media do not reflect or echo reality. However modern society take notice of climate change and disasters as they are communicated by professional media (Rhomberg 2009). Within the context of risk communication, particularly in terms of climate change and disasters, politicians, scientists and NGOs have to observe the logics of the media concerning news production public discourse and media consumption (see Carvalho and Burgess 2005). Knowing the rules and routines of the media is a prerequisite to develop strategies to find attention and support (Anderson 2009). Disasters, people affected and harm is often taken up by the mass media worldwide, however, it is difficult to communicate a differentiated picture about underlying vulnerabilities, mechanisms of climate change and particularly the uncertainties related to climate change (see Smith 2007). Additionally, Carvalho (2005) and Olausson (2009) underline that mass media is often closely linked to political awareness, that means also that mass media does solely provide little space for alternative frames of communicating climate change (Carvalho 2005, Olausson 2009). Furthermore, risk communication in the context of mass media has to acknowledge that the presentation of climate change is not only determined by the routines of mass media, but rather also by the different interest groups (see e. g. Dispensa and Brulle 2003). In this regard Boykoff and Boykoff (2007) conclude that this process might also leads to an informational bias, especially towards the presentation of sudden-onset hazards. In contrast climate change related risks are often related to future risks and risk modifications that are based on scenarios about the future, thus communication about possible effects of climate change inevitably involves uncertainty (see e.g. Morton et al. 2010). Thus, an important aspect of improving risk communication and the respective knowledge base is the acceptance and admission of the limits of knowledge (see Birkmann/Teichman 2010, p. 181). Additionally, it is essential to underline within risk communication strategies that disasters are determined not solely by one event or trigger, but by various developments that often run in parallel and that at a certain point in time reach (in their combination) a threshold that might lead to a disaster (see Dikau/Pohl 2007).

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 2-10. Lessons on Risk Perception and Communication from Early Warning Systems

[TBD – coordinate with chapter 9]

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2.9. Risk Accumulation and the Nature of Disasters

2.9.1. Risk Accumulation

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. It also reflects that the impacts of one hazard – and the response to it – can have implications for how the next hazard plays out. This is well illustrated by the example of El Salvador, where people living in temporary shelters after 1998 Hurricane Mitch were at greater risk during the 2001 earthquakes, due to the poor construction of the shelters (Wisner, 2001). The notion is important because it acknowledges the multiple causal factors of risk by implying the connection between development patterns and risk, as well as the links between one disaster and the next. In many ways, this notion, which stems from the disaster risk reduction community, embodies why climate change poses such a threat to humanity and ecosystems.

Risk accumulation can be driven by underlying factors such as 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 (Pelling and Satterthwaite, 2007). 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). Similar accumulation of risk may occur at larger scales in hazard-prone states, especially in context of conflict and displacement (e.g. UNDP, 2004).

A context-based understanding of these risks is essential to identify appropriate risk management strategies. 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 one of the most effective methods to address urban disaster risk in Africa is to support community processes amongst the most vulnerable groups so they can 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 that rapidly go out of date due to unplanned construction.

2.9.2. The Nature of Disasters and Barriers to Overcome

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; research-based knowledge must be considered relevant, true, unbiased, and applicable in order to have impact on decision makers in policy and practice (Mitchell et al. 2006, Weichselgartner and Kasperson 2010). Effective risk management also requires a good understanding of the underlying vulnerability, as well as effective communication and dissemination of risk knowledge. Also an enabling environment to provide those in need with access to means of protection. 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. 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 it is important highlight 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).

This chapter highlights how risk is determined not just by hazards, but importantly also by vulnerability and exposure. To address risk at its core therefore, rather than just superficially, transformative changes in development patterns are necessary. 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. However, there is often also strong pressure to restore the status quo as soon as possible after a disaster has happened, and unless proper risk assessment and reconstruction planning has been carried out even before a particular disaster occurs, the benefits of better analysis and more appropriate solutions have to be weighed against the cost of delays in restoring essential assets and services.

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 system 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 in some cases 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.

That then also leads to the research gap of how to inform robust decisions and improve the decision making process where uncertainties are high, including improved methods for identification, appraisal, monitoring and evaluation of flexible and incremental options.

A related 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 stakeholder engagement. An additional gap relates to the characterization and measurement of (adaptive) capacities, including implications for policy and practice in specific sectors and at various scales.

At the local level, a methodological gap is the development and application of appropriate climate risk assessment methodologies 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 related interest is improved characterization and quantification of various indirect feedbacks between climate change and disaster risk, e.g. 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 and/or to future gradual climate change, including through human systems and ecosystems, as well as how various policy options may affect these interactions (positively and/or negatively).

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

Dimensions	**Characteristics**	**Sources**
Multiple and Intersecting	(a) Social capital and the importance for climate change adaptation of acting collectively particularly in resource-dependent communities; (b) Although most often referred to as desirable, there are positive and negative benefits/distributional effects of social capital;	(a) Adger 2003 Social Capital, Collective Action, and Adaptation to Climate Change (b i) Aldrich, D. P., 2011: The Externalities of Strong Social Capital: Post-Tsunami Recovery in Southeast India. Forthcoming in Journal of Civil Society April 2011. Electronic copy available at: http://ssrn.com/abstract=1719642; (b ii) World Disasters Report 2007 - Focus on discrimination Accessed 20 January 2011 http://www.ifrc.org/Docs/pubs/disasters/wdr2007/WDR2007-English.pdf ; (b (b iii) Ibarraran, M. E., Ruth, M., Ahmad, S. and London, M., 2009 Climate change and natural disasters: macroeconomic performance and distributional impacts, Environ Dev Sustain (2009) 11:549–569

Gender	a) Unequal gender relations arising from patriarchal structures can create new vulnerabilities or worsen existing ones for women and girls in disasters. b) Men and women have different entitlements/access to resources and abilities to reduce their vulnerability through various coping and adaption practices c) Men may be more mobile and have more opportunities to use large blocks of time on a single pursuit (e.g. livelihood activities) while women generally cannot because of their range of reproductive duties and thus are disadvantaged in post-disaster recovery d) Women are a heterogeneous group and cannot be assumed to be equally vulnerable, everywhere and all of the time e) Gender is a cross cutting issue which can qualify all vulnerability dimensions. f) Gender should be understood as an inclusive term and not simply a binary (male, female) one. Groups defined/self-defining as transgender or non heterosexual are particularly invisible and under-researched; their marginalization leads to discriminatory practices in extreme events g) Increasing amounts of research have identified post-disaster violence against women	(a i) Enarson E. and Morrow, B. H. 1998 (a ii) Neumayer and Plümper 2007 (b i) Sen 1982 (c i) Eriksen, Brown and Kelly, 2005: 300-301 (d i) Fordham, 1999 (d ii) Enarson and Fordham, 2001; (d iii) Peacock *et al.* 1997; (d iv) Fothergill, 1996 (e i) ISDR Words Into Action (f i) Pincha C. and Krishna, N. H. 2009 Post-disaster death ex gratia payments and their gendered impact" Regional Development Dialogue (UNCRD) 30 (1) pp 95-105; (g i) Enarson, E. 1999 Violence Against Women in Disasters: A Study of Domestic Violence Programs in the United States and Canada, *Violence Against Women*, 5: 742-768; (g ii) Houghton Ros 2009 "Domestic Violence reporting and disasters in New Zealand" Regional Development Dialogue Vol 30 (1) pp 79-90

Age	In terms of age, it is often those at the extreme ends of the age range who are identified as vulnerable in disasters. (a) Children 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 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. (b) elderly people have been identified as at greater risk in heatwaves	(a i) Jabry, 2002; (a ii) Wisner, 2006b). (a iii) Bartlett, C., 2008: Climate change and urban children: impacts and implications for adaptation in low- and middle income countries *Environment & Urbanization* Vol 20(2): 501–519 (b) see Heat Wave Case Study
Race/ Ethnicity/ Religious Associations (link to culture)	a) Racial and ethnic inequities in several US disasters b) Evidence of differential access to relief	(a i) Fothergill, A., Maestas, E.G.M. and Darlington, J-Anne de R. 1999 "Race, Ethnicity and Disasters in the United States: A Review of the Literature" Disasters, 23(2):156-173; (a ii) Elliott, J. R. And Pais, J. 2006 "Race, class, and Hurricane Katrina: Social differences in human responses to disaster" Social Science Research 35 (2006) 295–321; (a iii) Cutter and Finch, 2008.
Dis/Ability	People with disabilities may be vulnerable in disasters because of their impairments and because they are more likely to be living in poverty, and they may be institutionalised and dependent on others. They are generally marginalized from disaster risk reduction planning or adaptation mechanisms. Disasters also create disabilities.	World Disasters Report 2007 - Focus on discrimination Accessed 20 January 2011 http://www.ifrc.org/Docs/pubs/disasters/wdr2007/WDR2007-English.pdf
Wealth/ Poverty	a) Vulnerability is not equal to poverty; it is context specific. However,	a) Blaikie *et al.*, 1994
Class/ Caste	a) Guatemalan earthquake of 1976 termed a 'classquake'	a) O'Keefe *et al.,* 1976

Table 2-3: *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 desertification, 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.

Table 2-4 *Examples of generated sensitivity and adaptive capacity indices for agriculture and fisheries in Sri Lanka*

Sensitivity index	Adaptive capacity index
For drought and flood	**For drought and flood**
Area of paddy cultivation	• Percentage of people employed in agriculture with education below O/L • Percentage of landless paddy farmers • Percentage agriculture share in income (among those employed in agriculture) • Percentage of paddy land not fed by major irrigation
For sea level rise	**For sea level rise**
Area of paddy cultivation within 5km from the coast line	• Percentage of people employed in agriculture with education below O/L • Percentage of landless paddy farmers • Percentage agriculture share in income (among those employed in agriculture) • Percentage of paddy land not fed by major irrigation

Table 2-5: *Possible Health Threats from Climate Change*

Climate Change Threat	Potential Health Impacts
Heat waves	• Direct deaths (heat stroke; dehydration) • Exacerbation of chronic cardiovascular and pulmonary conditions
Air pollution	• Increased concentration of ground-level ozone. • Exacerbation of chronic cardiovascular and pulmonary diseases
Flooding (coastal and other)	• Contamination of potable water • Increased exposure to disease and pollutants • Indoor mold and respiratory illness • Deaths (drowning and indirect causes) • Forced evacuation and relocation • Mental health problems
Deterioration of food and water supply	• Increase in food poisoning (salmonellosis) • Increase in water-borne diseases (cryptosporidiosis)
Vector-borne diseases	• Expansion of habitat for mosquitoes •Geographic shifts in malaria, other insect borne diseases
Increased sunlight (more outdoor activity)	• Skin cancer • Increased rate of eye cataracts
Drought	• Water shortages • Contamination of water supplies • Reduced personal and community hygiene
Deterioration of long-standing agricultural areas	• Impaired crop yields • Food shortages • Greater use of pesticides and fertilizers • Shifts in diet
Hurricane, typhoons and extreme storm frequency and severity	• Storm-related deaths • Major property damage and insurance losses • Mental health problems

Table 2-6: *Examples of vulnerability indicators for freshwater resources (Source: 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

Table 2-7 *Examples of observed and projected climate change impacts identified in the Fourth Assessment Report (AR4) (IPCC, 2007) that affect vulnerability and exposure.*

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/

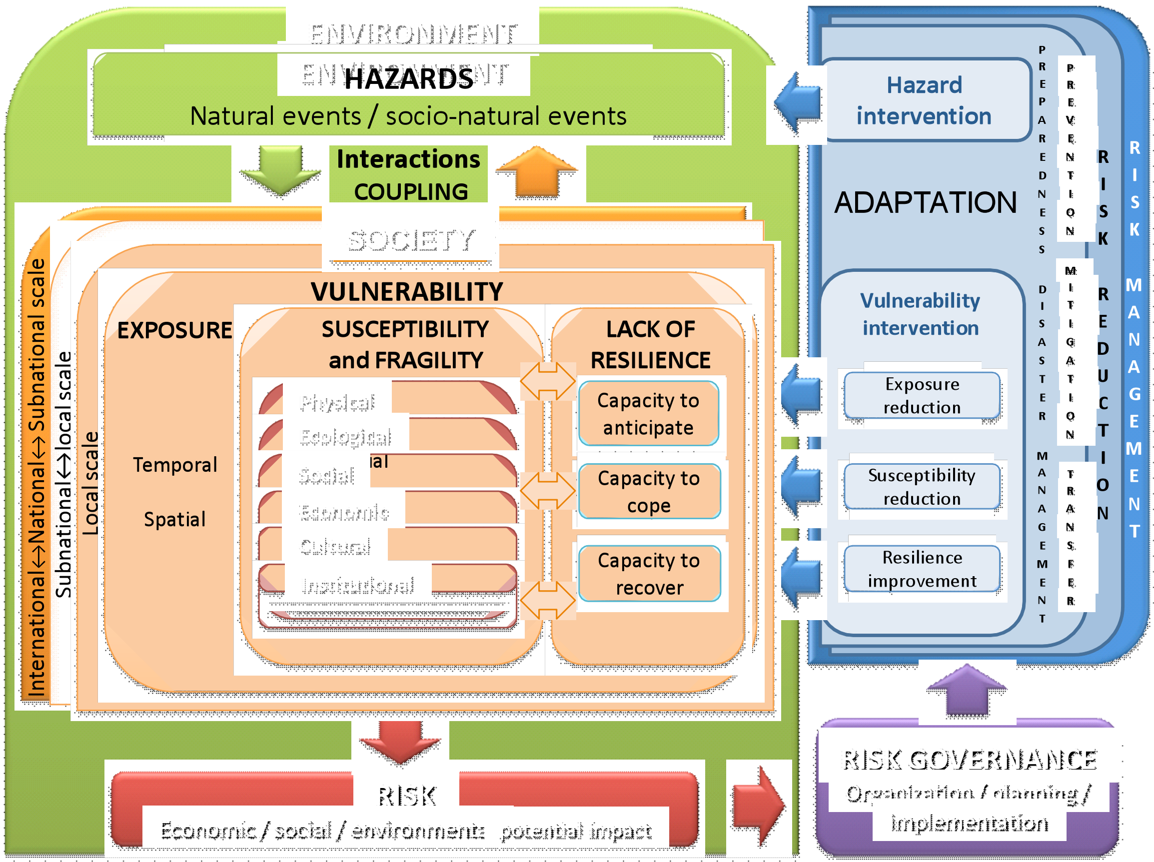

Figure 2-1: MOVE project framework on vulnerability and disaster risk assessment and management. Source: MOVE (2010).

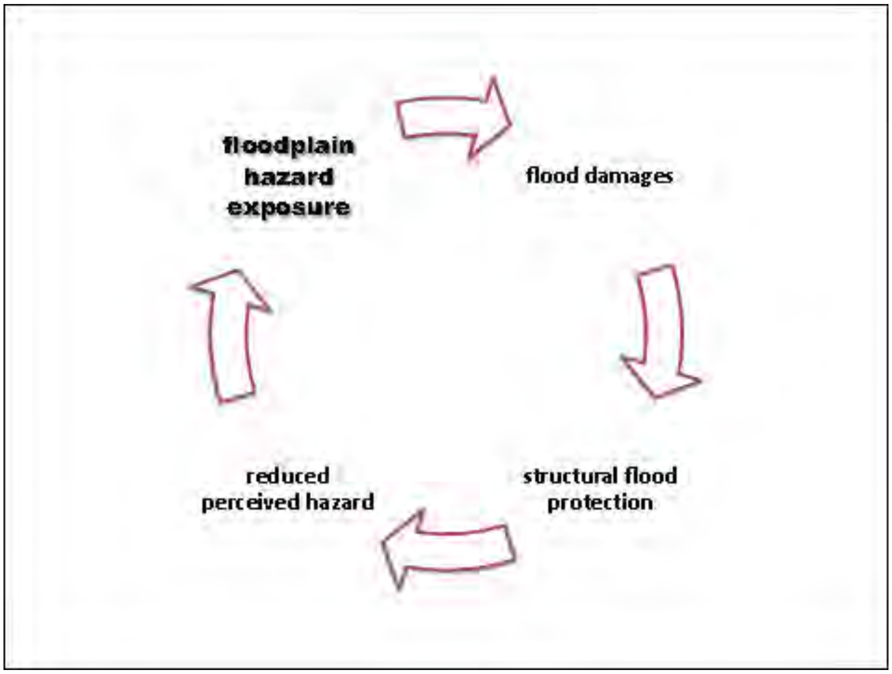

Figure 2-2. Reactive and maladaptive policy responses: the 'levee effect' in floodplain hazard exposure.

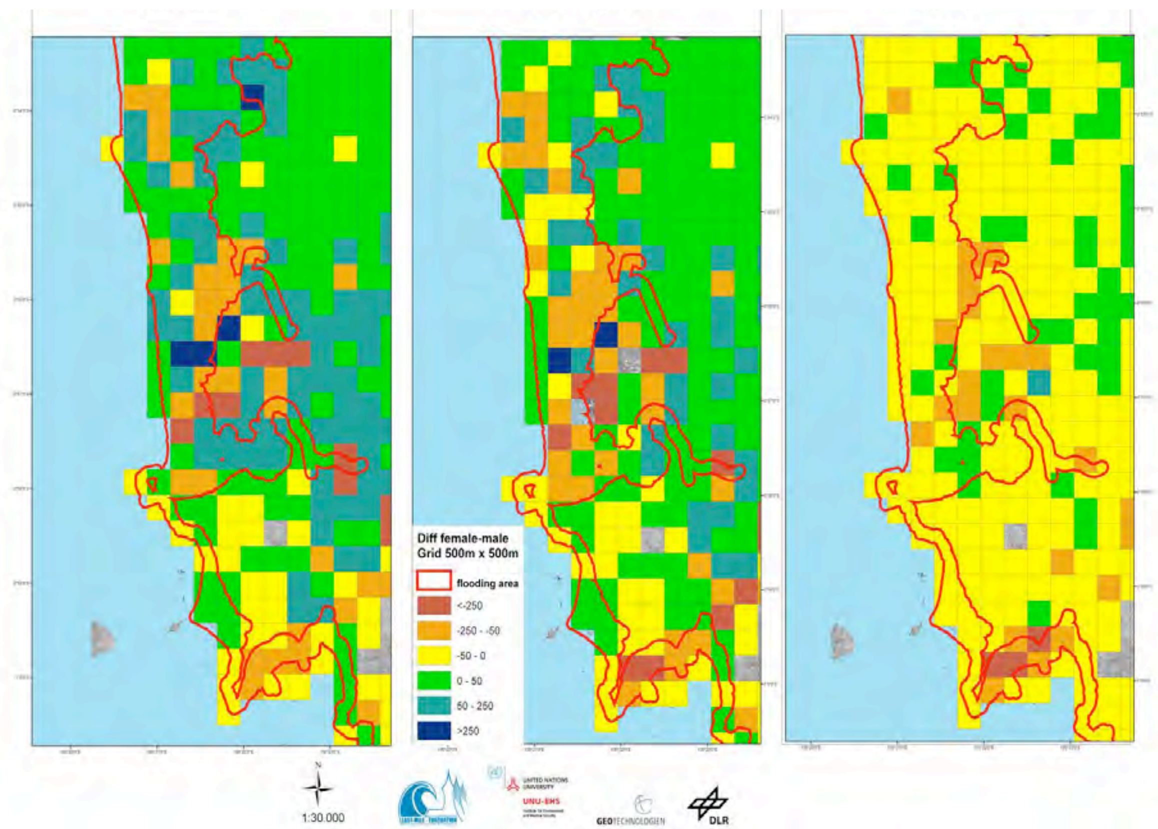

Figure 2-3: Difference between female-male population during morning, afternoon and night, for the coastal city of Padang, demonstrating differential exposure of women over time of day in the high risk zone close to the sea (Setiadi et al., 2010).

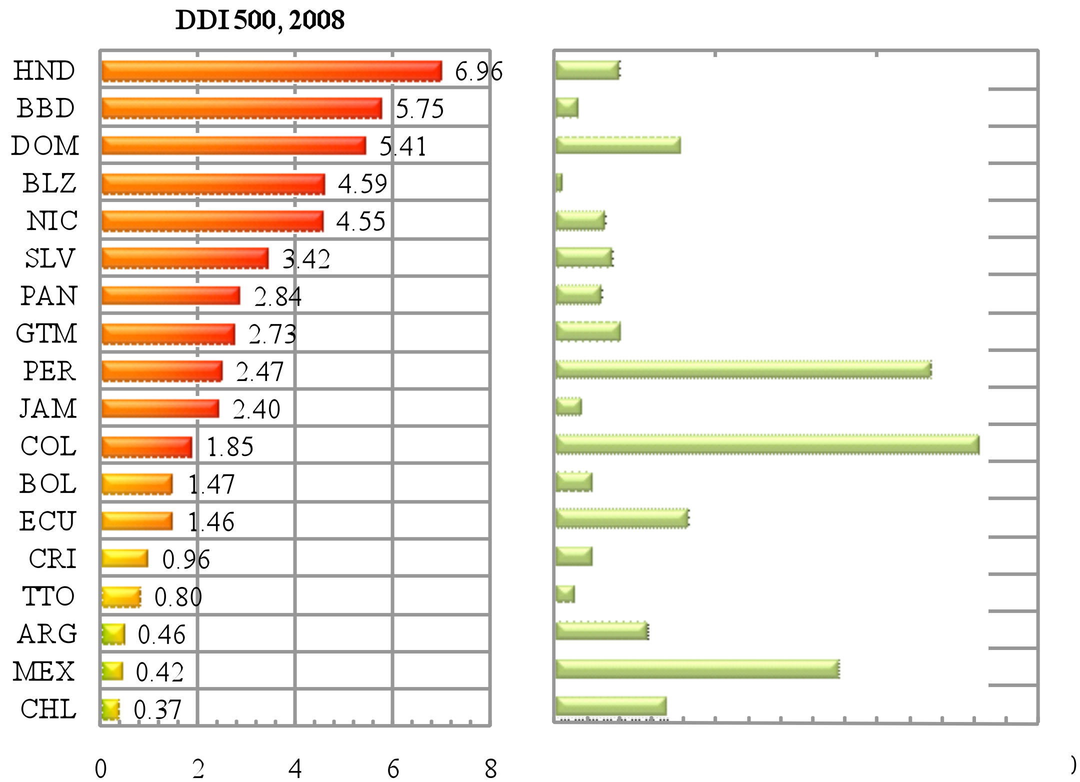

Figure 2-4: *Disaster Deficit Index (DDI) and Probable Maximum Loss in 500 Years for 18 countries of the Americas for 2008. Source: Cardona, 2010b*]

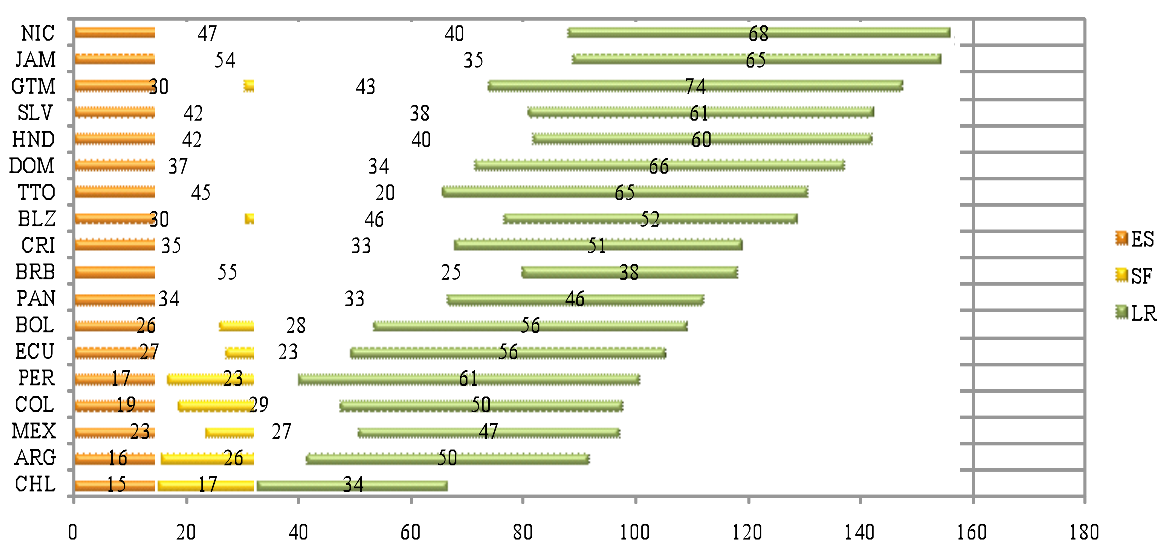

Figure 2-5: *Aggregate Prevalent Vulnerability Index (PVI) for 18 countries of the Americas for 2007. Source: Cardona, 2010b.*

Components of the PVI: ES: exposure and susceptibility; SF: socioeconomic fragilities; LR: lack of resilience