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 weather and climate events that affect the risk of extreme impacts on human society. That risk is determined not only by the climate and weather events (the hazards) but also by the exposure and vulnerability to these hazards. Therefore, effective adaptation and disaster risk management strategies and practices also depend on a rigorous understanding of the dimensions of exposure and vulnerability, as well as a proper assessment of changes in those dimensions. This chapter aims to provide that understanding and assessment, by further detailing the determinants of risk as presented in Chapter 1.

The first sections of this chapter elucidate the concepts that are needed to define and understand risk, and show that risk originates from a combination of social processes and their interaction with the environment (Sections 2.2 and 2.3), and highlight the role of coping and adaptive capacities (Section 2.4). The following section (2.5) describes the different dimensions of vulnerability and exposure as well as trends therein. Given that exposure and vulnerability are highly context-specific, this section is by definition limited to a general overview (a more quantitative perspective on trends is provided in Chapter 4). A methodological discussion (Section 2.6) 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 cross-cutting discussion of risk accumulation and the nature of disasters (Section 2.7).

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

2.2.1. Disaster Risk and Disaster

Disaster risk signifies the possibility of adverse effects in the future. It derives from the interaction of social and environmental processes, from the combination of physical hazards and the vulnerabilities of exposed elements (see Chapter 1). The hazard event is not the sole driver of risk, and there is *high confidence* that the levels of adverse effects are in good part determined by the vulnerability and exposure of societies and social-ecological systems (UNDRO, 1980; Cuny, 1984; Cardona, 1986, 1993, 2011; Davis and Wall, 1992; UNISDR, 2004, 2009b; Birkmann, 2006a,b; van Aalst 2006a).

Disaster risk is not fixed but is a continuum in constant evolution. A *disaster* is one of its many 'moments' (ICSU-LAC, 2010a,b), signifying unmanaged risks that often serve to highlight skewed development problems (Westgate and O'Keefe, 1976; Wijkman and Timberlake, 1984). Disasters may also be seen as the materialization of risk and signify 'a becoming real' of this latent condition that is in itself a social construction (see below; Renn, 1992; Adam and Van Loon, 2000; Beck, 2000, 2008).

Disaster risk is associated with differing levels and types of adverse effects. The effects may assume catastrophic levels or levels commensurate with small disasters. Some have limited financial costs but very high human costs in terms of loss of life and numbers of people affected; others have very high financial costs but relatively limited human costs. Furthermore, there is *high confidence* that the cumulative effects of small disasters can affect capacities of communities, societies, or social-ecological systems to deal with future disasters at sub-national or local levels (Alexander, 1993, 2000; Quarantelli, 1998; Birkmann, 2006b; Marulanda et al., 2008b, 2010, 2011; UNISDR, 2009a).

2.2.2. The Factors of Risk

As detailed in Section 1.1, *hazard* refers to the possible, future occurrence of natural or human-induced physical events that may have adverse effects on vulnerable and exposed elements (White, 1973; UNDRO, 1980; Cardona, 1990; UNDHA, 1992; Birkmann, 2006b). Although, at times, hazard has been ascribed the same meaning as risk, currently it is widely accepted that it is a component of risk and not risk itself. The intensity or recurrence of hazard events can be partly determined by environmental degradation and human intervention in natural ecosystems. Landslides or flooding regimes associated with human-induced environmental alteration and new climate change-related hazards are examples of such socio-natural hazards (Lavell, 1996, 1999a).

Exposure refers to the inventory of elements in an area in which hazard events may occur (Cardona, 1990; UNISDR, 2004, 2009b). Hence, if population and economic resources were not located in (exposed to) potentially dangerous settings, no problem of disaster risk would exist. While the literature and common usage often mistakenly conflate exposure and vulnerability, they are distinct. Exposure is a necessary, but not sufficient, determinant of risk. It is possible to be exposed but not vulnerable (for example by living in a floodplain but having sufficient means to modify building structure and behavior to mitigate potential loss). However, to be vulnerable to an extreme event, it is necessary to also be exposed.

Land use and territorial planning are key factors in risk reduction. The environment offers resources for human development at the same time as it represents exposure to intrinsic and fluctuating hazardous conditions. Population dynamics, diverse demands for location, and the gradual decrease in the availability of safer lands mean it is almost inevitable that humans and human endeavor will be located in potentially dangerous places (Lavell, 2003). Where exposure to events is impossible to avoid, land use planning and location decisions can be accompanied by other structural or non-structural methods for preventing or mitigating risk (UNISDR, 2009a; ICSU-LAC, 2010a,b).

V*ulnerability* refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events (UNDRO, 1980; Cardona, 1986, 1990, 1993; Liverman, 1990; Maskrey, 1993b; Cannon, 1994, 2006; Blaikie et al., 1996; Weichselgartner, 2001; Bogardi and Birkmann, 2004; UNISDR, 2004, 2009b; Birkmann, 2006b; Janssen et al., 2006; Thywissen, 2006). Vulnerability is related to predisposition, susceptibilities, fragilities, weaknesses, deficiencies, or lack of capacities that favor adverse effects on the exposed elements. Thywissen (2006) and Manyena (2006) carried out an extensive review of the terminology. The former includes a long list of definitions used for the term vulnerability and the latter includes definitions of vulnerability and resilience and their relationship.

An early view of vulnerability in the context of disaster risk management was related to the physical resistance of engineering structures (UNDHA, 1992), but more recent views relate vulnerability to characteristics of social and environmental processes. It is directly related, in the context of climate change, to the susceptibility, sensitivity, and lack of resilience or capacities of the exposed system to cope with and adapt to extremes and non-extremes (Luers et al., 2003; Schröter et al., 2005; Brklacich and Bohle, 2006; IPCC, 2001, 2007).

While vulnerability is a key concept for both disaster risk and climate change adaptation, the term is employed in numerous other contexts, for instance to refer to epidemiological and psychological fragilities, ecosystem sensitivity, or the conditions, circumstances, and drivers that make people vulnerable to natural and economic stressors (Kasperson et al., 1988; Cutter, 1994; Wisner et al., 2004; Brklacich and Bohle, 2006; Haines et al., 2006; Villagrán de León, 2006). It is common to find blanket descriptions of the elderly, children, or women as 'vulnerable,' without any indication as to what these groups are vulnerable to (Wisner, 1993; Enarson and Morrow, 1998; Morrow, 1999; Bankoff, 2004; Cardona, 2004, 2011).

Vulnerability can be seen as situation-specific, interacting with a hazard event to generate risk (Lavell, 2003; Cannon, 2006; Cutter et al., 2008). Vulnerability to financial crisis, for example, does not infer vulnerability to climate change or natural hazards. Similarly, a population might be vulnerable to hurricanes, but not to landslides or floods. From a climate change perspective, basic environmental conditions change progressively and then induce new risk conditions for societies. For example, more frequent and intense events may introduce factors of risk into new areas, revealing underlying vulnerability. In fact, future vulnerability is embedded in the present conditions of the communities that may be exposed in the future (Patt et al., 2005, 2009); that is, new hazards in areas not previously subject to them will reveal, not necessarily create, underlying vulnerability factors (Alwang et al., 2001; Cardona et al., 2003a; Lopez-Calva and Ortiz, 2008; UNISDR, 2009a).

While vulnerability is in general hazard-specific, certain factors, such as poverty, and the lack of social networks and social support mechanisms, will aggravate or affect vulnerability levels irrespective of the type of hazard. These types of generic factors are different from the hazard-specific factors and assume a different position in the intervention actions and the nature of risk management and adaptation processes (ICSU-LAC, 2010a,b). Vulnerability of human settlements and ecosystems is intrinsically tied to different socio-cultural and environmental processes (Kasperson et al., 1988; Cutter, 1994; Adger, 2006; Cutter and Finch, 2008; Cutter et al., 2008; Williams et al., 2008; Décamps, 2010; Dawson et al., 2011). Vulnerability is linked also to deficits in risk communication, especially the lack of appropriate information that can lead to false risk perceptions (Birkmann and Fernando, 2008), which have an important influence on the motivation and perceived ability to act or to adapt to climate change and environmental stressors (Grothmann and Patt, 2005). Additionally, processes of maladaptation or unsustainable adaptation can increase vulnerability and risks (Birkmann, 2011a).

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; ICSU-LAC 2010a,b). This notion underscores that society, in its interaction with the changing physical world, constructs disaster risk by transforming physical events into hazards of different intensities or magnitudes through social processes that increase the exposure and vulnerability of population groups, their livelihoods, production, support infrastructure, and services (Chambers, 1989; Wilches-Chaux, 1989; Cannon, 1994; Wisner et al., 2004; Wisner, 2006a; Carreño et al., 2007a; ICSU-LAC, 2010a,b). This includes:

- How human action influences the levels of exposure and vulnerability in the face of different physical events
- How human intervention in the environment leads to the creation of new hazards or an increase in the levels or damage potential of existing ones
- How human perception, understanding, and assimilation of the factors of risk influence societal reactions, prioritization, and decisionmaking processes.

There is *high agreement* and *robust evidence* that high vulnerability and exposure are mainly an outcome of skewed development processes, including those associated with environmental mismanagement, demographic changes, rapid and unplanned urbanization, and the scarcity of livelihood options for the poor (Maskrey, 1993a,b, 1994, 1998; Mansilla, 1996; Lavell, 2003; Cannon, 2006; ICSU-LAC, 2010a,b; Cardona, 2011).

Increases in disaster risk and the occurrence of disasters have been in evidence over the last five decades (Munich Re, 2011) (see Section 1.1.1). This trend may continue and may be enhanced in the future as a result of projected climate change, further demographic and socioeconomic changes, and trends in governance, unless concerted actions are enacted to reduce vulnerability and to adapt to climate change, including interventions to address disaster risks (Lavell, 1996, 1999a, 2003; ICSU-LAC, 2010a,b; UNISDR, 2011).

2.3. The Drivers of Vulnerability

In order to effectively manage risk, it is essential to understand how vulnerability is generated, how it increases, and how it builds up (Maskrey, 1989; Cardona, 1996a, 2004, 2011; Lavell, 1996, 1999a;

O'Brien et al., 2004b). Vulnerability describes a set of conditions of people that derive from the historical and prevailing cultural, social, environmental, political, and economic contexts. 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 organization, and access to resources (Watts and Bohle, 1993; Morrow, 1999; Bankoff, 2004). Thus, the effects of a disaster on any particular household result from a complex set of drivers and interacting conditions. It is important to keep in mind that people and communities are not only or mainly victims, but also active managers of vulnerability (Ribot, 1996; Pelling, 1997, 2003). Therefore, integrated and multidimensional approaches are highly important to understanding causes of vulnerability.

Some global processes are significant drivers of risk and are particularly related to vulnerability creation. There is *high confidence* that these include population growth, rapid and inappropriate urban development, international financial pressures, increases in socioeconomic inequalities, trends and failures in governance (e.g., corruption, mismanagement), and environmental degradation (Maskrey, 1993a,b, 1994, 1998; Mansilla, 1996; Cannon, 2006). Vulnerability profiles can be constructed that take into consideration sources of environmental, social, and economic marginality (Wisner, 2003). This also includes the consideration of the links between communities and specific environmental services, and the vulnerability of ecosystem components (Renaud, 2006; Williams et al., 2008; Décamps, 2010; Dawson et al., 2011). In climate change-related impact assessments, integration of underlying 'causes of vulnerability' and adaptive capacity is needed rather than focusing on technical aspects only (Ribot, 1995; O'Brien et al., 2004b).

Due to different conceptual frameworks and definitions, as well as disciplinary views, approaches to address the causes of vulnerability also differ (Burton et al., 1983; Blaikie et al., 1994; Harding et al., 2001; Twigg, 2001; Adger and Brooks, 2003, 2006; Turner et al., 2003a,b; Cardona, 2004; Schröter et al., 2005; Adger 2006; Füssel and Klein, 2006; Villagrán de León, 2006; Cutter and Finch, 2008; Cutter et al., 2008). Thomalla et al. (2006), Mitchell and van Aalst (2008), and Mitchell et al. (2010) examine commonalities and differences between the adaptation to climate change and disaster risk management communities, and identify key areas of difference and convergence. The two communities tend to perceive the nature and timescale of the threat differently: impacts due to climate change and return periods for extreme events frequently use the language of uncertainty; but considerable knowledge and certainty has been expressed regarding event characteristics and exposures related to extreme historical environmental conditions.

Four approaches to understanding vulnerability and its causes can be distinguished, rooted in political economy, social-ecology, vulnerability, and disaster risk assessment, as well as adaptation to climate change:

1) The pressure and release (PAR) model (Blaikie et al., 1994, 1996; Wisner et al., 2004) is common to social science-related vulnerability research and emphasizes the social conditions and root causes of exposure more than the hazard as generating unsafe conditions. This approach links vulnerability to unsafe conditions in a continuum that connects local vulnerability to wider national and global shifts in the political economy of resources and political power.
2) The social ecology perspective emphasizes the need to focus on coupled human-environmental systems (Hewitt and Burton, 1971; Turner et al., 2003a,b). This perspective stresses the ability of societies to transform nature and also the implications 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.
3) Holistic perspectives on vulnerability aim to go beyond technical modeling to embrace a wider and comprehensive explanation of vulnerability. These approaches differentiate exposure, susceptibility and societal response capacities as causes or factors of vulnerability (see Cardona, 1999a, 2001, 2011; Cardona and Barbat, 2000; Cardona and Hurtado, 2000a,b; 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 which underlines that vulnerability is dynamic and is the main driver and determinant of current or future risk.
4) In the context of climate change adaptation, different vulnerability definitions and concepts have been developed and discussed. One of the most prominent definitions is the one reflected in the IPCC Fourth Assessment Report, which describes vulnerability as a function of exposure, sensitivity, and adaptive capacity, as also reflected by, for instance, McCarthy et al. (2001), Brooks (2003), K. O'Brien et al. (2004a), Füssel and Klein (2006), Füssel (2007), and G. O'Brien et al. (2008). This approach differs from the understanding of vulnerability in the disaster risk management perspective, 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 potential 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.

The lack of a comprehensive conceptual framework that facilitates a common multidisciplinary risk evaluation impedes the effectiveness of disaster risk management and adaptation to climate change (Cardona, 2004). The option for anticipatory disaster risk reduction and adaptation exists precisely because risk is a latent condition, which announces potential future adverse effects (Lavell, 1996, 1999a). Understanding disaster risk management as a social process allows for a shift in focus from responding to the disaster event toward an understanding of disaster risk (Cardona and Barbat, 2000; Cardona et al., 2003a). This requires knowledge about how human interactions with the natural environment lead to the creation of new hazards, and how persons, property, infrastructure, goods, and the environment are exposed to potentially damaging events. Furthermore, it requires an understanding of the vulnerability of people and their livelihoods, including the allocation and distribution of social and economic resources that can work for or against the achievement of resistance, resilience, and security (ICSU-LAC, 2010a,b). Overall, there is *high confidence* that although hazard events are usually considered the cause of disaster risk, vulnerability and exposure are its key determining factors. Furthermore, contrary to the hazard, vulnerability and exposure can often be influenced by policy and practice, including in the short to medium term. Therefore disaster risk management and adaptation strategies have to address mainly these same risk factors (Cardona 1999a, 2011; Vogel and O'Brien, 2004; Birkmann, 2006a; Leichenko and O'Brien, 2008).

Despite various frameworks developed for defining and assessing vulnerability, it is interesting to note that at least some common causal factors of vulnerability have been identified, in both the disaster risk management and climate change adaptation communities (see Cardona, 1999b, 2001, 2011; Cardona and Barbat, 2000; Cardona and Hurtado, 2000a,b; McCarthy et al., 2001; Gallopin, 2006; Manyena, 2006; Carreño et al., 2007a, 2009; IPCC, 2007; ICSU-LAC 2010a,b; MOVE, 2010):

- *Susceptibility/fragility (in disaster risk management) or sensitivity (in climate change adaptation)*: physical predisposition of human beings, infrastructure, and environment to be affected by a dangerous phenomenon due to lack of resistance and predisposition of society and ecosystems to suffer harm as a consequence of intrinsic and context conditions making it plausible that such systems once impacted will collapse or experience major harm and damage due to the influence of a hazard event.
- *Lack of resilience (in disaster risk management) or lack of coping and adaptive capacities (in climate change adaptation)*: limitations in access to and mobilization of the resources of the human beings and their institutions, and incapacity to anticipate, adapt, and respond in absorbing the socio-ecological and economic impact.

There is *high confidence* that at the extreme end of the spectrum, the intensity of extreme climate and weather events – low-probability, high-intensity – and exposure to them tend to be more pervasive in explaining disaster loss than vulnerability itself. But as the events get less extreme – higher-probability, lower-intensity – the vulnerability of exposed elements plays an increasingly important role in explaining the level of impact. Vulnerability is a major cause of the increasing adverse effects of non-extreme events, that is, small recurrent disasters that many times are not visible at the national or sub-national level (Marulanda et al., 2008b, 2010, 2011; UNISDR, 2009a; Cardona, 2011; UNISDR, 2011).

Overall, the promotion of resilient and adaptive societies requires a paradigm shift away from the primary focus on natural hazards and extreme weather events toward the identification, assessment, and ranking of vulnerability (Maskrey, 1993a; Lavell, 2003; Birkmann, 2006a,b). Therefore, understanding vulnerability is a prerequisite for understanding risk and the development of risk reduction and adaptation strategies to extreme events in the light of climate change (ICSU-LAC, 2010a,b; MOVE, 2010; Cardona, 2011; UNISDR, 2011).

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).

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 organization 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 (Birkmann, 2011a), although coping capacity is often considered to be part of adaptive capacity (Levina and Tirpak, 2006).

2.4.1. Capacity and Vulnerability

Most risk studies prior to the 1990s focused mainly on hazards, whereas the more recent reversal of this paradigm has placed equal focus on the vulnerability side of the equation. Emphasizing 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).

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) 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 (Bohle, 2001; IPCC, 2001; Moss et al., 2001; Yodmani, 2001; Downing and Patwardhan, 2004; Brooks et al., 2005; Smit and Wandel, 2006; Gaillard, 2010):

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

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 features more frequently in global environmental change perspectives and is less prevalent in the hazards discourse.

Adaptive capacity refers to the ability of a system or individual 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), 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." 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 behavior, 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, organizations, 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 destabilization, 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 mobilize this capacity in an emergency is the manifestation of coping strategies (Gaillard, 2010). Furthermore, Birkmann (2011b) underscores that differences between coping and adaptation are also linked to the quality of the response process. While coping aims to maintain the system and its functions in the face of adverse conditions, adaptation involves changes and requires reorganization processes.

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 may lead to maladaptation (Yohe and Tol, 2002; Eriksen et al., 2005) (see Chapter 1). 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 recognized as the target of interventions (Adger et al., 2004). The United Nations Framework Convention on Climate Change, 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.

The relationship between capacity and vulnerability is interpreted differently in the climate change community of practice and the disaster risk management community of practice. 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 emphasis on vulnerability tended to ignore capacity, focusing too much on the negative aspects of vulnerability (Davis et al., 2004). Recognizing the role of capacity in reducing risk also indicates an acknowledgement that people are not 'helpless victims' (Bohle, 2001; Gaillard, 2010).

In many climate change-related studies, capacity was initially subsumed under vulnerability. The first handbooks and guidelines for adaptation emphasized impacts and vulnerability assessment as the necessary steps for determining adaptation options (Kate, 1985; Carter et al., 1994; Benioff et al., 1996; Feenstra et al., 1998). Climate change vulnerability was often placed in direct opposition to capacity. Vulnerability that was measured was seen as the remainder after capacity had been taken into account.

However, Davis et al. (2004), IDEA (2005), Carreño et al. (2007a,b), and Gaillard (2010) note that capacity and vulnerability are not necessarily 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) 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 low vulnerability.

2.4.2. Different Capacity Needs

The capacity necessary to anticipate and avoid being affected by an extreme event requires different assets, opportunities, social networks, and local and external institutions from capacity to deal with impacts and recover from them (Lavell, 1994; Lavell and Franco, 1996; Cardona, 2001, 2010; Carreño et al., 2007a,b; ICSU-LAC, 2010a,b; 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. 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 (Leichenko and O'Brien, 2002; Yohe and Tol, 2002; Brenkert and Malone, 2005; Brooks et al., 2005; Haddad, 2005; Vincent, 2007; Sharma and Patwardhan, 2008; Magnan, 2010) may not be similar with the identified drivers of capacities that helped in the past (*ex post*) and are associated more closely with experienced coping processes. Many of these elements are reflected in local, national, and international contexts in Chapters 5, 6, and 7 of this Special Report.

2.4.2.1. Capacity to Anticipate 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. 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.

Capacity for risk prevention and reduction may be understood as a series of elements, measures, and tools directed toward 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 (Batterbury, 2001; Eriksen and Silva, 2009).

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, 2010). 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 puts people at higher risk (Maskrey, 1989, 1994; Lavell, 1994, 1999b, 2003).

Up to the early 1990s, disaster preparedness and humanitarian response dominated disaster practice, and focus on capacity was limited to understanding inherent response capacity. Thus, emphasizing 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, 2003). 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, for example when flood risks are shifted from upstream communities to downstream communities through large-scale upstream dike construction (Birkmann, 2011a). Consequently, it is not sufficient to evaluate the success of adaptation or capacities to reduce risk by focusing on the objectives of one group only. The evaluation of success of adaptation strategies depends on the spatial and temporal scale used (Adger et al., 2005).

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. Response capacity is mostly used to refer to the ability of institutions to react following a natural hazard, in particular *ex post* during 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; IFRC, 2009). Furthermore, there are also response phases for gradual changes in ecosystems or temperature regimes caused by climate change. 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.

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; 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 Hurricane Mitch in 1998, turned into 'permanent' housing when nongovernmental organization (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). 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 often greatest during the recovery phase, when physical infrastructure has to be rebuilt and can be improved, and behavioral patterns and habits can be contemplated (Susman et al., 1983; Renn, 1992; Comfort et al., 1999; Vogel and O'Brien, 2004; Birkmann et al., 2010a). 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.

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 Hurricane Mitch), simply because the new location does not allow them easy access to their fields, to markets or roads, or to the sea (e.g., South and Southeast Asia after the 2004 tsunami).

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 out of sync with the evolving process of development. The recovery and reconstruction phases after a disaster provide an opportunity to rethink previous conditions and address the root causes of risk, looking to avoid reconstructing the vulnerability (IDB, 2007), but often the process is too rushed to enable effective reflection, discussion, and consensus building (Christoplos, 2006). Pushing the recovery toward 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.

The various capacities to respond and to survive hazard events and changes have also been discussed within the context of the concept of resilience. While originally, the concept of resilience was strongly linked to an environmental perspective on ecosystems and their ability to maintain major functions even in times of adverse conditions and crises (Holling, 1973), the concept has undergone major shifts and has been enhanced and applied also in the field of social-ecological systems and disaster risk (Gunderson, 2000; Walker et al., 2004; UN, 2005; Abel et al., 2006). Folke (2006) differentiates three different resilience concepts that encompass an engineering resilience perspective that focuses on recovery and constancy issues, while the ecological and social resilience focus on persistence and robustness and, finally, the integrated social-ecological resilience perspective deals with adaptive capacity, transformability, learning, and innovation (Folke, 2006). In disaster risk reduction the terms resilience building and the lack of resilience have achieved a high recognition. These terms are linked to capacities of communities or societies to deal with the impact of a hazard event or crises and the ability to learn and create resilience through these experiences. Recent papers, however, also criticize the unconsidered use or the simply transfer of the concept of resilience into the wider context of adaptation (see, e.g., Cannon and Müller-Mahn, 2010). Additionally, the lack of resilience has also been used as an umbrella to examine deficiencies in capacities that communities encompass in order to deal with hazard events. Describing the lack of resilience, Cardona and Barbat (2000) identify various capacities that are often insufficient in societies that suffer heavily during disasters, such as the deficiencies regarding the capacity to anticipate, to cope with, and to adapt to changing environmental conditions and natural hazards.

Other work has argued a different view on resilience, because the very occurrence of a disaster shows that there are gaps in the development process (UNDP, 2004). Lessons learned from studying the impacts of the 2004 Indian Ocean tsunami (Thomalla et al., 2009; Thomalla and Larsen, 2010) are informative for climate-related hazards. They suggest that:

- Social vulnerability to multiple hazards, particularly rare extreme events, tends to be poorly understood.
- There is an increasing focus away from vulnerability assessment toward resilience building; however, resilience is poorly understood and a lot needs to be done to go from theory to practice.
- 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 effort, competition, and tension between actors.

- Risk reduction is only meaningful and prioritized 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.

2.4.3. Factors of Capacity: Drivers and Barriers

There is *high confidence* that extreme and non-extreme weather and climate events also affect vulnerability to future extreme events, by modifying the resilience, coping, and adaptive capacity of communities, societies, or social-ecological systems affected by such events. 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, 2002; Marulanda et al., 2008b, 2010, 2011; UNISDR, 2009a). 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; urbanization; information technology; attention to human rights; agricultural capacity; strong international institutions; access to insurance; class structure; life expectancy, health, and well-being; degree of urbanization; access to public health facilities; community organizations; existing planning regulations at national and local levels; institutional and decisionmaking frameworks; existing warning and protection from natural hazards; and good governance (Cannon, 1994; Handmer et al., 1999; Klein, 2001; Barnett, 2005; Brooks et al., 2005; Bettencourt et al., 2006).

2.5. Dimensions and Trends of Vulnerability and Exposure

This section presents multiple dimensions of exposure and vulnerability to hazards, disasters, climate change, and extreme events. Some frameworks consider exposure to be a component of vulnerability (Turner et al., 2003a), and the largest body of knowledge on dimensions refers to vulnerability rather than exposure, but the distinction between them is often not made explicit. Vulnerability is: *multi-dimensional and differential* – that is, it varies across physical space and among and within social groups; *scale-dependent* with regard to space and units of analysis such as individual, household, region, or system; and *dynamic* – characteristics and driving forces of vulnerability change over time (Vogel and O'Brien, 2004). As vulnerability and exposure are not fixed, understanding the trends in vulnerability and exposure is therefore an important aspect of the discussion.

There is *high confidence* that for several hazards, changes in exposure and in some cases vulnerability are the main drivers behind observed trends in disaster losses, rather than a change in hazard character, and will continue to be essential drivers of changes in risk patterns over the coming decades (Bouwer et al., 2007; Pielke Jr. and Landsea, 1998; UNISDR, 2009a). In addition, there is *high confidence* that climate change will affect disaster risk not only through changes in the frequency, intensity, and duration of some 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.

Although trends in some of the determinants of risk and vulnerability are apparent (for example, accelerated urbanization), the extent to which these are altering levels of risk and vulnerability at a range of geographical and time scales is not always clear. While there is *high confidence* that these connections exist, current knowledge often does not allow us to provide specific quantifications with regional or global significance.

The multidimensional nature of vulnerability and exposure makes any organizing framework arbitrary, overlapping, and contentious to a degree. The following text is organized under three very broad headings: environmental, social, and economic dimensions. Each of these has a number of subcategories, which map out the major elements of interest.

2.5.1. Environmental Dimensions

Environmental dimensions include:

- Potentially vulnerable natural *systems (*such as low-lying islands, coastal zones, mountain regions, drylands, and Small Island Developing States (Dow, 1992; UNCED, 1992; Pelling and Uitto, 2001; Nicholls, 2004; UNISDR, 2004; Chapter 3)
- *Impacts* on systems (e.g., flooding of coastal cities and agricultural lands, or forced migration)
- The *mechanisms* causing impacts (e.g., disintegration of particular ice sheets) (Füssel and Klein, 2006; Schneider et al., 2007)
- *Responses* or *adaptations* to environmental conditions (UNEP/UNISDR, 2008).

There are important links between development, environmental management, disaster reduction, and climate adaptation (e.g., van Aalst and Burton, 2002), also including social and legal aspects such as property rights (Adger, 2000). For the purposes of vulnerability analysis in the context of climate change, it is important to acknowledge that the environment and human beings that form the socio-ecological system (Gallopin et al., 2001) behave in nonlinear ways, and are strongly coupled, complex, and evolving (Folke et al., 2002).

There are many examples of the interactions between society and environment that make people vulnerable to extreme events (Bohle et al., 1994) and highlight the vulnerability of ecosystem services (Metzger et al., 2006). As an example, vulnerabilities arising from floodplain encroachment and increased hazard exposure are typical of the intricate and finely balanced relationships within human-environment systems (Kates, 1971; White, 1974) of which we have been aware for several decades. Increasing human occupancy of floodplains increases exposure to flood hazards. It 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 alleviation measures (e.g., provision of embankments, channel modification, and other physical alterations of 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. A maladaptive policy response to such exposure provides structural flood defenses, which encourage the belief that the flood risk has been removed. This in turn encourages more floodplain encroachment and a reiteration of the cycle as the flood defenses (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.

Floodplains, even in low-lying coastal zones, have the potential to provide benefits and/or risks and it is the form of the *social* interaction (see next subsection) that determines which, and to whom. Climate variability shifts previous risk-based decisionmaking into conditions of greater uncertainty where we can be less certain of the probabilities of occurrence of any extreme event.

The environmental dimension of vulnerability also deals with the role of regulating ecosystem services and ecosystem functions, which directly impact human well-being, particularly for those social groups that heavily depend on these services and functions due to their livelihood profiles. Especially in developing countries and countries in transition, poorer rural communities often entirely depend on ecosystem services and functions to meet their livelihood needs. The importance of these ecosystem services and ecosystem functions for communities in the context of environmental vulnerability and disaster risk has been recognized by the 2009 and 2011 Global Assessment Reports on Disaster Risk Reduction (UNISDR, 2009a, 2011) as well as by the Millennium Ecosystem Assessment (MEA, 2005). The degradation of ecosystem services and functions can contribute to an exacerbation of both the natural hazard context and the vulnerability of people. The erosion of ecosystem services and functions can contribute to the decrease of coping and adaptive capacities in terms of reduced alternatives for livelihoods and income-generating activities due to the degradation of natural resources. Additionally, a worsening of environmental services and functions might also increase the costs of accessing these services, for example, in terms of the increased time and travel needed to access drinking water in rural communities affected by droughts or salinization. Furthermore, environmental vulnerability can also mean that in the case of a hazardous event occurring, the community may lose access to the only available water resource or face a major reduction in productivity of the soil, which then also increases the risk of crop failure. For instance, Renaud (2006) underscored that the salinization of wells after the 2004 Indian Ocean tsunami had a highly negative consequence for those communities that had no alternative access to freshwater resources.

2.5.1.1. Physical Dimensions

Within the environmental dimension, physical aspects refer to a location-specific context for human-environment interaction (Smithers and Smit, 1997) and to the material world (e.g., built structures).

The physical *exposure* of human beings to hazards has been partly shaped by patterns of settlement of hazard-prone landscapes for the countervailing benefits they offer (UNISDR, 2004). Furthermore, in the context of climate change, physical exposure is in many regions also increasing due to spatial extension of natural hazards, such as floods, areas affected by droughts, or delta regions affected by salinization. This does not make the inhabitants of such locations vulnerable per se because they may have capacities to resist the impacts of extreme events; this is the essential difference between exposure and vulnerability. 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, and 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). Further, Cutter's (1996) 'hazards of place' model of vulnerability expressly refers to the temporal dimension (see Section 2.5.4.2), which, in recognizing the dynamic nature of place vulnerability, argues for a more nuanced approach.

2.5.1.2. Geography, Location, Place

Aggregate trends in the environmental dimensions of exposure and vulnerability as they relate to geography, location, and place are given in Chapters 3 and 4, while this section deals with the more conceptual aspects.

There is a significant difference in exposure and vulnerability between developing and developed countries. While a similar (average) number of people in low and high human development countries may be exposed to hazards each year (11 and 15% respectively), the average numbers killed is very different (53 and 1% respectively) (Peduzzi, 2006).

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 (IPCC, 2001; McCarthy et al., 2001; Beg et al., 2002). Small Island Developing States, a number of which are also Least Developed Countries, are recognized as being highly vulnerable to external shocks including climate extremes (UN/DESA, 2010; Chapter 3). While efforts in climate change adaptation have been undertaken, progress has been limited, focusing on public awareness, research, and policy development rather than implementation (UN/DESA, 2010).

Developed countries are also vulnerable and have geographically distinct levels of vulnerability, which are masked by a predominant focus on direct impacts on biophysical systems and broad economic sectors. However, indirect and synergistic effects, differential vulnerabilities, and assumptions of relative ease of adaptation within apparently robust developed countries may lead to unforeseen vulnerabilities (O'Brien et al., 2006). Thus, development per se is not a guarantee of 'invulnerability.' Development can undermine ecosystem resilience on the one hand but create wealth that may enhance societal resilience overall if equitable (Barnett, 2001).

The importance of geography has been highlighted in an analysis of 'disaster hotspots' by Dilley et al. (2005). Hazard exposure (event incidence) is combined with historical vulnerability (measured by mortality and economic loss) in order to identify geographic regions that are at risk from a range of geophysical hazards. While flood risk is widespread across a number of regions, drought and especially cyclone risk demonstrate distinct spatial patterns with the latter closely related to the climatological pattern of cyclone tracks and landfall.

2.5.1.3. Settlement Patterns and Development Trajectories

There are specific exposure/vulnerability dimensions associated with urbanization (Hardoy and Pandiella, 2009) and rurality (Scoones, 1998; Nelson et al., 2010a,b). The major focus below is on the urban because of the increasing global trend toward urbanization and its potential for increasing exposure and vulnerability of large numbers of people.

2.5.1.3.1. The urban environment

Accelerated urbanization is an important trend in human settlement, which has implications for the consideration of exposure and vulnerability to extreme events. There has been almost a quintupling of the global urban population between 1950 and 2011 with the majority of that increase being in less developed regions (UN-HABITAT, 2011).

There is *high confidence* that rapid and unplanned urbanization processes in hazardous areas exacerbate vulnerability to disaster risk (Sánchez-Rodríguez et al., 2005). The development of megacities with high population densities (Mitchell, 1999a,b; Guha-Sapir et al., 2004) has led to greater numbers being exposed and increased vulnerability through, *inter alia*, poor infrastructural development (Uitto, 1998) and the synergistic effects of intersecting natural, technological, and social risks (Mitchell, 1999a). Lavell (1996) identified eight contexts of cities that increase or contribute to disaster risk and vulnerability and are relevant in the context of climate change:

1) The synergic nature of the city and the interdependency of its parts
2) The lack of redundancy in its transport, energy, and drainage systems
3) Territorial concentration of key functions and density of building and population
4) Mislocation
5) Social-spatial segregation
6) Environmental degradation
7) Lack of institutional coordination
8) The contrast between the city as a unified functioning system and its administrative boundaries that many times impede coordination of actions.

The fact that urban areas are complex systems poses potential management challenges in terms of the interplay between people, infrastructure, institutions, and environmental processes (Ruth and Coelho, 2007). Alterations or trends in any of these, or additional components of the urban system such as environmental governance (Freudenberg et al., 2008) or the uptake of insurance (McLemand and Smit 2006; Lamond et al., 2009), have the potential to increase exposure and vulnerability to extreme climate events substantially.

The increasing polarization and spatial segregation of groups with different degrees of vulnerability to disaster have been identified as an emerging problem (Mitchell, 1999b). For the United States, where there is considerable regional variability, the components found to consistently increase social vulnerability (as expressed by a Social Vulnerability Index) are density (urbanization), race/ethnicity (see below), and socioeconomic status, with the level of development of the built environment, age, race/ethnicity, and gender accounting for nearly half of the variability in social vulnerability among US counties (Cutter and Finch, 2008). Social isolation, especially as it intersects with individual characteristics (see Case Study 9.2.1) and other social processes of marginalization (Duneier, 2004) also play a significant role in vulnerability creation (or, conversely, reduction).

Rapidly growing urban populations may affect the capacity of developing countries to cope with the effects of extreme events because of the inability of governments to provide the requisite urban infrastructure or for citizens to pay for essential services (UN-HABITAT, 2009). However, there is a more general concern that there has been insufficient attention to both existing needs for infrastructure maintenance and appropriate ongoing adaptation of infrastructure to meet potential climate extremes (Auld and MacIver, 2007). Further, while megacities have been associated with increasing hazard for some time (Mitchell, 1999a), small cities and rural communities are potentially more vulnerable to disasters than big cities or megacities, since megacities have considerable resources for dealing with hazards and disasters (Cross, 2001) and smaller settlements are often of lower priority for government spending.

The built environment can be both protective of, and subject to, climate extremes. Inadequate structures make victims of their occupants and, conversely, adequate structures can reduce human vulnerability. The continuing toll of deaths and injuries in unsafe schools (UNISDR, 2009a), hospitals and health facilities (PAHO/World Bank, 2004), domestic structures (Hewitt, 1997), and infrastructure more broadly (Freeman and Warner 2001) are indicative of the vulnerability of many parts of the built environment. In a changing climate, more variable and with potentially more extreme events, old certainties about the protective ability of built structures are undermined.

The increase in the number and extent of informal settlements or slums (UN-HABITAT, 2003; Utzinger and Keiser, 2006) is important because they are often located on marginal land within cities or on the periphery because of the lack of alternative locations or the fact that areas close to river systems or areas at the coast are sometimes state land that can be more easily accessed than private land. Because of their location, slums are often exposed to hydrometeorological-related hazards such as landslides (Nathan, 2008) and floods (Bertoni, 2006; Colten, 2006; Aragon-Durand, 2007; Douglas et al., 2008; Zahran et al., 2008). Vulnerability in informal settlements can also be elevated because of poor health (Sclar et al., 2005), livelihood insecurity (Kantor and Nair, 2005), lack of access to service provision and basic needs (such as clean water and good governance), and a reduction in the capacity of formal players to steer developments and adaptation initiatives in a comprehensive, preventive, and inclusive way (Birkmann et al., 2010b). 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 rapidly growing informal and poor urban areas are often hotspots of hazard exposure, for a number of locations the urban poor have developed more or less successful coping and adaptation strategies to reduce their vulnerability in dealing with changing environmental conditions (e.g., Birkmann et al., 2010b).

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 (McGranahan et al., 2007; Nicholls et al., 2011). 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 (for more on this see Section 2.5.2.3 and Chapters 3, 5, and 9). For some cities there is clear evidence of a recent trend in loss of green space (Boentje and Blinnikov, 2007; Sanli et al., 2008; Rafiee et al., 2009) 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, urban heat island mitigation effects, and alterations in biodiversity (Wilby and Perry, 2006).

While megacities have been associated with increasing hazard for some time (Mitchell, 1999a), small cities and rural communities (see next section) are potentially more vulnerable to disasters than big cities or megacities, since megacities have considerable resources for dealing with hazards and disasters (Cross, 2001) and smaller settlements are often of lower priority for government spending.

Urbanization itself 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.

2.5.1.3.2. The rural environment

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, labor, ecosystem services, and other resources. All of these (and more) can be impacted by climate-related variability and extremes including changes in these associated with climate change. In either case, it is necessary to identify the many exogenous factors that affect a household's 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. The findings point to economic uncertainty over environmental risk, which most influences agricultural households' decisionmaking. However, there is not a direct and inevitable link between disaster impact and increased impoverishment of a rural population. In Nicaragua, Jakobsen (2009) found that 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 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 and were independent of having experienced Hurricane Mitch. Thus, while poor (rural) households may cope with the impacts of a disaster in the relatively short term, their level of vulnerability, arising from a complex of environmental, social, economic, and political factors, is such that they cannot escape the poverty trap or fully reinstate development gains.

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; it is not possible to show that either rural or urban environments are more vulnerable (or resilient). In either context there is the potential that climate risks can be either ameliorated or exacerbated by positive or negative adaptation processes and outcomes.

2.5.2. Social Dimensions

The social dimension is multi-faceted and cross-cutting. It focuses primarily on aspects of societal organization and collective aspects rather than individuals. However, some assessments also use the 'individual' descriptor to clarify issues of scale and units of analysis (Adger and Kelly, 1999; K. 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 demography, migration, and displacement, social groups, education, health and well-being, culture, institutions, and governance aspects.

2.5.2.1. Demography

Certain population groups may be more vulnerable than others to climate variability and extremes. For example, the very young and old are more vulnerable to heat extremes than other population groups (Staffogia et al., 2006; Gosling et al., 2009). 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. However, as discussed further below (Social Groups section), static checklists of vulnerable groups do not reflect the diversity or dynamics of people's changing conditions.

2.5.2.1.1. Migration and displacement

Trends in migration, as a component of changing population dynamics, have the potential to rise because of alterations in extreme climate event frequency. The United Nations Office for the Coordination of Humanitarian Affairs and the Internal Displacement Monitoring Centre have estimated that around 20 million people were displaced or evacuated in 2008 because of rapid onset climate-related disasters (OCHA/IDMC, 2009). Further, over the last 30 years, twice as many people have been affected by droughts (slow onset events not included in the previous point) as by storms (1.6 billion compared with approximately 718 million) (IOM, 2009). However, because of the multi-causal nature of migration, the relationship between climatic variability and change in migration is contested (Black, 2001) as are the terms environmental and climate refugees (Myers, 1993; Castles 2002; IOM, 2009). Despite an increase in the number of hydrometeorological disasters between 1990 and 2009, the International Organization on Migration reports no major impact on international migratory flows because displacement is temporary and often confined within a region, and displaced individuals do not possess the financial resources to migrate (IOM, 2009).

Although there is also a lack of clear evidence for a systematic trend in extreme climate events and migration, there are clear instances of the impact of extreme hydrometeorological 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, 2011); in the Mekong River Delta region, changing flood patterns appear to be associated with migratory movements (White, 2002; IOM, 2009); and Hurricane Katrina, for which social vulnerability, race, and class played an important role in outward and returning migration (Elliott and Pais, 2006; Landry et al., 2007; Myers et al., 2008), resulted in the displacement of over one million people. As well as the displacement effect, there is evidence for increased vulnerability to extreme events among migrant groups because of an inability to understand extreme event-related information due to language problems, prioritization of finding employment and housing, and distrust of authorities (Enarson and Morrow, 2000; Donner and Rodriguez, 2008).

Migration can be 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 economically and environmentally displaced persons 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 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. As part of the Impoverishment Risks and Reconstruction approach, Cernea (1996) outlines the eight basic risks to which people are subjected by displacement: landlessness, joblessness, homelessness, marginalization, food insecurity, increased morbidity, loss of access to common property resources, and social disarticulation. 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). Displacement for any group can be distressing, but for indigenous peoples it can result in particularly severe impacts. 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 (Cernea, 1996; Scudder, 2005).

Migration is an ancient coping mechanism in response to environmental (and other) change and does not inevitably result in negative outcomes, either for the migrants themselves or for receiving communities (Barnett and Webber, 2009). Climate variability will result in some movement of stressed people but there is *low confidence* in ability to assign direct causality to climatic impacts or to the numbers of people affected.

2.5.2.1.2. Social groups

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 (Bohle et al., 1994; Kasperson and Kasperson, 2001; Thomalla et al., 2006). Particular groups and conditions have been identified as having differential exposure or vulnerability to extreme events, for example race/ethnicity (Fothergill et al., 1999; Elliott and Pais, 2006; Cutter and Finch, 2008), socioeconomic class and caste (O'Keefe et al., 1976; Peacock et al., 1997; Ray-Bennett, 2009), gender (Sen, 1981), age (both the elderly and children; Jabry, 2003; Wisner, 2006b; Bartlett, 2008), migration, and housing tenure (whether renter or owner), as among the most common social vulnerability characteristics (Cutter and Finch, 2008). Morrow (1999) extends and refines this list to include residents of group living facilities; ethnic minorities (by language); recent migrants (including immigrants); tourists and transients; physically or mentally disabled (see also McGuire et al., 2007; Peek and Stough, 2010); large households; renters; large concentrations of children and youth; poor households; the homeless (see also Wisner, 1998); and women-headed households. Generally, the state of vulnerability is defined by a specific population at a particular scale; aggregations (and generalizations) are often less meaningful and require careful interpretation (Adger and Kelly, 1999).

One of the largest bodies of research evidence, 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 disaster, 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 including self-defined gender groups has been even more recent (e.g., Masika, 2002; Pincha and Krishna, 2009). The research evidence emphasizes 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 decisionmaking fora, and discriminated and acted against in post-disaster recovery and reconstruction efforts (Houghton, 2009; Sultana, 2010).

Women or other socially marginalized or excluded groups are not vulnerable through biology (except in very particular circumstances) but are made so by societal structures and roles. For example, in the Indian Ocean tsunami of 2004, many males were out to sea in boats, fulfilling their roles as fishermen, and were thus less exposed than were many women who were on the seashore, fulfilling their roles as preparers and marketers of the fish catch. However, the women were made vulnerable not simply by their location and role but by societal norms which did not encourage survival training for girls (e.g., to swim or climb trees) and which placed the majority of the burden of child and elder care with women. Thus, escape was made more difficult for women carrying children and responsible for others (Doocy et al., 2007).

The gender and disaster/climate change literature has also recognized resilience/capacity/capability alongside vulnerability. This elaboration of the vulnerability approach makes clear that vulnerability in these identified groups is not an immutable or totalizing condition. The vulnerability 'label' can reinforce notions of passivity and helplessness, which obscure the very significant, active contributions that socially marginalized groups make in coping with and adapting to extremes. An example is provided in Box 2-2.

2.5.2.2. Education

The education dimension ranges across the vulnerability of educational building structures; issues related to access to education; and also sharing and access to disaster risk reduction and climate adaptation information and knowledge (Wisner, 2006b). 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). In addition to knowledge and information, explicit environmental education programs among children and adults may have benefits for public understanding of risk, vulnerability, and exposure to extreme events (UNISDR, 2004; Kobori, 2009; Nomura, 2009; Patterson et al., 2009; Kuhar et al., 2010), because they promote resilience building in socio-ecological systems through their role in stewardship of biological diversity and ecosystem services, provide the opportunity to integrate diverse forms of knowledge and participatory processes in resource management (Krasny and Tidball, 2009), and help promote action towards sustainable development (Waktola, 2009; Breiting and Wikenberg, 2010).

Many lives have been lost through the inability of education infrastructure to withstand extreme events. Where flooding is a recurrent phenomenon schools can be exposed or vulnerable to floods. For example, a survey of primary schools' flood vulnerability in the Nyando River catchment of western Kenya revealed that 40% were vulnerable, 48% were

Box 2-2 | Integrating Disaster Risk Reduction, Climate Adaptation, and Resilience-Building: the Garifuna Women of Honduras

The Garifuna women of Honduras could be said to show multiple vulnerability characteristics (Brondo, 2007). 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 marginalized; 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 (Fordham et al., 2011).

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, there was a lack of external support and so the Comité women organized themselves and 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, 16 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), and improved their communities' nutrition, incomes, natural resources, and risk management. They continue to partner with local, regional, and international networks for advocacy and knowledge exchange. The women and communities are still at risk (Drusine, 2005) but these strategies help reduce their socioeconomic vulnerability and dependence on external aid (Fordham et al., 2011).

marginally vulnerable, and 12% were not vulnerable; the vulnerability status was attributed to a lack of funds, poor building standards, local topography, soil types and inadequate drainage (Ochola et al., 2010). Improving education infrastructure safety can have multiple benefits. For example, the Malagasy Government initiated the Development Intervention Fund IV project to reduce cyclone risk, including safer school construction and retrofitting. In doing so, awareness and understanding of disaster issues were increased within the community (Madagascar Development Intervention Fund, 2007).

The impact of extreme events can limit the ability of parents to afford to educate their children or require them (especially girl children, whose access to education is typically prioritized less than that of boy children) to work to meet basic needs (UNDP, 2004; UNICEF, 2009).

Access to information related to early warnings, response strategies, coping and adaptation mechanisms, science and technology, and 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, the mode of information transfer or exchange must be considered because there is emerging evidence of a growing digital inequality (Rideout, 2003) that may influence trends in vulnerability as an increasing amount of information about extreme event preparedness and response is often made available via the internet (see Chapter 9). Evidence has existed for some time that people who have experienced natural hazards (and thus may have information and knowledge gained directly through that experience) are, in general, better prepared than those who have not (Kates, 1971). However, this does not necessarily translate into protective behavior because of what has been called the 'prison of experience' (Kates, 1962), in which people's response behavior is determined by the previous experience and is not based on an objective assessment of current risk. In the uncertain context of climate-related extremes, this may mean people are not appropriately educated regarding the risk.

2.5.2.3. Health and Well-Being

The health dimension of vulnerability includes differential physical, physiological, and mental health effects of extreme events in different regions and on different social groups (McMichael et al., 2003; van Lieshout et al., 2004; Haines et al., 2006; Few, 2007; 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 center building structures; inability to access health services because of storms and floods). Vulnerability can also be understood in terms of functionality related to communication, medical care, maintaining independence, supervision, and transportation. In addition individuals including children, senior citizens, and pregnant women and those who may need additional response assistance including the disabled, those living in institutionalized settings, those from diverse cultures, people with limited English proficiency or are non-English speaking, those with no access to transport, have chronic medical disorders, and have pharmacological dependency can also be considered vulnerable in a health context.

Unfortunately, the health dimensions of disasters are difficult to measure because of difficulties in attributing the health condition (including mortality) directly to the extreme event because of secondary effects; in addition, some of the effects are delayed in time, which again makes attribution difficult (Bennet, 1970; Hales et al., 2003). The difficulty of collection of epidemiological data in crisis situations is also a factor, especially in low-income countries. Further understanding the post-traumatic stress disorder dimensions of extreme climate events and the psychological aspects of climate change presents a number of challenges (Amstadter et al., 2009; Kar, 2009; Mohay and Forbes, 2009; Furr et al., 2010; Doherty and Clayton, 2011).

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 medical conditions (e.g., diabetics are at increased risk during heat waves); acquired conditions (e.g., malaria immunity); and genetic factors (Balbus and Malina, 2009). Vulnerability can be viewed both from the perspective of the population groups more likely to experience adverse health outcomes and from the perspective of the public health and health care interventions required to prevent adverse health impacts during and following an extreme event.

For some extreme weather events the vulnerable population groups depend on the adverse health outcome considered. For example, in the case of heat waves socially isolated elderly people with pre-existing medical conditions are vulnerable to heat-related health effects (see Chapter 9). For floods, 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 (Ahern et al., 2005), while 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). Flooding has been found to increase the risk of mental health problems, pre- and post-event, in both adults and children (Ginexi et al., 2000; Reacher et al., 2004; Ahern et al., 2005; Carroll et al., 2006; Tunstall et al., 2006; UK Department of Health, 2009). A UK study of over 1,200 households affected by flooding suggested that there were greater impacts on physical and mental health among more vulnerable groups and poorer households and communities (Werritty et al., 2007). However, while there is evidence for impacts on particular social groups in identified disaster types, there are some social groups that are more likely to be vulnerable whatever the hazard type; these include those at the extremes of the age range, those with underlying medical conditions, and those otherwise stressed by low socioeconomic status. The role of socioeconomic factors supports the necessity of a social, and not just a medical, model of response and adaptation.

A number of public health impacts are expected to worsen in climate-related disasters such as storms, floods, landslides, heat, drought, and wildfire. These are highly context-specific but range from worsening of existing chronic illnesses (which could be widespread), through possible toxic exposures (in air, water or food), to deaths (expected to be few to moderate but may be many in low-income countries) (Keim, 2008). 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 or mitigate displacement, and effective warning and informing systems (Keim, 2008). Further, it is important to consider the synergistic effects of NaTech disasters (Natural Hazard Triggering a Technological Disaster) where impacts can be considerable if only single, simple hazard events are planned for. In an increasingly urbanized world, interactions between natural disasters and simultaneous technological accidents must be given attention (Cruz et al., 2004); the combination of an earthquake, tsunami, and radiation release at the Japanese Fukushima Nuclear Power plant in March 2011 is the most recent example. Lack of provision of these services increases population vulnerability, particularly in individuals with greater biological sensitivity to an adverse health outcome. 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 recognized in the context of extreme climate events (Burkle and Greenough, 2008; Keim, 2008).

Deteriorating environmental conditions as a result of extremes (including land clearing, salinization, dust generation, altered ecology; Renaud, 2006; Middleton et al., 2008; Ellis and Wilcox, 2009; Hong et al., 2009; Ljung et al., 2009; Johnson et al., 2010; Tong et al., 2010) can impact key ecosystem services and exacerbate climate sensitive disease incidence (e.g., diarrheal disease; Clasen et al., 2007), particularly via deteriorating water quality and quantity.

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 (Bouchama et al., 2007) has been noted to be on the increase in a number of developed countries (Skelton et al., 2009; Stamatakis 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.

However, trends in well-being and health are difficult to assess. Indicators that characterize a lack of well-being and a high degree of susceptibility are, for example, indicators of undernourishment and malnutrition. The database for the Millennium Development Goals and respective statistics of the Food and Agriculture Organization (FAO) underscore that trends in undernourishment are spatially and temporally differentiated. While, as but one example, the trend in undernourished people in Burundi shows a significant increase from 1991 to 2005, an opposite trend of a reduction in the percentage of undernourished people can be observed in Angola (see UN Statistics Division, 2011; FAOSTAT, 2011). Thus, evidence exists that trends in vulnerability, e.g., in terms of well-being and undernourishment change over time and are highly differentiated in terms of spatial patterns.

In considering health-related exposure and vulnerability to extreme events, evidence from past climate/weather-related disaster events (across a range of hazard types for which lack of space precludes coverage) makes clear the links to a range of negative outcomes for physical and mental health and health infrastructure. Furthermore, there is clear evidence (Haines et al., 2006; Confalonieri et al., 2007) that current and projected health impacts from climate change are multifarious and will affect low-income groups and low-income countries the most severely, although high-income countries are not immune.

2.5.2.4. Cultural Dimensions

The broad term 'culture' embraces a complexity of elements that can relate to a way of life, behavior, 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 summarized 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:

- 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 two ethnic groups have adopted very different strategies due to cultural values and historical relations, despite their presence in the same physical environment and their shared experience of climate change (Nielsen and Reenberg, 2010).
- *Locally Based Risk Management Culture.* Wisner (2003) has argued that the point in developing a 'culture of prevention' is to build networks at the neighborhood level capable of ongoing hazard assessment and mitigation at the micro level. He has noted that while community based NGOs 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 be found to extend the agenda of Community-Based Organizations 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 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). However, this can be problematic if adaptation is limited to specific local interests only.

Traditional behaviors 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., 2007, 2010). Furthermore, cultural practices are often subtle and may be opaque to outsiders. The early hazards paradigm literature (White, 1974; Burton et al., 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).

Research findings emphasize the importance of considering the role – and cultures – of religion and faith in the context of disaster. This includes the role of faith in the recovery process following a disaster (e.g., Davis and Wall, 1992; Massey and Sutton, 2007); religious explanations of nature (e.g., Orr, 2003; Peterson, 2005); the role of religion in influencing positions on environment and climate change policy (e.g., Kintisch, 2006; Hulme, 2009); and religion and vulnerability (Guth et al., 1995; Chester, 2005; Elliott et al., 2006; Schipper, 2010).

The cultural dimension also includes the potential vulnerability of aboriginal and native peoples in the context of climate extremes. Globally, indigenous populations are frequently dependent on primary production and the natural resource base while being subject to (relatively) poor socioeconomic conditions (including poor health, high unemployment, low levels of education, and greater poverty). This applies to groups from Canada (Turner and Clifton, 2009), to Australia (Campbell et al., 2008), to the Pacific (Mimura et al., 2007). Small island states, often with distinct cultures, typically show high vulnerability and low adaptive capacity to climate change (Nurse and Sem, 2001). However, historically, indigenous groups have had to contend with many hazards and, as a consequence, have developed capacities to cope (Campbell, 2006) such as the use of traditional knowledge systems, locally appropriate building construction with indigenous materials, and a range of other customary practices (Campbell, 2006).

Given the degree of cultural diversity identified, the importance of understanding differential risk perceptions in a cultural context is reinforced (Marris et al., 1998). Cultural Theory has contributed to an understanding of how people interpret their world and define risk according to their worldviews: hierarchical, fatalistic, individualistic, and egalitarian (Douglas and Wildavsky, 1982). Too often policies and studies focus on 'the public' in the aggregate and too little on the needs, interests, and attitudes of different social and cultural groups (see also Sections 2.5.2.1.2 and 2.5.4).

2.5.2.5. Institutional and Governance Dimensions

The institutional dimension is a key determinant of vulnerability to extreme events (Adger, 1999). Institutions have been defined in a broad sense to include "habitualized behavior and rules and norms that govern society" (Adger, 2000) and not just the more typically understood formal institutions. This view allows for a discussion of institutional structures such as property rights and land tenure issues (Toni and Holanda, 2008) that govern natural resource use and management. It forms a bridge between the social and the environmental/ecological dimensions and can induce sustainable or unsustainable exploitation (Adger, 2000). Expanding the institutional domain to include political economy (Adger, 1999) and different modes of production – feudal, capitalist, socialist (Wisner, 1978) – raises questions about the vulnerability *of* institutions and the vulnerability caused *by* institutions (including government). Institutional factors play a critical role in adaptation (Adger, 2000) as they influence the social distribution of vulnerability and shape adaptation capacity (Næss et al., 2005).

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 that 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). For example, social capital/assets (Portes, 1998; Putnam, 2000) – "the norms and networks that enable people to act collectively" (Woolcock and Narayan, 2000) – have a role in vulnerability reduction (Pelling, 1998). Social capital (or its lack) is both a cause and effect of vulnerability and thus can result in either positive benefit or negative impact; to be a part of a social group and accrue social assets is often to indicate others' exclusion. It also includes attempts to reframe climate debates by acknowledging the possibility of diverse impacts on human security, which opens up human rights discourses and rights-based approaches to disaster risk reduction (Kuwali, 2008; Mearns and Norton, 2010).

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 recognize 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) adopts the latter approach. This guideline document, which has been field tested by NGOs, 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 167 characteristics (organized under five thematic areas) also refers to institutional forms for (and processes of) engagement with risk assessment, risk management, and hazard and vulnerability mapping. These have been championed by institutions working across scales to create the Hyogo Framework for Action (UNISDR, 2007a) and associated tools (Davis et al., 2004; UNISDR, 2007b) with the goal to reduce disaster risk and vulnerability. However, linkages across scales and the inclusion of local knowledge systems are still not integrated well in formal institutions (Næss et al., 2005).

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; Mitchell and van Aalst, 2008; Mitchell et al., 2010). Thus, 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 either vulnerability creation or reduction (Comfort et al., 1999). Furthermore, risk-specific policies must also be integrated (see the slippage between UK heat and cold wave policies, Wolf et al., 2010a). However, further study of the role of institutions in influencing vulnerability is called for (O'Brien et al., 2004b).

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 habitualized behavior and norms that govern society and guide actors are representing governance structures (Adger, 2000; Biermann et al., 2009). These formal and informal governance structures also determine vulnerability, since they influence power relations, risk perceptions, and constitute the context in which vulnerability, risk reduction, and adaptation are managed.

Conflicts between formal and informal governance or governmental and nongovernmental 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 expend resources to deal with increasing flood events (e.g., adapting their livelihoods and production patterns to changing flood regimes), formal adaptation strategies, particularly in developing countries, prioritize structural measures (e.g., dike systems or relocation strategies) that have severe consequences for the vulnerability of communities dependent on local ecosystem services, such as fishing and farming systems (see Birkmann, 2011a,b). These conflicts between formal and informal or governmental and nongovernmental management systems and norms are an important factor that increase vulnerability and reduce adaptive capacity of the overall system (Birkmann et al., 2010b). Countries with institutional and governance fragilities often lack the capacity to identify and reduce risks and to deal with emergencies and disasters effectively. 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 resilience and vulnerability.

In some developed countries, the last 30 years have witnessed a shift in environmental governance practices toward more integrated approaches. 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 the global in environment policies (Karlsson, 2007), and co-management and involvement of stakeholders from all sectors in the management of natural resources (Plummer, 2006; McConnell, 2008), although some have also questioned the efficacy of this new paradigm (Armitage et al., 2007; Sandstrom, 2009).

2.5.3. Economic Dimensions

Economic vulnerability can be understood as the susceptibility of an 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. At a macroeconomic level, adverse impacts include effects on gross domestic product (GDP), consumption, and the fiscal position (Mechler et al., 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 focusing 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, in this context, denotes the ability of economic agents to absorb risk financially (Arrow and Lind, 1970). There are many ways to absorb the financial burdens of disasters, with market-based insurance being one, albeit prominent, option, although more particularly in a developed country context. Households as economic agents often use informal mechanisms relying on family and relatives abroad or outside a disaster area; governments may simply rely on their tax base or international assistance. Yet, 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; Marulanda et al., 2008a; Cardona, 2009; Cummins and Mahul, 2009). 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 et al., 2005).

There is a distinct scale aspect to the economic dimension of exposure and vulnerability. While evidence of the economic costs of known disasters indicate impacts may be under 10% of GDP (Wilbanks et al., 2007), at smaller and more local scales the costs can be significantly greater. A lack of good data makes it difficult to provide meaningful and specific assessments other than to acknowledge that, without investment in adaptation and resilience building measures, the intensification or increased frequency of extreme weather events is bound to impact GDP growth in the future (Wilbanks et al., 2007).

Work and Livelihoods

At the individual and community levels, work and livelihoods are an important facet of the economic dimension. These are often 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 (Pantuliano and Wekesa, 2008). Further, there is increasing recognition that disasters and extreme events are stresses and shocks within livelihood development processes (Cannon et al., 2003; see Kelman and Mather, 2008, for a discussion of cases applying to volcanic events).

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 (see also Section 2.5.1.3). 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 (Paavola, 2008).

Human vulnerability to natural hazards and income poverty are largely codependent (Adger, 1999; UNISDR, 2004) but poverty does not equal vulnerability in a simple way (e.g., Blaikie et al., 1994); the determinants and dimensions of poverty are complex as well as its association with climate change (Khandlhela and May, 2006; Demetriades and Esplen, 2008; Hope, 2009). It is important to recognize that adaptation measures need to specifically target climate extremes-poverty linkages as not all poverty reduction measures reduce vulnerability to climate extremes and vice versa. Further, measures are required across scales because the drivers of poverty, although felt at a local level, may necessitate tackling political and economic issues at a larger scale (Eriksen and O'Brien, 2007; K. O'Brien et al., 2008).

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 because it has the potential to simultaneously increase greenhouse gas emissions. Furthermore, growth is often reliant on critical infrastructure which itself may be affected by extreme events. There are many questions still to be answered by research about the impacts of varying economic policy changes including the pursuit of narrow development trajectories and how this might shape vulnerability (Tol et al., 2004; UNDP, 2004; UNISDR, 2004)

2.5.4. Interactions, Cross-Cutting Themes, 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). Increasingly it is recognized that collaboration and integration is necessary both to set appropriate policy agendas and to better understand the topic of interest (K. O'Brien et al., 2008), although McLaughlin and Dietz (2008) have made a critical analysis of the absence of an integrated perspective on the interrelated dynamics of social structure, human agency, and the environment.

Reviewing singular dimensions of vulnerability cannot provide an appropriate level of synthesis. Considerable conceptual advances arose from the early recognition that so-called natural disasters were not 'natural' at all (O'Keefe et al., 1976) but were the result of structural inequalities rooted in political economy. This critique required analysis of more than the hazard component (Blaikie et al., 1994). Further, it demonstrated how crossing disciplinary and other boundaries (e.g., those separating disaster and development, or developed and developing countries) can be fruitful in better understanding extremes of various kinds (see Hewitt, 1983). If we consider food security/vulnerability (as just one example), an inclusive analysis of the vulnerability of food systems (to put it broadly), must take account of aspects related to, *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 et al., 2005); landscape ecology (Fraser, 2006); human ecology (Bohle et al., 1994); and political ecology (Pulwarty and Riebsame, 1997; Holling, 2001; see Chapter 4 for further discussion of food systems and food security). More generally, in relation to hazards, disaster risk reduction, and climate extremes, productive advances have been made in research adopting a coupled human/social-environment systems approach (Holling, 2001; Turner et al., 2003b) which recognizes the importance of integrating often separate domains. For example, in analyzing climate change impacts, vulnerability, and adaptation in Norway, O'Brien et al. (2006) argue that a simple examination of direct climate change impacts underestimates the, perhaps more serious and larger, synergistic impacts. They use an example of projected climate change effects in the Barents Sea, which may directly impact keystone fish species. However, important as this finding is, climate change may also influence the transport sector (through reduction in ice cover); increase numbers of pollution events (through increased maritime transport of oil and other goods); may risk ecological and other damages as a result of competition from introduced species in ballast water; which, in turn, are aggravated by increases in ocean temperatures. Neither the potential level of impact nor the processes of adaptation are best represented by a singular focus on a particular sector but must consider interactions between sectors and institutional, economic, social, and cultural conditions (O'Brien et al., 2006).

2.5.4.1. Intersectionality and Other Dimensions

The dimensions discussed above generate differential effects but it is important to consider not just differences between single categories (e.g., between women and men) but the differences *within* a given category (e.g., 'women'). This refers to intersectionality, where, for example, gender may be a significant variable but only when allied with race/ethnicity or some other variable. In Hurricane Katrina, it mattered (it still matters) whether you were black or white, upper class or working class, home owner or renter, old or young, woman or man in terms of relative exposure and vulnerability factors (Cutter et al., 2006; Elliott and Pais, 2006).

Certain factors are identified as cross-cutting themes of particular importance for understanding the dynamic changes within exposure, vulnerability, and risk. In the Sphere Project's minimum standards in humanitarian response, children, older people, persons with disabilities, gender, psychosocial issues, HIV and AIDS, and environment, climate change, and disaster risk reduction are identified as cross-cutting themes and must be considered, not as separate sectors, which people may or may not select for attention, but must be integrated within each sector (Sphere Project, 2011). Exactly which topics are selected as cross-cutting themes, to be incorporated throughout an activity, is context-specific. Below, we consider just two: different timing (diachronic aspects within a single day or across longer time periods) and different spatial and functional scales.

2.5.4.2. Timing, Spatial, and Functional Scales

Cross-cutting themes of particular importance for understanding the dynamic changes within exposure, vulnerability, and risk are different timing (diachronic aspects within a single day or across longer time periods) and different spatial and functional scales.

2.5.4.2.1. Timing and timescales

Timing and timescales 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 timescales is the fact that different hazards and their recurrence 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 different 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 present socioeconomic data. However, a key challenge for enhancing knowledge of exposure and vulnerability as key determinants of risk requires improved data and methods to project and identify directions and different development pathways in demographic, socioeconomic, and political trends that can adequately illustrate potential increases or decreases in vulnerability with the same time horizon as the changes in the climate system related to physical-biogeochemical projections (see Birkmann et al., 2010b).

Furthermore, the time dependency of risk analysis, particularly if the analysis is conducted at a specific point in time, has been shown to be critical. Newer research underlines that exposure – especially the exposure of different social groups – is a highly dynamic element that changes not only seasonally, but also during the day and over different days of the week (e.g., Setiadi, 2011). Disasters also exacerbate pre-disaster trends in vulnerability (Colten et al., 2008).

Consequently, time scales and dynamic changes over time have to be considered carefully when conducting risk and vulnerability assessments for extreme events and creeping changes in the context of climate change. Additionally, changes in the hazard frequency and timing of hazard occurrence during the year will have a strong impact on the ability of societies and ecosystems to cope and adapt to these changes.

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 like slow-onset hazards such as drought or desertification) deals with fast-onset events, in discrete, even if extensive, locations, requiring immediate action. The latter group typically focuses on conditions that occur in a dispersed form over lengthy time periods and which are much more challenging in their identification and measurement (Thomalla et al., 2006). Risk perception may be reduced (Leiserowitz, 2006) for such events remote in time and/or space, such as some climate change impacts are perceived to be. Thus, in this conceptualization, different time scales are an important constraint when dealing with the link between disaster risk reduction and climate change adaptation (see Thomalla et al., 2006; Birkmann and von Teichman, 2010).

However, it is important to also acknowledge that disaster risk reduction considers risk reduction within different time frames; it encompasses short-term emergency management/response strategies and long-term risk reduction strategies, for example, building structures to resist 10,000-year earthquakes or flood barriers to resist 1,000-year storm surges. Modern prospective risk management debates involve security considerations decades ahead for production, infrastructure, houses, hospitals, etc.

2.5.4.2.2. 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) analyze a complex mix of influences (both positive and negative) on the vulnerability, and coping and adaptive capacity of southern African farmers in dealing with climate variability. These include the impacts of globalization on national-level policies and local-level experiences (e.g., structural adjustment programs reducing local-level agricultural subsidies on the one hand, and on the other, trade liberalization measures opening up new opportunities through diversification of production in response to drought). Also Turner et al. (2003a,b) 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 functional 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 may modify encompass different functional scales that cannot be sufficiently captured with one approach. For example, policy setting and management of climate change and of disaster risk reduction are usually the responsibility of different institutions or departments, thus it is a challenge to develop a coherent and integrated strategy (Birkmann and von 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.

2.5.4.3. Science and Technology

Science and technology possess the potential to assist with adaptation to extreme climate events, however there are a number of factors that determine the ultimate utility of technology for adaptation. These include an understanding of the range of technologies available, the identification of the appropriate role for technology, the process of technology transfer, and the criteria applied in selection of the technology (Klein et al., 2006). For major sectors such as water, agriculture, and health a range of possible so-called 'hard' and 'soft' technologies exist such as irrigation and crop rotation pattern (Klein et al., 2006) or the development of drought-resistant crops (IAASTD, 2009) in the case of the agricultural sector.

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), their efficacy in the context of risk and vulnerability reduction remain undetermined.

The increasing integration of a range of emerging weather and climate forecasting products into early warning systems (Glantz, 2003) has helped reduce exposure to extreme climate events because of an increasing improvement of forecast skill over a range of time scales (Goddard et al., 2009; Stockdale et al., 2009; van Aalst, 2009; Barnston et al., 2010; Hellmuth et al., 2011). Moreover, there is an increasing use of weather and climate information for planning and climate risk management in business (Changnon and Changnon, 2010), food security (Verdin et al., 2005), and health (Ceccato et al., 2007; Degallier et al., 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).

2.6. Risk Identification and Assessment

Risk accumulation, dynamic changes in vulnerabilities, and the different phases of crises and disaster situations constitute a complex environment for identifying and assessing risks and vulnerabilities, risk reduction measures, and adaptation strategies. Understanding of extreme events and disasters is a pre-requisite for the development of adaptation strategies in the context of climate change and risk reduction in the context of disaster risk management.

Current approaches to disaster risk management typically involve four distinct public policies or components (objectives) (IDEA, 2005; Carreño, 2006; IDB, 2007; Carreño et al., 2007b):

1) Risk identification (involving individual perception, evaluation of risk, and social interpretation)
2) Risk reduction (involving prevention and mitigation of hazard or vulnerability)
3) Risk transfer (related to financial protection and in public investment)
4) Disaster management (across the phases of preparedness, warnings, response, rehabilitation, and reconstruction after disasters).

The first three actions are mainly *ex ante* – that is, 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 (Cardona, 2004; IDB, 2007). Risk identification, through vulnerability and risk assessment can produce common understanding by the stakeholders and actors. It is the first step for risk reduction, prevention, and transfer, as well as climate adaptation in the context of extremes.

2.6.1. Risk Identification

Understanding risk factors and communicating risks due to climate change to decisionmakers and the general public are key challenges. These challenges include developing an improved understanding of underlying vulnerabilities, and societal coping and response capacities.

There is *high confidence* that the selection of appropriate vulnerability and risk evaluation approaches depends on the decisionmaking context. The promotion of a higher level of risk awareness regarding climate change-induced hazards and changes requires an improved understanding of the specific risk perceptions of different social groups and individuals, including those factors that influence and determine these perceptions, such as beliefs, values, and norms. This also requires attention for appropriate formats of communication that characterize uncertainty and complexity (see, e.g., Patt et al., 2005; Bohle and Glade, 2008; Renn, 2008, pp. 289; Birkmann et al., 2009; ICSU-LAC, 2011a,b, p. 15).

Appropriate information and knowledge are essential prerequisites for risk-aware behavior and decisions. Specific information and knowledge on the dynamic interactions of exposed and vulnerable elements include livelihoods and critical infrastructures, and potentially damaging events, such as extreme weather events or potential irreversible changes such 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 various elements (Kasperson et al., 2005; Patt et al., 2005; Renn and Graham, 2006; Biermann, 2007; Füssel, 2007; Bohle and Glade, 2008; Cutter and Finch, 2008; Renn, 2008; Biermann et al., 2009, Birkmann et al., 2009, 2010b; Cardona, 2010; Birkmann, 2011a; ICSU-LAC, 2011a,b), including:

- Processes by which persons, property, infrastructure, goods, and the environment itself are exposed to potentially damaging events, for example, understanding exposure in its spatial and temporal dimensions.
- Factors and processes that determine or contribute to the vulnerability of persons and their livelihoods or of socio-ecological systems. This includes an understanding of 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.
- How climate change affects 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., NaTech hazards), irreversible changes, or increasing probabilities of hazard events occurrence.
- Different tools, methodologies, and sources of knowledge (e.g., expert/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, for example, of new risks (sea level rise) and of current adaptation strategies.
- 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.
- Adaptive capacity status and limits of adaptation. This includes the need to assess potential capacities for future hazards and for dealing with uncertainty. Additionally, more knowledge is needed on the various and socially differentiated limits of adaptation. These issues also imply an improved understanding on how different adaptation measures influence resilience and adaptive capacities.

2.6.2. Vulnerability and Risk Assessment

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 a broad and multidisciplinary research field. In this regard, vulnerability and risk assessments can have different functions and goals.

Risk and vulnerability assessment depend 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 (UNISDR, 2004; IPCC, 2007).

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. They serve different functions and goals (see IDEA, 2005; Birkmann, 2006a; Cardona, 2006; Dilley, 2006; Wisner, 2006a; IFRC, 2008; Peduzzi et al., 2009).

Risk assessment at the local level presents specific challenges related to a lack of data (including climate data at sufficient resolution, but also socioeconomic 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).

To inform risk management, it is desirable that risk assessments are locally based and result in increased awareness and a sense of local ownership of the process 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 guidance on how to assess climate vulnerability at the community level are available from several sources (see 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 and rigorous analysis of the participatory findings, and the need to keep the process simple, participatory, and implementable at scale. Chapter 5 provides further details on the implementation of risk management at local levels.

The International Standards Organization defines risk assessment as a process to comprehend the nature of risk and to determine the level of risk (ISO, 2009a,b). Additionally, communication within risk assessment and 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 systematizing 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., IDEA, 2005; Birkmann, 2006a; Cardona, 2008; IFRC, 2008), in order to define priorities, select alternative strategies, or 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).

Vulnerability and risk assessments are key strategic activities that inform both disaster risk management and climate change adaptation. These require 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.

Risk estimates are thus intended to be prospective, anticipating scientifically possible hazard events that may occur in the future. Usually technical risk analyses have been associated with probabilities. Taking into account epistemic and aleatory uncertainties the probabilistic estimations of risk attempt to forecast damage or losses even where insufficient data are available on the hazards and the system being analyzed (UNDRO, 1980; Fournier d'Albe, 1985; Spence and Coburn, 1987; Blockley, 1992; Coburn and Spence, 1992; Sheldon and Golding, 1992; Woo, 1999; Grossi and Kunreuther, 2005; Cardona et al., 2008a,b; Cardona 2011). In most cases, approaches and criteria for simplification and for aggregation of different information types and sources are used, due to a lack of data or the inherent low resolution of the information. This can result in 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). Measures such as loss exceedance curves and probable maximum loss for different event return periods 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; ERN-AL, 2011; UNISDR, 2011). However, it is also evident that more qualitative-oriented risk assessment approaches are focusing on deterministic approaches and the profiling of vulnerability using participatory methodologies (Garret, 1999).

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 to make decisions on risk management objectives and goals (Cardona et al., 2003a; IDEA, 2005; Cardona, 2006, 2008, 2010; Carreño et al., 2007b).

However, quantitative approaches for assessing vulnerability need to be complemented with qualitative approaches to capture the full complexity and the various tangible and intangible aspects of vulnerability in its different dimensions. It is important to recognize that complex systems involve multiple variables (physical, social, cultural, economic, and environmental) that cannot be measured using the same methodology. Physical or material reality have a harder topology that allows the use of quantitative measure, while collective and historical reality have a softer topology in which the majority of the attributes 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 nonlinear 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 decisionmaking. Results can be verified and risk management/adaptation priorities can be established (Carreño et al., 2007a, 2009).

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 that also account for dynamic changes in vulnerability, exposure, and risk; and the need to address the requirements of

Box 2-3 | Developing a Regional Common Operating Picture of Vulnerability in the Americas for Various Kinds of Decisionmakers

The Program of Indicators of Disaster Risk and Risk Management for the Americas of the Inter-American Development Bank (IDEA, 2005; Cardona, 2008, 2010) provides a holistic approach to relative vulnerability assessment using social, economic, and environmental indicators and a metric for sovereign fiscal vulnerability assessment taking into account that extreme impacts can generate financial deficit due to a sudden elevated need for resources to restore affected inventories or capital stock.

The Prevalent Vulnerability Index (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, socioeconomic, 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 2-1 shows the aggregated PVI (Exposure, Social Fragility, Lack of Resilience) for 2007.

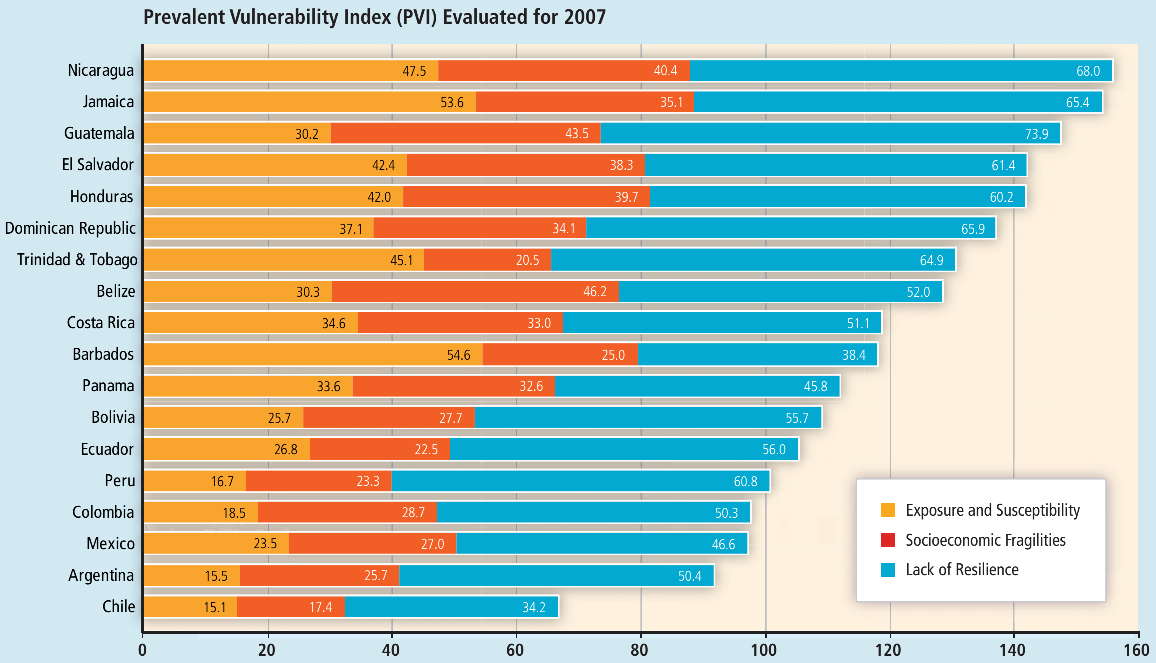

Figure 2-1 | Aggregate Prevalent Vulnerability Index (PVI) for 19 countries of the Americas for 2007. Source: Cardona, 2010.

Vulnerability and therefore risk are also the result of unsustainable economic growth and deficiencies that may be corrected by means of adequate development processes, reducing susceptibility of exposed assets, socioeconomic fragilities, and improving capacities and resilience of society (IDB, 2007). The information provided by an index such as the PVI can 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 may take priority in risk management actions as corrective and prospective measures or interventions of vulnerability from a 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 the national level; this is a limitation for its application at other sub-national scales.

On the other hand, 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

Continued next page →

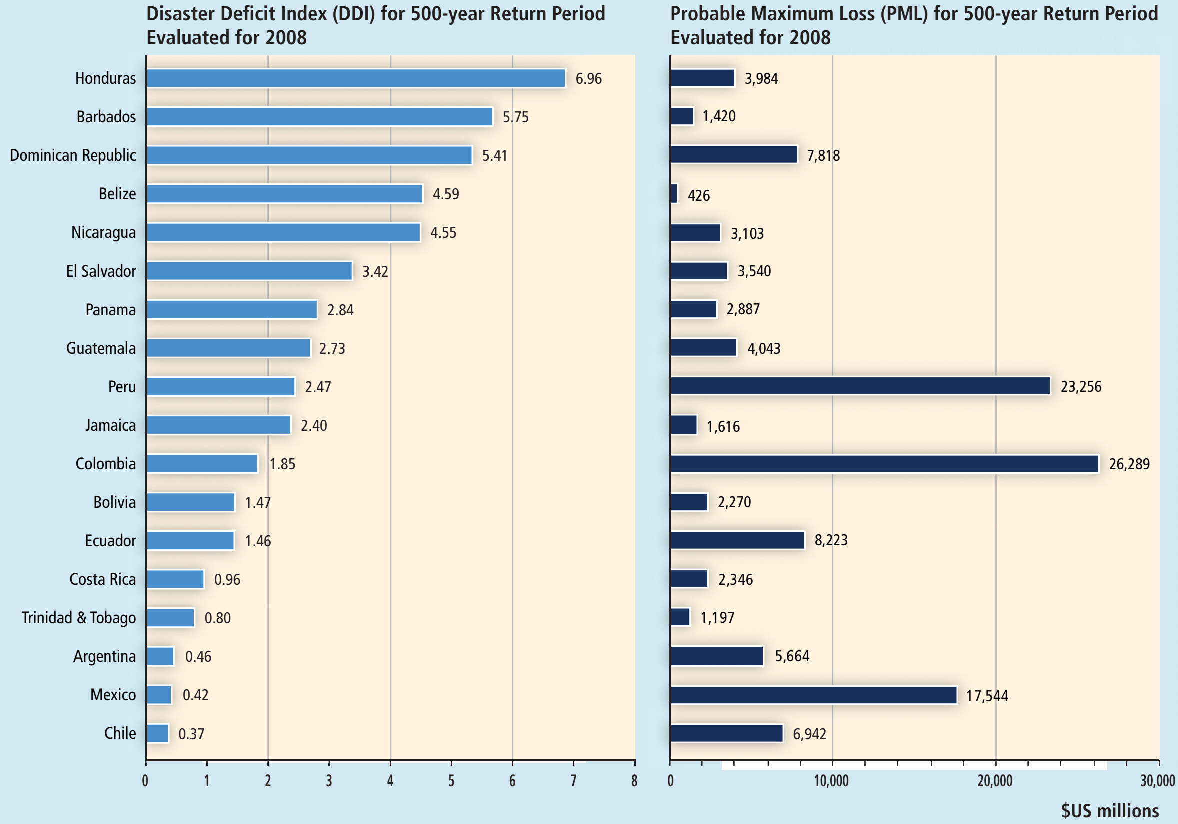

Figure 2-2 | Disaster deficit index (DDI) and probable maximum loss (PML) in 500 years for 19 countries of the Americas for 2008. Source: Cardona, 2010.

reposition costs are liabilities that become materialized when the hazard events occur. The Disaster Deficit Index (DDI) 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 a 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 2-2 shows the DDI for 2008.

A DDI greater than 1.0 reflects the country's inability to cope with extreme disasters, even when it would go into as much debt as possible: the greater the DDI, the greater the gap between the potential losses and the country's ability to face them. This disaster risk figure is interesting 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 sub-national levels can be studied by economic, financial, and planning analysts, who can evaluate the potential budget problem and the need to take into account these figures in the financial planning.

decisionmakers and the general public. Many 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, e.g., 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; Dilley 2006). A more integrative and holistic perspective captures 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, for example, 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 integrative and holistic perspectives have been developed by Turner et al. (2003a), Birkmann (2006b), and Cardona (2001). Key elements of these holistic views are the identification of causal linkages between factors of vulnerability and risk and the interventions (structural, non-structural) that nations, societies, and communities or individuals make to reduce their vulnerability or exposure to hazards. Turner et al. (2003a) underline the need to focus on different scales simultaneously, in order to capture the linkages between different scales (local, national, regional, etc.). The influences and linkages between different scales can be difficult to capture, especially due to their dynamic nature during and after disasters, for example, through inputs of external disaster aid (Cardona, 1999a,b; Cardona and Barbat, 2000; Turner et al., 2003a; Carreño et al., 2005, 2007a, 2009; IDEA, 2005; Birkmann, 2006b; ICSU-LAC, 2011a,b).

Several methods have been proposed to measure vulnerability from a comprehensive and multidisciplinary perspective. In some cases composite indices or indicators intend to capture favorable 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 future disasters can be considered 'soft' and usually non-hazard dependent conditions, that aggravate the impact. Box 2-3 describes two of these approaches, based on relative indicators, useful for monitoring vulnerability of countries over time and to communicate it to country's development and financial authorities in their own language.

To enhance disaster risk management and climate change adaptation, risk identification and vulnerability assessment may be undertaken in different phases, that is, before, during, and even after disasters occur. This includes, for instance, the evaluation of the continued viability of measures taken and the need for further or different adaptation/risk management measures. Although risk and vulnerability reduction are the primary actions to be conducted before 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 Birkmann and Fernando, 2008; ICSU-LAC, 2011a,b). 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 organizations (see Bohle, 2008). 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., 2009, 2010a).

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 (see also Section 3.1.7). 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 integrative and consistent 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.

There is *medium evidence* (given the generally limited amount of long-term evaluations of impacts of adaptation and risk management interventions and complications associated with such assessments), but *high agreement* that adaptation and risk management policies and practices will be more successful if they take the dynamic nature of vulnerability and exposure into account, including the explicit characterization of uncertainty and complexity (Cardona 2001, 2011; Hilhorst, 2004, ICSU-LAC, 2010, Pelling, 2010). Projections of the impacts of climate change can be strengthened by including storylines of changing vulnerability and exposure under different development pathways. Appropriate attention to the dynamics of vulnerability and exposure is particularly important given that the design and implementation of adaptation and risk management strategies and policies can reduce risk in the short term, but may increase vulnerability and exposure over the longer term. For instance, dike systems can reduce hazard exposure by offering immediate protection, but also encourage settlement patterns that may increase risk in the long term. For instance, in the 40-year span between Hurricanes Betsy and Katrina, protective works – new and improved levees, drainage pumps, and canals – successfully protected New Orleans and surrounding parishes against three hurricanes in 1985, 1997, and 1998. These works were the basis for the catastrophe of Katrina, having enabled massive development of previously unprotected areas and the flooding of these areas that resulted when the works themselves were shown to be inadequate (Colten et al., 2008). For other examples, see Décamps (2010).

The design of public policy on disaster risk management is related to the method of evaluation used to orient 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* (Corral, 2000). For more details see Cardona (2004, 2011).

Several portfolio-level climate risk assessment methods for development agencies have paid specific attention to the risk of variability and extremes (see, e.g., Burton and van Aalst, 1999, 2004; Klein, 2001; van Aalst, 2006b; Klein et al., 2007; Agrawala and van Aalst, 2008; Tanner, 2009). Given the planning horizons of most development projects (typically up to about 20 years), even if the physical lifetime of the investment may be much longer, and need to combine attention to current and future risks, these tools provide linkages between adaptation to climate change and enhanced disaster risk management even in light of current hazards. For more details on the implementation of risk management at the national level, see Chapter 6.

2.6.3. Risk Communication

How people perceive a specific risk is a key issue for risk management and climate change adaptation effectiveness (e.g., Burton et al., 1993; Alexander, 2000; Kasperson and Palmlund, 2005; van Sluis and van Aalst, 2006; ICSU-LAC, 2011a,b) since responses are shaped by perception of risk (Grothmann and Patt, 2005; Wolf et al., 2010b; Morton et al., 2011).

Risk communication is a complex cross-disciplinary field that involves reaching different audiences to make risk comprehensible, understanding and respecting audience values, predicting the audience's response to the communication, and improving awareness and collective and individual decisionmaking (e.g., Cardona, 1996c; Mileti, 1996; Greiving, 2002; Renn, 2008). Risk communication failures have been revealed in past disasters, such as Hurricane Katrina in 2005 or the Pakistan floods in 2010 (DKKV, 2011). 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-centered risk communication is therefore a key to improve vulnerability and risk reduction in the context of extreme events, particularly in the context of people-centered early warning (DKKV, 2011). Weak and insufficient risk communication as well as the loss of trust in government institutions in the context of early warning or climate change adaptation can be seen as a core component of institutional vulnerability.

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-centered risk communication can contribute 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 Grothmann and Patt 2005; van Aalst et al., 2008).

Understanding the ways in which disasters are framed 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., 2003a; Birkmann, 2006a,b,c; Cardona, 2008; Cutter and Finch, 2008; ICSU-LAC, 2011a,b). 'Framing' refers to the way a particular problem is presented or viewed. Frames are shaped by knowledge of and underlying views of the world (Schon and Rein, 1994). It is related to the organization of knowledge that people have about their world in the light of their underlying attitudes toward key social values (e.g., nature, peace, freedom), their notions of agency and responsibility (e.g., individual autonomy, corporate responsibility), and their judgments about reliability, relevance, and weight of competing knowledge claims (Jasanoff and Wynne, 1997). 'Early warning' implies information interventions into an environment in which much about vulnerability is assumed. In this regard, risk communication is not solely linked to a top-down communication process, rather effective risk communication requires recognition of communication as a social process meaning that risk communication also deals with local risk perceptions and local framing of risk. Risk communication thus functions also as a tool to upscale local knowledge and needs (bottom-up approach). Therefore, effective risk communication achieves both informing people at risk about the key determinants of their particular risks and of impending disaster risk (early warning), and also engages different stakeholders in the definition of a problem and the identification of respective solutions (see van Aalst et al., 2008).

Climate change adaptation strategies as well as disaster risk reduction approaches need public interest, leadership, and acceptance. The generation and receipt of risk information occurs through a diverse array of channels. Chapter 5 and others discuss the important role of mass media and other sources (see, e.g., the case of Japan provided in Sampei and Aoyagi-Usui, 2009). Within the context of risk communication, particularly in terms of climate change and disasters, decisionmakers, scientists, and NGOs have to act in accordance with media requirements concerning news production, public discourse, and media consumption (see Carvalho and Burgess, 2005). Carvalho (2005) and Olausson (2009) underline that mass media is often closely linked to political awareness and is framed by its own journalistic norms and priorities; that means also that mass media provides little space for alternative frames of communicating climate change (Carvalho, 2005; Olausson, 2009). Boykoff and Boykoff (2007) conclude that this process might also lead to an informational bias, especially toward the presentation of events instead of a comprehensive analysis of the problem. Thus, an important aspect of improving risk communication and the respective knowledge base is the acceptance and admission of the limits of knowledge about the future (see Birkmann and von Teichman, 2010).

2.7. Risk Accumulation and the Nature of Disasters

The concept 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, marginalization, and disaster risk over time (Maskrey, 1993b; Lavell, 1994). 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 the 1998 Hurricane Mitch were at greater risk during the 2001 earthquakes due to the poor construction of the shelters (Wisner, 2001b). The concept of risk accumulation acknowledges the multiple causal factors of risk by the connecting development patterns and risk, as well as the links between one disaster and the next.

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 underinvestment in drainage infrastructure. Development and governance processes that increase the marginalization of specific groups, for example, through the reduction of access to health services or the exclusion from information and power – to name just a few – can also severely increase the susceptibility of these groups and at the same time erode societal response capacities. The classic example is disaster risk in urban areas in many rapidly growing cities in developing countries (Pelling and Wisner, 2009b). 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; where 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, 2009a), aggravated by limited resources to cope and recover from disasters when they occur – 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 is then realized when an extreme hazard event occurs (UNISDR, 2009a). Similar accumulation of risk may occur at larger scales in hazard-prone states, especially in the 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. Bull-Kamanga et al. (2003) suggest that one of the most effective methods to address urban disaster risk in Africa is to support community processes among 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 dated maps used to plan and develop large physical construction and facilities.

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. Thus disasters are often the product of parallel developments that sometimes reach a tipping point, where the cumulative effect of these parallel processes results in disaster (Dikau and Pohl, 2007; Birkmann, 2011b). After that point, recovery may be slowed by conflict between processes and goals of reconstruction (Colten et al., 2008). In addition, there is often strong pressure to restore the status quo as soon as possible after a disaster has happened, even if that status quo means continued high levels of disaster risk. Sometimes, however, disasters themselves can be a window of opportunity for addressing the determinants of disaster risk. With proactive risk assessment and reconstruction planning, more appropriate solutions can be realized while restoring essential assets and services during and after disasters (Susman et al., 1983, Renn, 1992; Comfort et al., 1999; Vogel and O'Brien, 2004).

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