Chapter 1. Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability, and Resilience

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Contents

Executive Summary

This assessment report examines the challenge presented by the management of extreme events and disasters in the context of anthropogenic climate change, with the goal of providing guidance for advancing climate change adaptation. This effort integrates knowledge developed and employed by the disaster risk management community. Climate change adaptation and disaster risk management seek to inform climate-related decisions and reduce disaster risk, thus supporting and promoting sustainability in social and economic development.

Anthropogenic climate change is expected to shift the distribution of climate and weather characteristics (temperature, precipitation, wind, sea level, etc.), driving changes in spatial and temporal averages and the frequency, magnitude, and character of extreme physical events [1.2, Chapter 3]. Physical extremes occur at a variety of temporal and spatial scales. Depending on timing and geographic location, gradual climate changes may result in the crossing of thresholds that enhance extreme events.

When extreme events involve *extreme direct and indirect social and economic impacts* leading to a severe disruption of the normal, routine functioning of the affected society, they contribute to the occurrence of "disaster". Extreme impacts and disasters may arise from non-extreme events, while extreme events often may not lead to extreme impacts [1.2, Chapter 4]. Disaster may arise from lesser physical events in the presence of physical and ecological conditions that affect human welfare and security and social vulnerability, short-duration events superimposed onto a gradual trend, the presence of multiple hazards, or the timing of extreme events. The relative importance of different types of physical events, of events not previously experienced in particular locales, and uncertainty in each of these characteristics will change over time, as will vulnerability and exposure**.**

Climate change adaptation cannot be effectively pursued without understanding the diverse ways in which social processes contribute to the construction and reduction of disaster risk [1.1, Chapter 2]. Disasters are predicated on the existence of vulnerability, which can be exacerbated by social processes and/or events [Chapter 2]. Disaster risk is often causally related to ongoing, chronic or persistent environmental, economic or social risk factors. Poverty is generally, but not always, associated with increases in vulnerability [chapter 2]. This complicates disaster risk prevention and reduction efforts. The reduction of, or response to, extreme impacts is often complicated by the lack of reliable and timely information on disaster risk.

Risk assessment is a starting point for climate change adaptation and disaster risk reduction and transfer. The assessment and analysis process may employ a variety of tools according to management context, access to data and technology, and stakeholders involved [1.3]. These tools will vary from formalized and sophisticated probabilistic risk analysis to more labour intensive, qualitative schemes. Any form of risk assessment must confront difficulties in estimating the likelihood and magnitude of extreme events and their impacts [1.2, 1.3]. Effective risk communication requires exchanging, sharing, and integrating knowledge about climate-related risks among all stakeholder groups. Among individual stakeholders and groups, perceptions of risk are driven by psychological and cultural factors, values, and beliefs.

Learning to manage uncertainty and dynamic complexity is central to climate change adaptation, which can be seen as a process of shifting coping ranges in anticipation of future risks [1.4]. Disaster risk management and climate change adaptation offer frameworks for advanced learning processes that may help reduce or avoid a host of barriers which may undermine planned adaptation efforts, or lead to implementation of maladaptive measures. [1.3, 1.4]. Case studies can provide insight into how societies perceive and act on risk, i.e. how they filter the complexity associated with risk assessment and risk management [1.4, chapter 9]. Strategies to adapt to short-timescale climate variability may offer insight into effective information and communication, as well as managerial, technological, and wealth constraints on adaptive efforts. Because of the deep uncertainty and the long timeframe associated with climate change, robust adaptation efforts require iterative risk management strategies [1.3].

Effective risk management involves integrative approaches implemented at multiple spatial, social, and temporal scales [1.1, 1.3]. Although climate risks are location-specific, they are constructed, understood and responded to at the individual household through to the national and international levels, in the context of economic, political, technological, and cultural shifts. Climate change adaptation policy, strategies and interventions will only be successful if the complex interactions between phenomena and actions at local, sub-national, national and international scales are appreciated and anticipated.

The synergic interaction between disaster risk, poverty, degradation of ecosystem services, inappropriate land use planning, and poor governance in some countries suggests that effective interventions would be designed with a composite agenda of development, poverty reduction, climate change adaptation, and disaster risk reduction [1.3]. Such an effort would require a novel level of institutional integration and coordination. Holistic institutional frameworks (for strategy, policy-making, financing) that include development concerns have been shown to be more appropriate in several countries [1.3, Chapter 9]. Historical examples support the mutually reinforcing nature of generic (development) and specific (climate-related) adaptive capacity [1.3].

1.1. Introduction

1.1.1. Purpose and Scope of the Assessment Report

Anthropogenic climate change is projected to continue during this century and beyond. This conclusion is robust under a wide range of scenarios for future greenhouse gas emissions, including some that anticipate emissions mitigation (IPCC, 2007a). While specific outcomes of climate change are uncertain, it is *virtually certain* that the frequency, intensity, and variability of extreme and non-extreme climate events, in addition to the mean values of climate variables, will be altered (chapter 3). These alterations are very likely to change the nature and frequency of weather and climate extremes that can contribute to disasters, although this does not necessarily imply only intensification or increases in the number of such events. It is in particular *very likely* that the length, frequency and/or intensity of heatwaves will continue to increase over most land areas, and *likely* that the frequency of heavy precipitation (or proportion of total rainfall from heavy falls) will increase over many areas. If not effectively managed, such changes are *very likely* to lead to an increase in some climate-related disaster risks, and in the number, size and spatial extent of disasters related to these specific extremes. Changes in some other weather and climate extremes, e.g. droughts or tropical cyclones, are more difficult to predict with confidence, but change can still be expected and these will also *very likely* affect disaster risk.. At the same time, climate change may reduce hydrological- and meteorological- related disaster risk in some circumstances (e.g., via a reduction in the number of extremely cold days and nights).

New, improved or strengthened disaster risk reduction processes will undoubtedly be required in many geographical areas affected by climate change. This is all the more important if one considers that disaster risk reduction and adaptation to historical climate variability have not been widely or uniformly successful, as is clearly demonstrated by the consistent, rapid growth in real economic disaster losses and livelihood disruption associated with meteorological and hydrological events over the last 50 years (UN, 2009). This is the case despite important advances in the reduction of loss of life associated with improved early warning systems (UN, 2009). The Hyogo

Framework for Action (UNISDR, 2005), adopted by 168 governments, provides a point of reference to describe disaster risk reduction and its practical implmentation. Subsequent United Nations statements (UNISDR, 2008a; 2009a; 2009b; 2009c) stress the need to move forward with a closer integration of disaster risk reduction and climate change adaptation concerns and goals, all in the context of development.

This report addresses one general and three specific challenges associated with anthropogenic climate change and its effects on extreme events, disaster and disaster risk, disaster risk management and climate change adaptation. The general challenge is to assess why and how the management of extreme events and disasters (based on historical experience and evolution in practice) could be integrated more closely with and contribute to climate change adaptation objectives and processes, in the context of development.

The three specific challenges are:

1) To assess the relevance and utility of the concepts, methods, strategies and instruments employed in the management of climate-associated disaster risk under conditions of historical climate, for future climate change adaptation.
2) To assess the new challenges and requirements that climate change and climate change adaptation brings to the disaster risk management field.
3) To assess the implications of such revisions in the field of disaster risk management for climate change adaptation.

The first section of the present chapter briefly introduces the basic concepts, definitions, contexts and management approaches descibed in this assessment report. Later sections of this chapter define critical aspects of significance to the management challenge, particularly the subjects of extreme events and extreme impacts; disaster risk management, reduction, and transfer; integration with climate change and adaptation processes; and, the notions of coping and adaptation.

This assessment report as a whole is organized into three major parts. The first four chapters focus on generic questions that are common to managing adaptation to climate change, extreme events, and disaster at any level of governance and any type of social aggregation. The second part (chapters 5-8) focuses on distinct levels of governance and social aggregations, and how such adaptation may be coordinated with the non-climate goals and objectives of each. Finally, chapter 9 focuses on experience gained from specific instances of extreme impact and disaster, highlighting key conclusions from earlier chapters. These case studies are referred to throughout the other chapters.

1.1.2. Disaster Risk and Disaster: Basic Concepts for Risk Management and Adaptation

1.1.2.1. Key Concepts and Definitions

The “skeleton” definitions of key terms and concepts presented in this chapter take into account a number of existing official glossary definitions (ISO, 2010; IPCC 2007b; IPCC 2007c; UNISDR, 2009d) but also reflect the fact that concepts and definitions evolve as knowledge, needs and contexts vary. Disaster risk management and climate change adaptation are dynamic fields, and will necessarily continue to exhibit an evolution in concepts and definitions of key notions. A glossary which incorporates the basic definitions is provided at the end of this report. In subsequent chapters, variants among these definitions will be examined and considered in detail where necessary. Figure 1-1 provides an schematic representation of the relationships among many of the concepts defined here.

[INSERT FIGURE 1-1 HERE
Figure 1-1: The key concepts and scope of this report. The figure indicates schematically key concepts involved in disaster risk management and climate change adaptation, and the interaction of these with sustainable development.]

Disaster risk is defined for the purposes of this report as the potential for loss or damage to lives, livelihoods, health status, economic and cultural assets, services (including environmental) and infrastructure, which could occur in a community or society due to the effect of particular physical events occurring within some specified future time period. This qualitative statement will be expressed formally later in this assesment (section 1.3 and chapter 2).

Disaster risk reduction is defined as the concept, process and objective of reducing existing, or anticipating new disaster risks through systematic efforts to analyze and manage their causal factors. This includes reducing the exposure to hazards, lessening the vulnerability of people, livelihoods and assets, insuring the appropriate sustainable management of land, water, and other components of the environment, and improving the preparedness for, response to and recovery from the impacts of adverse physical events. Emphasis is on universal concepts involved in the consideration of reducing disaster risks as opposed to the specific management actions and activities for doing so and which are captured under the notion of disaster risk management (see below).

Disaster, the actualization or materialization of disaster risk, is defined as the existence of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread human, material, economic or environmental damage or losses that require immediate emergency response to satisfy critical human needs under conditions of severe stress and which may require external support for recovery.

Climate change adaptation refers to the adjustment in natural systems in response to actual climatic stimuli or their effects, and in human systems, in response to both actual and expected stimuli, such as to moderate harm or exploit beneficial opportunities. This modifies the IPCC (2007b) definition that speaks of the “adjustment in natural and human systems in response to actual and expected climatic stimuli, such as to moderate harm or exploit beneficial opportunities”.

Disaster risk management is defined as the systematic process of using administrative directives, organizations and operational skills, abilities and capacities to implement policies, strategies and specific mechanisms which promote increased or improved risk awareness and evaluation, tangible means to reduce disaster risks, disaster response, increased coping capacities and recovery practices, and lessen the potential or actual adverse impacts of physical events on society. In this chapter and report the use of the term **risk management** should be interpreted as being a synonym of disaster risk management, unless otherwise made explicit.

Extreme events are defined by the IPCC (Baede, 2007) as those that are “rare within their statistical reference distribution at a particular place. Definitions of ‘rare’ vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called ‘extreme weather’ may vary from place to place…”. In the present assessment (glossary) such events are defined in terms of “the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends (“tails”) of the range of observed values of the variable. [...] Absolute thresholds (rather than these relative thresholds based on the range of observed values of a variable) can also be used to identify extreme events (e.g., specific critical temperatures for health impacts). [...]” (see section 1.2 and chapter 3 for further discussion of this definition).

Although such events are often associated with disaster (which entails extreme societal impacts), this is not necessarily the case. Non-extreme physical events can also lead to disasters where physical or societal conditions foster this (section 1.1.2 and chapters 2-4). In any one place, the range of disaster-inducing events can increase if social conditions deteriorate. Although the theme of “extreme” climate events and the risk they may signify is a central concern for this assessment, it is the reduction and anticipation of overall disaster risk, including that arising from non-extreme physical events, as well as the overall advancement of adaptation practices, that are the more general concern.

In fact, the vast majority of disasters registered annually in most disaster databases are not associated with extreme events as defined probabilistically (section 1.2 and chapter 3), yet have important, potentially extreme, impacts for local and regional societies in isolation or when they accumulate (UN, 2009; CRED, 2010; Corporación OSSO, 2010). The Desinventar database has been used by UNISDR, the Inter-American Development Bank, and others to examine small and medium scale disaster occurrences and “extensive risk” (the wide scale, accumulative loss and damage caused by the aggregation of many small events) in Latin America and Asia in particular (IDEA, 2005; UN, 2009; Corporación OSSO, 2010).

The definitions of disaster risk and disaster posited above do not include the extreme impacts of climate and hydrological events on ecosystems or the physical earth system per se. In this assessment, such impacts may be relevant to disaster if, among others possibilities: i) they impact livelihoods negatively; ii) they have consequences for global food security; and iii) they have serious impacts on human health.

Extreme physical ecosystem impacts are nevertheless considered in detail in chapter 4 as an important aspect of the impact of and adaptation to extreme events that have significant consequences for human wellbeing. In excluding such impacts from the definition of "disaster" employed here, we are in no way underestimating their broader significance (e.g., their existence value) or suggesting they should not be dealt with under the rubric of adaptation concerns and management needs. Rather, we are establishing their position within the conceptual framework of climate related, socially-defined "disaster and disaster risk" studies and the management options available.

1.1.2.2. Disaster Risk

Climate change adaptation and disaster risk management seek to reduce factors and modify environmental and human contexts that contribute to climate-related disaster risk, thus supporting and promoting sustainability in social and economic development. Given the central importance of the notion of disaster risk, a useful and necessary starting point for conceptual convergence and the promotion of integration is to assure that there is clarity as to the causal factors associated with such risk.

Disaster risk cannot exist without the potential occurrence of damaging physical events. But such events are not in and of themselves sufficient to explain disaster risk or project its potential magnitude.

When physical events, such as tropical cyclones, floods, and drought, can affect exposed elements of human systems in a negative manner, they assume the characteristic of **hazard.** Hazard is the potential occurrence of a natural or human-induced physical event, that can contribute to negative effects such as loss of life, injury or other health impacts, as well as damage and loss to assets, infrastructure, livelihoods, service provision and environmental resources.

Exposure refers to the presence of people, livelihoods, environmental services and resources, economic, social and cultural assets, and infrastructure in areas subject to the occurrence of potentially damaging physical events and which, thereby, are subject to potential future loss and damage. Quantification of such loss depends amongst other things, on the magnitude of an event in a given location. The definition of exposure in this assessment subsumes physical and biological systems under the concept of "environmental services and resources", accepting that these are fundamental for human welfare and security (Gaspar, 2010). Non-geographical exposure can also exist to events at distance in space and/or time from a vulnerable object, for example where food insecurity is encountered as a result of global market changes in part a result of drought, or flood impacts on crop production in another place. In such cases, exposure is not associated with the hazard itself but with the reach of mediating social (in this case largely economic and regulatory) institutions.

Physical events are transposed into **hazards** where social elements (or environmental resources that support human welfare and security) are exposed to their potentially damaging or transforming impacts (Smith, 1996; Tobin and Montz, 1997; Cardona, 1986, 1996, 2010; Lavell, 2003; Wisner *et al.,* 2004), so that hazard should be considered a latent threat rather than the event itself. Risk reduction and adaptation interventions require prior recognition of this latent risk and its social and physical dimensions (ICSU-LAC, 2010).

Under exposed conditions, future loss and damage will be the result of a physical event (or events) interacting with socially constructed conditions denoted as **vulnerability**. Vulnerability**,** when used with reference to human systems, is defined here as the susceptibility or predisposition for loss and damage to human beings and their livelihoods, as well as their physical, social and economic support systems, when affected by physical events. This includes the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist and recover from the impact of a physical event (Wisner *et al.,* 2004). Vulnerability may be evaluated according to a variety of quantitative and qualitative metrics (Schneider *et al.,* 2007; Cardona, 2010). The term **sensitivity** is often used to connote susceptibility in the above context.

Vulnerability is a function of diverse historical, social, economic, political, cultural, institutional, natural resource, and environmental conditions and processes. The concept has been developed as a theme in disaster work since the 1970s (Baird *et al.,* 1975; O'Keefe *et al.,* 1976; Wisner *et al.,* 1977; Gaillard, 2010) and variously modified in different fields and applications in the interim. A detailed discussion of this notion and so called "vulnerability factors" is provided in chapter 2.

The importance of vulnerability to the disaster risk management community may be appreciated in the way it helped reveal the role of social factors in the explanation of risk, moving away from purely physical explanations of loss and damage (see Hewitt, 1983 for an early critique of the "physicalist" interpretation of disaster).

Geographical exposure as such is not vulnerability, although vulnerability can not exist without exposure and is many times specific to different hazards. Where exposure to potentially damaging physical events is not accompanied by some degree of vulnerability of the exposed social elements, then loss and damage will not ensue. Differential levels of vulnerability will lead to differential levels of damage and loss under similar conditions of exposure to physical events of a given magnitude.

The fundamentally social connotation and "predictive" value of vulnerability is emphasized in the definition used here. The earlier IPCC definition of vulnerability refers to "the degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC, 2007b). The latter definition makes physical causes and their effects an explicit aspect of vulnerability while the social context is encompassed by sensitivity and adaptive capacity (defined later). In the definition used here, the social context is emphasized explicitly, and vulnerability is independent of physical events (O'Brien *et al.,* 2007).

The notion of **mitigation** in the climate change literature refers to the reduction of the rate of climate change and of its causal factors, whereas in disaster risk reduction work it refers to the amelioration of disaster risk or disaster itself through reduction of existing hazards, exposure or vulnerability. This report presumes that mitigation is a substantive action that can be applied in different contexts where attenuation of existing conditions is required. **Disaster risk mitigation** refers to actions that reduce risk prior to event impact; **disaster mitigation** is used to refer to actions that attempt to limit futher adverse conditions once disaster has materialized.

The "negative" concept of vulnerability has been contrasted and complimented with the "positive" idea of **capacities.**

Capacity refers to the conditions and characteristics that permit society at large (institutions, local groups, individuals, etc.) equitable access to and use of the social, economic, psychological, cultural and livelihood-related natural resources, as well as access to information and insitutions of governance necessary to reduce vunlnerability (adaptive or disaster risk reduction capacity) and deal with its consequences afterwards (coping and resilience). This definition approaches the definition of capabilities referred to in Amyrtya Sen's "capabilities approach to development" (Sen, 1983).

Some specialists see lack of capacity as being one dimensión of overall vulnerability, while others see it as a counter balance. The existence of vulnerability does not mean an absolute lack of capacities.

Introduced into disaster work by Anderson and Woodrow (1989) as a means, amongst other objectives, to shift the analytical balance from the negative aspects of vulnerability to the positive actions by people, the notion of capacity is fundamental to imagining and designing a conceptual shift favouring disaster risk reduction and climate change adaptation. Effective **capacity building,** the notion of stimulating and providing for growth in capacities**,** requires a clear image of the future with clearly established goals.

The notions of hazard, exposure, vulnerability, capacities and disaster risk as presented above reflect an emerging and increasingly consolidated understanding that disaster risk, while potentiated by an objective, physical condition, is fundamentally a "social construction", the result of social choice, social constraints, societal action and inaction. Risk assessment using both quantitative (actuarial and mathematical) and qualitative (e.g., social and psychological) measures are required to render a complete description (section 1.3; Douglas and Wildavsky, 1983; Wisner *et al.,* 2004; Cardona, 2004; Weber 2006). In considering the process of the social construction of risk, there is a long existing awareness of the role of development policy and practice in shaping disaster risk through, amongst other processes, the alteration of ecosystem structure and function, disregard for natural hazard events, a lack of land use planning, and an emphasis on emergency response to the detriment of risk reduction (UNEP, 1972; Hagman, 1984, Wijkman and Timberlake, 1988, Bender, 1989). Present day circumstances only reinforce that conclusion (Wisner *et al.,* 2004; UN, 2009). Where disaster risk reduction is successful, it is considered and practiced as a dimension of development planning (section 1.1.3, section 1.3.2, and chapters 5-8); risk can be effectively managed only through socially sustainable decisions and concerted human action (ICSU-LAC, 2010).

The contribution of physical events to disaster risk is characterized by statistical distributions in order to elucidate the options for risk reduction and adaptation (section 1.2 and chapter 3). But, the explicit recognition of the political, economic, social, cultural, physical and psychological elements of risk leads to a spectrum of potential outcomes of physical events, including those captured under the notion of **extreme social or ecosystem impacts** (section 1.2 and chapter 4). Where climate change introduces a break with past environmental systems functioning so that forecasting hazard becomes less determined by past trends, it is necessary to reconsider established indicators of human vulnerability. Sustainable and resilient disaster risk reduction under climate change will rely on direct management of risks, in the context of the wider socio-economic systems that can foster adaptive capacities while coping with experienced and expected disaster.

1.1.2.3. Response and Recovery from Disaster

Disaster occurs when a physical event triggers the actualization or materialization of disaster risk.

Disaster management, a component of comprehensive disaster risk management, begins once the immediacy of the disaster event has become evident and resources and capacities are put in place with which to respond ex ante and ex post. It includes early warning, contingency planning, emergency response (immediate post impact support for the satisfaction of critical human needs under conditions of severe stress) and, eventually, recovery. Disaster management is required due to the existence of "residual" disaster risk that neither ongoing disaster risk reduction or adaptation processes have managed to reduce sufficiently or eliminate (IDB, 2007). The response to disaster will affect future disaster risk reduction and adaptation efforts. The fostering of active grass roots community involvement, the use of installed local and community capacities, and the decentralization of decision making in disaster preparedness and response have been considered critical for improving future risk reduction and adaptation (Alexander, 2000; Wisner *et al.,* 2004).

Post-impact response and disaster recovery encompasses diverse concepts, of which **coping** and **resilience** are the most salient.

Coping (elaborated upon in section 1.4 and chapter 2) is defined here as the use of available skills, resources and opportunities to address, manage and overcome the adverse conditions associated with emergencies or disasters, with the aim of reaching some minimum accepted basic standard of normality in the short to medium terms. **Coping capacities** are the abilities of people, families, other groups, organizations, insitutions and systems, using available skills, resources and opportunities, to address, manage and overcome adverse conditions associated with emergencies or disasters. **Adaptive capacity** is defined as the ability of people, families, other groups and organizations, institutions and systems, using available skills, resources and opportunities, to positively anticípate and adjust to the risk associated with climate change and associated conditions (sea level rise, glacial ice loss, etc.).

The IPCC definition of adaptive capacity refers to “the ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences” (IPCC, 2007b). This definition recognizes that adaptation can be anticipatory and planned (pro-active) and/or reactive and unplanned, and thus is very broad and inclusive, subsuming disaster risk management for climate-related risks as one type of activity through which society can deal with climate change impacts. The definition posits that adaptation is not only moderation of future damage but also coping with realized consequences (e.g. disaster), in contrast with the definition of adaptation as adjustment to or anticipation of risk (as opposed to disaster) used here (see section 1.4 and chapter 2).

Resilience is defined here as the ability of a system, society, organization or insitution, community, group, family or individual to anticipate, absorb, accommodate to or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation or restoration of its essential basic structures and functions. As Gaillard (2010) points out**,** this term has been used in disaster studies since the 1970s (Torry, 1979) and has its origins in engineering (Gordon, 1979), ecology (Holling, 1973) and child psychology (Werner *et al.,* 1971).

Although now widely employed in disaster risk reduction and adaptation work, resilience is subject to diverse interpretations. The term is used by some in reference to situations at any point along the risk or disaster “cycle” or “continuum”, that is, before, during, or after the impact of the physical event. Others consider “vulnerability” and “lack of capacities” as sufficient for explaining the range of levels of success that are found in different recovery scenarios (Wisner *et al.,* 2004). Under this latter formulation, vulnerability both potentiates original loss and damage and also impedes recovery.

Finally, the term resilience, “bouncing back”, and its conceptual cousin, coping, emphasize a return to a previous status quo or some other marginally acceptable level, such as “surviving”, as opposed to generating a process that leads to improved conditions, as in “bouncing forward” or “thriving”. The dynamic and often uncertain consequences of climate change (as well as development trends such as urbanization) for hazard and vulnerability profiles makes bouncing back an increasingly unattractive aim on risk management grounds. Increasingly, conceptions of resilience of social-ecological systems include the ability to self-organize, learn, and adapt over time. Chapter 8 draws out the importance of learning that is emphasized within this more forward-looking application of resilience. Chapters 2 and 8 address the notion of resilience and its importance in discussions on sustainability, disaster risk reduction and adaptation in greater detail.

1.1.3. Climate Change Adaptation and Disaster Risk Management

The reduction or prevention of climate-related disaster risk is a critical function of disaster risk management and climate change adaptation. However, the two practices do have significant differences as regards concepts, methodologies and practice that must be taken into account in the search for greater synergy between them.

Approaches to disaster and disaster risk management have undergone very significant changes over the last thirty years. These changes have occurred under the stimulus of changing concepts, multidisciplinary involvement, social and economic demands, as well as institutional changes reflected in the UN declaration of the International Decade for Natural Disaster Reduction in the 1990’s, the establishment of the International Strategy for Disaster Reduction, and the 2005 Hyogo Framework for Action. Increasing emphasis has been placed on proactive disaster risk reduction as a dimension of development and development planning.

Developing and implementing means to respond to disasters has long been a primary objective of what has been known as “disaster” or “emergency” management. The recent emergence of disaster risk management reflects an increasing turn from disaster to disaster risk as the central concept and planning concern. Disaster risk management places greater emphasis on building resistance (the ability to not be damaged or seriously affected) to the potential impacts of physical events at various social or territorial scales.

Both climate change adaptation and disaster risk reduction comprise a corrective (that is, reactive) and prospective (that is, proactive) dimension, operating respectively under already existing and new expected or possible risk conditions (Lavell, 2003), covering the full spectrum of disaster risk contexts, from pre-impact conditions through to response and recovery.

Section 1.3 examines in more detail the process of transition to more development based disaster risk concerns and the current status of climate change adaptation practice as a prelude to examining the barriers and options for greater integration of the two practices.

1.1.4. Framing Disaster Risk Management and Adaptation Processes

At least two key fundamental contexts and questions arise in establishing the boundaries of the phenomena and social processes that concern disaster risk management and climate change adaptation and therefore highly influence their success: 1) the degree to which the focus is on extreme events, instead of on a more inclusive approach that considers the full continuum of physical events with potential for damage, the social contexts in which they occur, and the potential for such events to generate “extreme impacts” or disasters; and, 2) a consideration of the most appropriate socio-territorial scale (i.e., aggregations, see Schneider *et al.,* 2007) for fostering a deeper understanding of risk causation and risk intervention by involuntary or voluntary risk constructors, risk bearers, and the risk interveners.

1.1.4.1 Exceptionality, Extremity, Routine, and Everyday Life

Interpretations based on the physical causes and the role of extreme events in explaining loss and damage have been referred to as “physicalist” (Hewitt, 1983) while notions developed around the continuum of normal, everyday-life risk factors through to a linked consideration of physical and social extremes have been defined as “comprehensive”, “integral” or “holistic” insofar as they embrace the social as well as physical aspects of disaster risk and take into consideration evolving experience, time, and history (Cardona, 2001; ICSU-LAC, 2010). The latter perspective has been a major contributing factor in the development of the so-called “vulnerability paradigm” as a basis for understanding disaster (Wisner *et al.,* 2004; Hewitt, 1983, 1997).

Additionally, attention to the role of small and medium scale disasters and their relationship to so-called “extensive risk” (UN, 2009) highlights the need to deal integrally with the problem of cumulative disaster loss and damage, looking across the different scales of experience both in human and physical worlds, in order to advance the efficacy of adaptation. The design of mechanisms and strategies based on the reduction and elimination of every day or chronic risk factors (Sen, 1983; World Bank 2001), as opposed to actions based solely on the “exceptional” or “extreme” events, is one obvious corollary of this approach. The ability to deal with risk, crisis, and change has been seen to be closely related to an individual’s life experience with smaller scale, more regular physical and social occurrences (Maskrey, 1989; Lavell, 2003; Wisner, 2004). These concepts point toward the possibility of reducing vulnerability and increasing resilience to climate-related disaster by broadly focusuing on exposure and socially-determined susceptibility or sensitivity across a range of risks.

As illustrated in Box 1-1, many of the extreme impacts associated with climate change, and their attendant additional risks and opportunities, will inevitably need to be understood and responded to principally at the scale of the individual, the individual household, and the community, in the framework of localities and their organizational and management options, and in the context of the many other day to day changes experienced, including those of economic, political, technological, and cultural nature. As this real example illustrates, every-day life, history and a sequence of crises can affect attitudes and ways of approaching more extreme or complex problems. In contrast, many agents and institutions of disaster risk management and climate change adaptation activities necessarily operate from a different perspective, given the still highly centralized and top down approaches found in many parts of the world today.

_____ START BOX 1-1 HERE ____

Box 1-1. Title TBD

Joseph is eighty years old. He and his father and his grandfather have witnessed many changes. Their homes have shifted back and forth from the steep slopes of the South Pare Mountains at 1,500 m to the plains 20 km away, near the Pangani River at 600 m, in Tanzania. What do “changes” (mabadiliko) mean to someone whose father saw the Germans and English fight during the First World War and whose grandfather defended against Maasai cattle raids when Victoria was still Queen?

Joseph outlived the British time. He saw African Socialism come and go after Independence. A road was constructed parallel to the old German rail line. Successions of commercial crops were dominant during his long life, some grown in the lowlands on plantations (sisal, kapok, and sugar), and some in the mountains (coffee, cardamom, ginger). He has seen staple foods change as maize became more popular than cassava and bananas. Land cover has also changed. Forest retreated, but new trees were grown on farms. Pasture grasses changed as the government banned seasonal burning. The Pangani River was dammed, and the electricity company decides how much water people can take for irrigation. Hospitals and schools have been built. Insecticide treated bed nets recently arrived for the children and pregnant mothers.

Joseph has nine plots of land at different altitudes spanning the distance from mountain to plain, and he keeps in touch with his children who work them by mobile phone. What is “climate change” (mabadiliko ya tabia nchi) to Joseph? He has suffered and benefited from many changes. He has lived through many droughts with periods of hunger, witnessed floods, and also seen landslides in the mountains. He is skilled at seizing opportunities from changes – small and large: “Mabadiliko bora kuliko mapumziko” (Change is better than resting).

The provenance is taken from an original field work interview undertaken by Ben Wisner in November 2009 in Same District, Kilimanjaro Region, Tanzania in the context of the U.S. National Science Foundation funded research project "Linking Local Knowledge and Local Institutions for the Study of Adaptive Capacity to Climate Change: Participatory GIS in Northern Tanzania."

_____ END BOX 1-1 HERE ____

1.1.4.2. Territorial Scale, Disaster Risk, and Adaptation

Climate-related disaster risk, is most adequately depicted, measured and monitored at the local or micro level where the actual interaction of hazard and vulnerability are worked out in-situ (Lavell, 2003). At the same time, it is accepted that risk construction processes are not limited to specifically local or micro processes but, rather, to diverse environmental, economic social and ideological influences whose sources are to be found at scales from the international through to the national, sub-national and local, each potentially in constant flux (Wisner *et al.,* 2004). Changing commodity prices in international trading markets and their impacts on food security and the welfare of agricultural workers, decisions on location and cessation of agricultural production by international corporations, deforestation in the upper reaches of river basins and land use changes in urban hinterlands are but a few of such “extra-territorial” influences on local risk. Moreover, disasters once materialized have ripple effects that many times go well beyond the directly affected zones, as the early 2011 flooding in Queensland, Australia illustrated once more with regard to the overall impact on the national economy and other regions dependent on the affected areas for industrial inputs and services. Thus, disaster risk management and adaptation policy, strategies and institutions will very probably only be successful where understanding and intervention is based on multi-territorial and social scale principles and where phenomena and actions at local, sub-national, national and international scales are construed in interacting, concatenated ways (Lavell, 2002; UN, 2009; chapters 5-9).

1.1.5. A Summary: A Basis for Advancing Holistic, Integrated, and Interdisciplinary Understanding

We conclude that a more holistic, integrated, trans-disciplinary approach to risk assessment is needed to overcome and integrate the (at times) different approaches and visions provided by the climate change adaptation and disaster risk management communities and sub-communities (ICSU-LAC, 2010). Key aspects include the ways physical extremes and non-extremes are viewed, the manner in which vulnerability and changes and challenges in everyday life are depicted, and the way exceptional circumstances are characterized. Dividing the world up sectorally or thematically for management ends while offering undoubted advantages for certain levels of analysis, specialization and efficiency, may however undermine a thorough understanding of the complexity and interaction of the human and physical factors involved in the constitution and definition of a problem at different social, temporal and territorial scales. In contrast, an integrated approach would recognize the complex relationships between diverse social, temporal and spatial contexts and components and that participatory methods and basic decentralization principles could facilitate effectiveness of both climate change adaptation and disaster risk management.

1.2. Extreme Events, Extreme Impacts, and their Management for Advancing Climate Change Adaptation

1.2.1. Extreme Events, Extreme Impacts, and Disasters

Discussion and definition of (short duration) “extreme weather” or (longer lasting - months to years) “extreme climate” ‘events‘ and their relationship with “extreme impacts” and “disasters” are common in both the disaster risk and climate change adaptation literature. Perspectives on extreme events vary widely, from a statistical or threshold-based definition of measured physical attributes of phenomena used by natural scientists and engineers (see chapter 3) to a concern with the fragility of social systems often expressed qualitatively by social scientists (chapter 2).

In the following discussion, quantitative definitions of different classes of extreme events are explored before considering what characteristics determine that an impact is extreme, how one may define extreme impacts, how climate change may affect our understanding of extreme events and extreme impacts, and how these topics might be considered and communicated.

1.2.2. Extreme Events Defined in Physical Terms

1.2.2.1. Definitions of Extremes

The full range of severe weather and climate reflects the interactions of dynamic and thermodynamic processes over a very wide range of space and timescales, resulting in highly variable atmospheric temperatures, motions, and precipitation, covering at least seven orders of magnitude of timescales - from the passage of an intense tornado lasting minutes to a drought lasting decades. Similarly, the spatial scale of severe weather varies from local to continental.

In addition to providing a long-term mean of weather, ‘climate’ characterizes the full spectrum of means and exceptionality associated with ‘unusual’ and unusually persistent weather. The World Meteorological Organization (WMO, 2010) differentiates the terms: “At the simplest level the weather is what is happening to the atmosphere at any given time. Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time.”

Where there is sufficient data to develop an overall distribution of a key weather or climate parameter, it is possible to define a value at some probability, as required in engineering design (this presupposes, however, that the climate over the period in which the parameter has been sampled is stationary (Milly *et al.,* 2008) and the record is long enough to capture low frequency events). The extremity of a weather or climate event of a given magnitude depends on geographic context (see section 1.1 and chapter 3): a month of daily temperatures corresponding to the expected Spring climatological daily maximum in Chennai would be termed a heat wave in France; a snow storm expected every year in New York would provoke a disaster when it occurs in southern China. Furthermore, the consequences of a one in ten annual probability event are, for some purposes, not sufficiently rare to result in unusual social consequences, which are specific to location and social context. Nonetheless, absolute, universal thresholds do also exist, e.g., a change in the incidence of freezing days may allow disease vectors to thrive. Also, an extreme event in the present climate may become much more common under future climate conditions. These various aspects are considered in the new definition of "extreme (weather and climate) events" provided in the glossary.

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The availability of observational data is of central relevance for defining climate characteristics and for disaster risk management, and while data for temperature and precipitation are widely available, some variables, such as soil moisture, are almost unmonitored, or, like extreme wind speeds and other low frequency occurrences, not monitored with sufficient spatial resolution or temporal continuity (chapter 3).

When the overall distribution of the mean climate changes, other parameters may shift relative to the change in the mean behaviour. For example a warmer mean climate could result from fewer cold days (leading to a reduction in the overall distribution of temperatures) or more hot days (leading to an expansion in the temperature distribution) or both. The issue of the scaling of changes in extreme events with respect to changes in mean temperatures is addressed further in chapter 3.

1.2.2.2. The Diversity and Range of Extremes

The identification and definition of all those weather and climate events that are relevant from a disaster risk management perspective depends on the stakeholders involved, and is broader than can be listed here. Out of the raw materials of precipitation, winds, and temperatures there is a broad concoction of severe weather events. In the extreme, water, whether it falls as rain, freezing rain (rain falling through a surface layer below freezing), snow or hail, can lead to damaging consequences (Peters *et al.,* 2001). The absence of precipitation (McKee *et al.,* 1993) as well as excess evapotranspiration from the soil (Box 3.2) can be climate extremes. Extreme surface winds are chiefly associated with structured storm circulations (Emanuel, 2003; Clark *et al.,* 2006; von Ahn *et al.,* 2004). Each storm type, including tropical and extra-tropical storms, as well as intense convective thunderstorms, presents a spectrum of size, forward speed, and intensity. In the extreme tail of the distribution of intensity there may be damaging extremes of surface winds, while slow forward speeds for intense storms lead to extremes of precipitation. A single extreme storm may bring extremes of precipitation and wind. The prolonged absence of winds is a climate extreme that can also be a hazard, leading to build-ups of urban pollution and disruptive fog (McBean, 2006).

1.2.2.3. Atmosphere-Hydrosphere Extremes

The behavior of the atmosphere is also highly interlinked with that of the hydrosphere and terrestrial environment so that extreme (or sometimes non-extreme) atmospheric events, such as for rainfall, may cause (or contribute to) other rare physical events such as extreme river levels, landslides and avalanches. Among the more important extreme events resulting from climate and weather interacting with the hydrosphere and geosphere are:

- Coastal flooding and severe wave action generated by large cyclonic storms reflecting wind and pressure related sea-level anomalies (Xie *et al.,* 2004).
- River flows (whether from intense precipitation, spring thaw of accumulated winter snowfall, precipitation falling on saturated ground, or an outburst from an ice, landslide, moraine or artificially dammed lake) exceeding the 1- or 2-year maximum, and thereby expanding beyond the natural channel (or for more extreme flows beyond the artificial defenses) to produce 'floods' (Gurnell and Petts, 1995). According to the scale of the catchment, river systems are tuned to react to particular durations of intense precipitation, with steep short mountain streams, and urban drainage systems responding to rainfall totals over a few hours, while peak flows on major continental rivers reflect precipitation extremes of weeks over extended areas (Wheater, 2002).
- Long term reductions in precipitation, or dwindling of residual summer snow and ice melt (Rees and Collins, 2006), or increased evapotranspiration from higher temperatures, often exacerbated by human

groundwater extraction, reducing ground water levels, causing spring-fed rivers to disappear (Konikow and Kendy, 2005).
- Landslides (Dhakal and Sidle, 2004) triggered by raised ground water levels after excess rainfall or melting slopes of permafrost.

Similarly, because physical impacts such as droughts, floods and landslides may occur as the result of a previously rare combination of several non-extreme events, changes in mean climate (e.g., mean temperature changes or mean precipitation changes) also need to be considered.

1.2.3. Extreme Impacts

1.2.3.1. Three Classes of Impacts

Some literature reserves the term "extreme event" for the initial meteorological phenomenon (Easterling *et al.,* 2000; Jentsch *et al.,* 2007), some includes the consequential physical impacts, like flooding, and some the entire spectrum of outcomes on humans, society, and ecosystems (Rich *et al.,* 2008). In this report, we use "extreme event" to refer to physical phenomena including some (e.g., flooding) which may have a human component to causation (chapter 3 and glossary). We contextualize "impact" to include: a) changes in the natural physical environment, like beach erosion from storms and mudslides; b) changes in ecosystems, such as the blow-down of forests in hurricanes, the bleaching of coral reefs in warming events; and c) loss or damage (according to a variety of metrics) to human or societal conditions and assets. An "extreme impact" reflects highly significant and enduring consequences to society or ecosystems. Disaster, as defined in this report (section 1.1), is comprised of extreme impacts on society, which may be associated with extreme impacts on the physical environment and on ecosystems. However, impacts are not always negative: flood-inducing rains can have beneficial effects on the following season's crops, while an intense freeze may reduce insect pests at the subsequent year's harvest.

Extreme impacts to human, ecological or physical systems can be the result of a single extreme event, a compound of extremes or non-extremes (for example, wildfire, followed by heavy rain leading to landslides and soil erosion), or simply the persistence of conditions, such as those that lead to drought (see chapter 9 for examples). Whether an extreme event results in extreme impacts to humans and social systems depends on the degree of exposure and the level of resistance, in addition to the magnitude of the physical event. Extreme impacts on human systems may be associated with non-extreme events where vulnerability and exposure are high (section 1.1, chapter 9). A key weather parameter may cross some critical vulnerability threshold at that location (such as heatwave-induced mortality, or frost damage to crops), so that the distribution of the impact shifts in a way that is disproportionate to physical changes. A comprehensive assessment of projected impacts of changes in climate extremes with enhanced greenhouse gas concentrations needs to consider how changes in atmospheric conditions (temperature, precipitation) translate to impacts on physical (e.g., droughts, floods, sea level rise), ecological (e.g., forest fires) and human systems (e.g. casualties, infrastructure damages). For example, a large spatial scale of an extreme event can (as in an ice storm or windstorm) have an exaggerated disruptive impact due to the systemic societal dependence on electricity transmission and distribution networks (Peters *et al.,* 2006). Links between climate events and physical impacts are addressed in chapter 3, while links to ecosystems and human systems impacts are addressed in chapter 4.

1.2.3.2. The Extreme 'Event'

In considering the range of weather and climate extremes, along with their impacts, the term "event" as used in the literature does not adequately capture the compounding of outcomes from successive physical phenomena, e.g., a procession of serial storms tracking across the same region (as in Jan-Feb 1990 and Dec 1999 across Western Europe (Ulbrich *et al.,* 2001)). Sometimes locations affected by extremes within the 'same' large-scale stable atmospheric circulation can be far apart, as for example the Russian heatwave and Indus valley floods in Pakistan in Summer 2010 (Blackburn *et al.,* 2010). Atmospheric teleconnections also characterize the principal drivers of oceanic sea surface temperatures, and equatorial winds, in particular the El Niño Southern Oscillation.

The aftermath of one extreme may precondition successor events. High groundwater levels and river flows can persist for months, increasing the probability of a later storm causing flooding, as on the Rhine in 1995 (Fink *et al.,* 1996). A variety of feedbacks and other interactions connect extreme events and ecological responses in a way that may amplify physical impacts (chapter 3). For example, reductions in soil moisture intensify heat waves (Seneviratne *et al.,* 2006), while droughts following rainy seasons turn vegetation into fuel that can be consumed in wildfires (Westerling and Swetman, 2003, which in turn promote soil run off and landslides when the rains return (Cannon *et al.,* 2001). However, extremes can also interact to reduce disaster risk. The wind-driven waves in a hurricane bring colder waters to the surface from beneath the thermocline; for the next month, any cyclone whose path follows too closely will tend to lose intensity (Emanuel, 2001). Intense rainfall accompanying monsoons and hurricanes also brings great benefits to society and ecosystems; on many occasions they help to fill reservoirs, sustain temporal agriculture and alleviate summer drought conditions in arid zones (e.g., Cavazos *et al.,* 2008).

The attribution of extremes remains problematic and as a generality single extreme events cannot be simply and directly attributed to *anthropogenic* climate change, as there is always a chance the event in question might have occurred naturally (Hegerl *et al.,* 2007). A further complication is that extreme impacts sometimes result from the interactions between two unrelated geophysical phenomena such as a moderate storm surge coinciding with an extreme spring tide, as in the most catastrophic UK storm surge flood of the past 500 years in 1607 (Horsburgh and Horritt, 2006). Climate change may alter both surges and cause gradual sea level rise, compounding such future extremes (see Section 3.5.3 and 3.5.5).

1.2.3.3. Metrics to Quantify Social Impacts and the Management of Extremes

Metrics to quantify social and economic impacts (and thus used to define extreme impacts) may include, among others (Below *et al.,* 2009):
- Human casualties and injuries
- Number of permanently or temporarily displaced people
- Number of directly and indirectly affected persons
- Impacts to properties, measured in terms of numbers of buildings damaged or destroyed
- Impacts to infrastructure and lifelines
- Impacts on ecosystem services
- Impacts on crops and agricultural systems
- Impacts on disease vectors
- Impacts on financial or economic loss (including insurance loss)
- Impacts on coping capacity and need for external assistance.

All of these may be calibrated according to the magnitude, rate, duration, and degree of irreversibility of the effects (Schneider *et al.,* 2007). These metrics may be quantified and implemented in the context of probabilistic risk analysis in order to inform policies in a variety of contexts (see section 1.3.2.1).

Information on direct, indirect and collateral impacts is generally available for many large-scale disasters and is systematized and provided by organizations such as the Economic Commission for Latin America, large reinsurers, and the CRED database (CRED, 2010). Information on impacts of smaller, more recurrent events is far less accessible and more restricted in the number of robust variables it provides. The Desinventar database (Corporation OSSO, 2010), now available for over 24 countries worldwide, and the SHELDUS database, for the USA (HVRI, 2010), are attempts to satisfy this need. However, the lack of data on many impacts impedes complete knowledge of the global social and economic impacts of smaller scale disasters (UN, 2009, section 1.1)

1.2.3.4. Traditional Adjustment to Extremes

Disaster risk management and planned adaptation may be seen as attempts to duplicate or promote through planned mechanisms adjustments that society and nature have accomplished on many occasions “spontaneously” in the past.

A natural example of susceptibility (or resistance) is a tree uprooted or felled by or withstanding extreme winds. Resistance is strongly species-dependent, having evolved according to the climatology where that tree was indigenous (Canham *et al.,* 2001). In their original habitat, trees typically withstand wind extremes expected in their habitat every 10-50 years, but not extremes that lie beyond their average lifespan of 100-500 years (Ostertag *et al.,* 2005).

In contrast to natural systems, human systems (including systems of protection) have many times been explicitly designed to withstand a certain range of expected extremes. On the island of Guam, within the most active and intense zone of tropical cyclone activity on earth, buildings are constructed to the most stringent wind design code in the world, requiring a bunker style able to withstand wind speeds of 76ms^{-1} as expected every few decades (International Building Codes, 2003). The far greater frequency of mid-latitude extratropical cyclones than low latitude tropical cyclones means that for coastal habitation, indigenous building practices were less likely to be resilient in the tropics than in the windier (and storm surge affected) mid latitudes (Minor, 1983).

Communities accustomed to periodic droughts employ wells, boreholes, pumps, dams, and water harvesting and irrigation systems. Those with houses exposed to high seasonal temperatures employ thick walls and narrow streets, have developed passive cooling systems, adapted lifestyles or acquired air conditioning. In regions unaccustomed to heat waves, the absence of such systems, in particular in the houses of the most vulnerable elderly or sick, contributes to excess mortality, as in Paris, France in July 2003 (Vandentorren *et al.,* 2004) or California July 2006 (Gershunov *et al.,* 2009).

1.2.4. Distinguishing Disasters

Disasters may be viewed as extreme social impacts associated with severe disruptions of the routine functioning of the affected society. Extreme physical events or impacts do not on their own necessarily imply disasters. Some definitions of ‘disasters’ for the purposes of tabulating occurrences rely only on exceedance of thresholds of numbers of killed or injured, number of affected or repair costs (CRED, 2010; Below *et al.,* 2009). Building on the definition set out in Section 1.1.1, some have argued that societal impacts resulting from weather, climate or hydrological events become disasters once they surpass thresholds in at least one of three dimensions: spatial (so that damages cannot be restored from proximate capacity), temporal (so that recovery becomes frustrated by further damages), and intensity of impact on the affected population (undermining, although not necessarily totally eliminating) the capacity of the society to repair itself (Alexander, 1993). While extreme physical events may be the principal trigger of many very large or catastrophic disasters, a disaster may also arise from a concatenation of physical, ecological and social reactions to lesser physical events (Cardona *et al.,* 2009). Pre-existing social processes may exacerbate disasters and events, such as financial crises, trade policies, wars, disease outbreaks etc. In focusing on the social context of disasters, Quarantelli (1986) proposed the use of the notion of ‘disaster occurrences or occasions’ in place of ‘events’ due to the abrupt and circumstantial nature of the connotation commonly attributed to the word “event”, which belies the complexity and temporality of disaster.

1.3. Disaster Risk Management, Reduction, and Transfer

Risks appear in the context of human choices – such as where to live, in what dwellings, what vehicles to use for transport, what crops to grow, what infrastructure to support economic activities – that aim to satisfy human wants and needs (Renn, 2008). Ideally, any action to manage, reduce, or transfer disaster risk would involve consideration of the physical and biological systems that affect human wants and needs, and the ability to utilize these systems. Such actions would also take into consideration human judgments about what constitutes risk, how to weigh such risk alongside other values and needs, and the social and economic contexts that determine whose judgments influence individuals’ and societal responses to those risks. The concept of *risk governance* provides a useful framework for integrating consideration of these disparate but complimentary elements. Risk governance seen from the perspective of disaster risk management includes the core concepts of risk analysis and communication– as well as consideration of the legal, institutional and social contexts in which risks are perceived and assessed, and the networks of actors, rules, and institutions that help determine how judgments about risk are formed and acted upon (Renn, 2008).

1.3.1. Probabilistic Risk Analysis

Probabilistic Risk Analysis (PRA, see box 1-2) (Bedford and Cooke, 2001) provides an important set of quantitative concepts used in a wide range of economic, environmental, engineering, medical, and other applications to estimate various risks and to evaluate alternative options for reducing and managing them. The disaster risk management and climate change literatures use this framework for the risk analysis stage of risk governance. In many contexts, other, qualitative approaches are preferable to PRA, while in some situations resources and capabilities to implement PRA are simply unavailable. Nonetheless, PRA provides widely applicable methods and an important conceptual foundation for much of disaster risk management and climate change adaptation.

_____ START BOX 1-2 HERE _____

Box 1-2. Probabilistic Risk Analysis

In its simplest form, PRA defines risk as the product of the probability that some event will occur and the adverse consequences of that event.

$$\text{Risk} = \text{Probability x Consequence} \quad (1)$$

For instance, the risk a community faces from flooding from a nearby river might be calculated as the likelihood that the river floods the town, inflicting causalities among inhabitants and disrupting the community's economic livelihood. This likelihood is multiplied by the value people place on those casualties and economic disruption. Eq (1) provides a quantitative representation of the qualitative definition of disaster risk given in Section 1.1. Alternative, more complex formulations express risk as a product of hazard, exposure, and vulnerability. All three factors contribute to "consequences". Hazard and vulnerability can both contribute to the "probability": the former the likelihood of the physical event (e.g. the river flooding the town) and the latter the likelihood of the consequence resulting from the event (e.g. casualties and economic disruption).

While simple in concept, Eq (1) is often difficult to implement in practice. As emphasized throughout this report, estimates of the likelihood of consequences arising from some physical event require judgments about a community's ability to resist damage and to recover from any damage inflicted (see discussion of vulnerability and resilience in Section 1.1). The valuation of consequences can be determine via a variety of metrics (see section 1.2.3.3) and may vary greatly from person to person, depending on factors such as their values and interests, their previous experience with such consequences, and the extent to which they feel they have any control over the consequences.

_____ END BOX 1-2 HERE _____

The PRA framework supports disaster risk management and climate change adaptation by providing information that can help in the evaluation and choice of options for managing, reducing, and transferring risk, and potentially, contribute to standardizing and integrating information and informing decisions across various levels of administration. Where one can quantify the costs of such actions in the same units as the consequences (box 1-2, Eq (1)), one can compare those costs to their resulting reductions of risk and evaluate which combinations of actions provide the greatest expected gains in welfare. For instance, insurance companies will estimate their expected losses by using simulation models to project the frequency and intensity of future events (hazards model) and the damage and its distribution caused by such events (vulnerability models). Firms combine this information with estimates of the fraction of damage property covered by insurance to help set their prices for such insurance (SwissRe, 2010). The framework, in conjunction with tools like spatial modeling, also supports administrative judgments of where risk does and does not exist, for instance flood risk maps which use estimates of threshold probabilities to categorize particular regions as at risk for floods. In this way, it can inform resource allocation decisions. Where quantification proves more difficult, the conceptual framework of PRA may nevertheless provide general guidance for decisions.

The overall risk governance framework put forward by Renn includes five steps: pre-assessment, appraisal, characterization/evaluation, management, and communications (Renn, 2008). PRA contributes most significantly to the characterization/evaluation stage.

1.3.2. Challenges in Implementing the Probabilistic Risk Framework

Many factors influence the outcomes of efforts to manage, reduce, and transfer risk, including some that create barriers to achieving outcomes perceived as satisfactory. Two factors – imprecise probabilities and difficulties in communicating about extremes -- present particular challenges to the characterization and evaluation of the risks associated with extreme events. A discussion of barriers in the more general context of maladaptation is found in section 1.4.3.2.

1.3.2.1. Challenge of Imprecise Estimate of Probabilities and Consequences

Extreme events, extreme impacts, and disasters pose a particular set of challenges for implementing probabilistic approaches because their relative infrequency often makes it difficult to obtain adequate data that could be used in Eq.1 to estimate the probabilities and consequences.

The likelihood of extreme events is most commonly described by the return period, the mean interval expected between one such event and its recurrence. For example, one might speak of a 100-year flood or a 50-year windstorm. More formally, these intervals are inversely proportional to the ‘annual exceedance probability,’ the likelihood that an event exceeding some magnitude occurs in any given year. Thus the 100-year flood has a 1% chance of occurring in any given year (which translates into a 37% chance of a century passing without at least one such flood ($(1-0.01)^{100}$=37%). The long return period of extreme events can make it difficult to reliably estimate their frequency. Statistical methods exist that can estimate frequencies longer than available data time series (Milly *et al.,* 2002). However, climate change presents the challenge of non-stationarity (Milly *et al.,* 2008), where the statistical properties of weather events do not stay constant over time. This exacerbates the already difficult estimation challenge by altering frequencies and consequences of extremes in difficult-to-predict ways (chapter 3; Meehl *et al.,* 2007; NRC, 2009; TRB, 2008).

Estimating the likelihood of various consequences and their value is at least as challenging as estimating the likelihood of extreme events. Projecting future vulnerability and response capacity involves predicting the behavior of complex human systems under potentially stressful and novel conditions. Section 1.4 describes some of the challenges such system complexity may pose for effective risk assessment. In addition, disasters affect socio-economic systems in multiple ways so that assigning a quantitative value to the consequences of a disaster proves difficult (see section 1.2.3.3). The literature distinguishes between direct losses, which are the immediate consequences of the disaster-related physical phenomenon, and indirect losses that are the consequences that result from the disruption of life and activity after the immediate impacts of the event (Pelling et. al., 2002; Lindell and Prater, 2003; Cochrane, 2004; Rose, 2004).

The disaster risk management and climate change communities have explored a variety of methods to help support decisions when it proves difficult or impossible to accurately estimate probabilities of events and of the adverse consequences suffered by the human systems with which these events interact. Qualitative scenario methods are often used (Parson *et al.,* 2007). The fuzzy set approach is an efficient method for incorporating subjective uncertainty and addressing social issues, perception, and risk communication in management of disasters (Chongfu, 1996; Karimi and Hullermeier, 2007; El-Baroudy and Simonovic, 2004; Simonovic, 2011). To help communicate imprecision in probabilistic estimates, the IPCC uncertainty guidance (IPCC, 2006) asks for both quantitative judgments about ranges of probabilities and qualitative judgments about confidence in these estimates. Probabilistic risk analysis can often be implemented in situations in which the probabilities are imprecise by employing ranges of values or sets of distributions, rather than single values or single best-estimate distributions (Morgan *et al.,* 2009).

1.3.2.2. Barriers to Effective Communication about Extremes

1.3.2.2.1. Cognitive barriers

The literature on judgment and decision-making suggests various cognitive barriers to individuals and organizations properly assimilating and responding to information about low probability/high severity events. To be effective, disaster risk management and climate change adaptation would address these barriers by engaging a wide range of stakeholder groups -- such as scientists, policy makers, private firms, non-governmental organizations, media, educators, and the public -- in a process of exchanging, integrating and sharing knowledge and information. Sustainability science promotes interactive co-production of knowledge between experts and other actors, based on transdisciplinarity (Jasanoff, 2004; Pohl *et al.,* 2010) and social learning (Pelling *et al.,* 2008; Pahl-Wostl, 2009).

As described in the judgment and decision-making literature, the concepts of disaster, risk, and disaster risk management have very different meanings and interpretations in expert and non-expert contexts (Sjöberg, 1999a). Experts in the private and public sectors often apply the probabilistic risk analysis framework. In contrast, the general public, politicians, and the media tend to focus on the concrete adverse consequences of such events, absent from the probabilistic context (Sjöberg, 1999b). To the extent that they respond to risk information transmitted in probabilistic form, they often do so in ways that diverge sharply from formal probability theory. By definition (if not always in practice), the application of understanding of risks associated with extreme events by experts is based in large part on analytic tools. Non-experts, on the other hand, rely to a greater extent on more readily available and more easily processed information. These gaps between expert and non-expert understanding of extreme events present important communication challenges (Weber and Stern, in press).

Quantitative methods exist that can allow people operating in expert contexts to use observed data, often from long time series, to make systematic and internally consistent estimates of the probability of future events. Individuals, including non-experts and experts making estimates without the use of formal methods (Barke *et al.,* 1997), often predict the likelihood of encountering an event in the future by consulting their past experiences with such events. The "availability" heuristic (i.e., useful shortcut) is commonly applied, in which the likelihood of an event is judged by the ease with which past instances can be brought to mind (Tversky and Kahneman, 1979). Extreme events, by definition, have a low probability of being represented in past experience and thus will be relatively unavailable. Experts and non-experts alike may essentially ignore such events until they occur, as in the case of a hundred-year flood (Hertwig *et al.,* 2004). When extreme events do occur with severe and thus memorable consequences, people's estimates of their future risks will, at least temporarily, become inflated (Weber *et al.,* 2004).

Judgments of risk made in non-expert contexts may be influenced more by emotional reactions to events (e.g., feelings of fear and loss of control) than by analytic assessments of their likelihood (Loewenstein *et al.,* 2001). When expert assessment provides predictions about extreme events, making them "available", people frequently ignore such forecasts if the extreme event fails to elicit strong emotional reactions, but will also overreact to such forecasts when the events elicit feelings of fear or dread (Weber, 2006). Ignoring the risk of extremes is common in low income, hazard prone communities. Even with sufficient information, every day concerns and satisfaction of basic wants may supplant longer-term disaster risk concerns (Maskrey, 1988; Wisner *et al.,* 2004). Furthermore, some differences between expert and non-expert frameworks may reflect distinct cultural or philosophical approaches to risk rather than inadequate grasp of probabilistic approaches (Section 1.3.2.2.3).

1.3.2.2.2. Asymmetric reactions to gains and losses

Statistical theories and concepts related to dispersion or extremity of events treat the direction of deviations from average conditions or central tendency in a symmetric fashion. In contrast, the reactions of the general public, politicians, and the media are typically far stronger to deviations in the negative direction (perceived losses) than to deviations in the positive direction (perceived gains) (Kahneman and Tversky, 1979). Both imagined and experienced negative extreme events capture individual and societal attention and resources, as there is strong motivation to reduce the likelihood or impact of such events. Such asymmetry may arise from cognitive barriers as well as cultural and ideological influences (Section 1.3.2.2.3).

1.3.2.2.3. Influence of culture and ideology

In addition to being influenced by cognitive shortcuts (Kahneman and Tversky, 1979), the perceptions of risks and extremes by nonscientists and their reactions to such risks and events are also shaped by motivational processes (Weber, 2010). Cultural theory combines insights from anthropology and political science to provide a conceptual framework and body of empirical studies that seek to explain societal conflict over risk (Douglas, 1992). People's worldview and political ideology guide attention towards events that threaten their desired social order (Douglas and Wildavsky, 1982). Risk in this framework is defined not as damages or losses, but as the disruption of a social equilibrium. Personal beliefs also influence which sources of expert forecasts of extreme climate events will be trusted. Different cultural groups put their trust into different organizations, from national meteorological services to independent farm organizations to the IPCC; their values, beliefs, and corresponding mental models will be receptive to different types of interventions (Dunlap and McCright, 2008; Malka and Krosnick, 2009).

Factual information interacts with social, institutional, and cultural processes in ways that may amplify or attenuate public perceptions of risks and extreme events (Kasperson *et al.,* 1988). The US public's distrust of nuclear power following the accident at Three Mile Island provides an example of the cultural filtering of engineering safety data, where social amplification increased public perceptions of the risks of nuclear power far beyond levels that would be indicated by application of accident statistics in isolation (Fischhoff *et al.,* 1983). Such public transformation of expert-provided risk signals can be seen as a corrective mechanism by which cultural subgroups of society augment a science-based risk analysis with psychological risk dimensions not traditionally considered (Slovic, 2000). Evidence from health, social psychology, and risk communication literature suggests that social and cultural risk amplification processes modify perceptions of risk in either direction and in ways that may generally be socially adaptive, but can also bias reactions in socially undesirable ways in specific instances (APA, 2009).

1.3.3. Current Framework for Disaster Risk Management

Comprehensive approaches, such as those introduced in section 1.1 and box 1.2, are often more easily developed conceptually than practically, and are more accepted and utilized in academic, NGO and international agencies than in many national disaster or disaster risk agencies (Wisner *et al.,* 2004; Twigg, 2004; UN, 2009; Wisner *et al.,* forthcoming; Beer and Hamilton, 2002). Differential access to information and education, varying levels of debate and discussion, as well as contextual, ideological, institutional, and other related factors cause countries to exhibit a wide range of acceptance or resistance to the various challenges of risk management. One such challenge is to ensure the transition to greater emphasis on comprehensive Disaster Risk Management while not removing attention from disaster preparedness and response needs (see Hewitt, 1983; Smith, 1996; Tobin and Montz, 1997; Blaikie *et al.,* 1996; Hewitt, 1997; Wisner *et al.,* 2004, Lavell, 2003; Gaillard, 2010, for background and review of some of the historical changes in favor of disaster risk management). The introduction of disaster risk reduction concerns in established disaster response agencies may have led to a down grading of efforts to improve disaster response, distracting scarce resources in favor of risk reduction aspects (Alexander, 2000; Twigg, 2004; DFID, 2004; DFID, 2005).

The transition in favor of comprehensive or integral disaster risk management has been stimulated by the increasingly accepted and documented relationship between disaster risk and skewed development processes (Sen, 1982; Wijkmans and Timberlake, 1988; Hagmann, 1984; Lavell, 1999, 2003, 2009; Wisner *et al.,* 2004; UNDP, 2004; UN, 2009; Dulal *et al.,* 2009). For example, significant differentiation in the gains from development and in the incidence of chronic or every day risk, which particularly affect poorer persons and families, is widely accepted to be a major contributor to the more specific existence of disaster risk. A reduction of the rate of ecosystem services depletion, improvements in urban land use and territorial organization processes, the strengthening of rural livelihoods, and general and specific advances in urban and rural governance, are indispensable to achieving the composite agenda of poverty reduction, disaster risk reduction and climate change adaptation (UN, 2009).

The growing developmental and public sector economic impacts of disasters, particularly in small, poor and island state economies, has led to rapidly increasing concerns for post-impact financing of recovery. In this context the concept of risk transfer has received increased interest and salience. Also described as “risk sharing”, this approach refers to mechanisms that permit risk to be transferred to willing third parties or be shared among a larger group, through financial vehicles such as insurance. In their direct form, such mechanisms offer financial protection but do not as such reduce the risk of primary loss and damage. However, properly configured risk transfer mechanisms can encourage disaster risk reduction when insurance rates are allowed to reflect the existing level of risk, with rates being lower where action is taken to reduce primary risk and higher where such actions are not taken (see Lavell and Lavell, 2009, for examples of such uses amongst poor communities in the Bolivian uplands and the city of Manizales in Colombia). Chapters 5, 6, 7, and 9 discuss risk transfer in some detail.

The gradual evolution of policies that favor disaster risk reduction objectives as a component of development planning procedures has inevitably placed the preexisting emergency or disaster response oriented institutional and organizational arrangements under scrutiny.

The prior absolute dominance of response-based organizations, where aspects of so-called disaster prevention were stimulated, has been complemented with the increasing incorporation of economic and social sector and territorial development agencies or organizations, as well as planning and finance ministries. Systemic, as opposed to single agency approaches, are now evolving in many places. Synergy, collaboration, coordination, and the development of multidisciplinary and multiagency schemes are increasingly seen to be required to guarantee risk reduction and risk management in a sustainable development framework (see Ramírez and Cardona, 1996, on the early 1989 creation and subsequent development of the then innovative Colombian system).

1.3.4. Climate Change Adaptation Framework

Climate change adaptation attempts to anticipate future impacts and respond to those already experienced. The early climate change literature focused on identifying and characterizing vulnerabilities to human and natural systems (IPCC, 1995). In recent years this literature has grown to include informing efforts to manage or reduce those vulnerabilities, as organizations worldwide have begun to take such actions (UNDP 2008; WDR 2010; ACC 2010). The current IPCC definition of adaptation envisions climate changes as the primary driver of adaptation decisions. While this view can inform trade-offs and synergies between adaptation and greenhouse gas mitigation, the climate change adaptation literature increasingly considers the concept of climate-related decisions, which are choices by individuals or organizations, the outcomes of which can be expected to be affected by climate change and its interactions with ecological, economic, and social systems (NRC 2009, Brown *et al.,* 2006, McGray *et al.,* 2007, Dulal *et al.,* 2009, Colls *et al.,* 2009). For instance, choosing to build in a low-lying area whose future flooding risk may increase due to climate change represents a climate-related decision. Such a decision is climate-related whether or not the decision makers recognize it as such.

A key concern and contribution of the climate change adaptation literature has been a focus on the need to anticipate future climate, biophysical, and socioeconomic conditions, which in general will be different to those in the present and affect the success of near-term decisions. Climate change adaptation aims to address changes on two different timescales: i) gradual, long-term changes in biophysical systems, such as sea levels, precipitation patterns, and the distribution of ecosystems and ii) weather extremes. Both types of changes can affect the level and complicate the management of disaster risk because many risks may become simultaneously more severe (chapter 3) and more difficult to estimate accurately. In some cases, the probability and consequences of both may have already changed outside the bounds of past historical experience (chapter 3 and 4).

Climate change adaptation has increasingly adopted an iterative risk management framework (Carter *et al.,* 2007; Jones and Preston 2011). This framework recognizes that the process of implementing PRA does not constitute a single set of judgments at some point in time, but rather an ongoing assessment, action, reassessment, and response that will continue – in the case of many climate-related decisions – for decades if not longer (ACC 2010). A key challenge in implementing such iterative risk management for climate change adaptation is that the uncertainties associated with many climate-related decisions present decision makers with conditions where the probability estimates are imprecise and/or the structure of the models that relate actions to consequences are under-determined (NRC 2009; Morgan et. al., 2009). Such deep or severe uncertainty (Lempert and Collins 2007) can characterize not only understanding of future climatic events but also future patterns of human vulnerability and the capability to respond to such events. With complex, poorly understood physical and socio-economic systems like many of those involved in climate-related decisions, research and other learning may enrich our understanding over time, but the amount of uncertainty, as measured by our ability to make specific, accurate predictions, may grow larger. In addition, theory and models may change in ways that make them less, rather than more reliable as predictive tools over time (Oppenheimer *et al.,* 2008). Climate change adaptation approaches for addressing such uncertainties may contribute to disaster risk management (Schipper, 2009; McGray *et al.,* 2007; IIED 2009).

Both the climate change adaptation and vulnerability literatures often take an actor-oriented view (Nelson et. al., 2007; Wisner et. al., 2004; McLaughlin and Dietz 2007) that focuses on particular agents faced with a set of decisions and which can make choices based on their various preferences; their institutional interests, power, and capabilities; and the information they have available. The resilience literature shares an interest in the anticipation of and response to change but tends to take a systems view (Nelson et. al., 2007; Olsson et. al., 2006; Walker *et al.,* 2006; Berkes, 2007) that considers multi-interacting agents and their relationships in and with complex social, ecological, and geophysical systems (Miller et. al., 2010). The resilience literature can help disaster risk management and climate change adaptation to highlight issues such as the tension between resilience against specific, known disturbances and novel and unexpected ones, the tension between resilience at different spatial and temporal scales, and the tension between the ability of a system to persist in its current state and its ability to transform to a fundamentally new state (section 1.4; ICSU, 2002; Berkes, 2007).

Similarly to disaster risk management, the climate change adaptation literature increasingly emphasizes the importance of addressing climate change in the context of a broader range of issues. For instance, because in less developed regions vulnerability, adaptive capacity and exposure are critically influenced by existing structural deficits (low income and high inequality, lack of access to health and education, lack of security and political access, etc), scholars have argued that building adaptive capacity is a dialectic, two-tiered process in which climatic risk management (specific adaptation capacity) and deeper level socioeconomic and political reform (generic adaptation capacity) iterate to shape overall vulnerability (Lemos *et al.,* 2007; Tompkins *et al.,* 2008).

In-depth studies suggest that risk management alone will have limited success in reducing overall vulnerability despite increasing coping ability for those at risk. Particularly in the context of less developed regions, it is likely that the two forms of adaptation capacity are contingent on each other, that is, to access the benefits of climatic risk management, extremely vulnerable human systems require a minimum level of generic adaptation capacity. In Bangladesh, despite persisting poverty, improved disaster response and relative higher levels of households adaptive capacity has dramatically decreased the number of deaths as a result of flooding (del Ninno *et al.,* 2002; del Ninno *et al.,* 2003). However, in drought-ravaged NE Brazil, there are many examples of vulnerable households that lacked the minimum capacity to take advantage of risk management interventions such as seed distribution programs, either because they lacked money to travel to pick up the seeds or because they could not afford to forego a day's labor to enroll and participate in the program (Lemos, 2003). In Burkina Faso, farmers were limited in their ability to use seasonal forecasts (a risk management strategy) because they lacked minimal resources (basic agricultural technology such as plows, alternative crop varieties, fertilizers, etc.) to be able to respond to the projections (Ingram *et al.,* 2002).

Moreover, climatic risk management approaches can create positive synergies with development goals through participatory and transparent approaches (such as participatory vulnerability mapping or local disaster relief committees) that empower local households and institutions (e.g., (Degg and Chester, 2005; Nelson, 2005)).

1.3.5. Integrating Disaster Risk Management and Climate Change Adaptation

A principal goal of the present assessment report is to capitalize on the potential synergies between the fields of disaster risk management and climate change adaptation. Both fields share a common conceptual interest in understanding and reducing the risk created by the interactions of human and biophysical systems. Disaster risk management can help those practicing climate change adaptation to address impacts now and in the future. Climate change adaptation can help those practicing disaster risk management to more effectively address future conditions that differ from those of today. There are similarities in concepts, objectives and approaches that offer great promise for improved outcomes in both fields. In many countries, experience is growing on how to implement cooperative, inter-sector and multi or interdisciplinary approaches (ICSU, 2002; Brown *et al.,* 2006; McGray *et al.,* 2007; Lavell and Lavell, 2009; Lavell, 2010). Commonality revolves around a concern for the impacts of both extreme and non-extreme climate events on society under varying conditions of exposure and vulnerability; a concern for the reduction of vulnerability; and a concern with climate change and variability in the present-day and the future. Furthermore, concern for pre-impact risk management or adaptation is complimented with concerns for post impact response and recovery mechanisms in both fields.

The difficulties experienced with integration of these concepts and practices have been variously explained by differences in: historical and evolutionary processes; conceptual and definitional bases; processes of social knowledge construction and the ensuing scientific compartmentalization of subject areas; institutional and organizational funding and instrumental backgrounds; scientific origins and baseline literature; conceptions of the relevant causal relations and the relative importance of different risk factors, as well as the lack of full understanding between the fields in terms of content, significance and method (see Sperling and Szekely, 2005; Schipper and Pelling, 2006; Thomalla, 2007; Schipper and Burton, eds., 2009; Tear Fund, 2008, Mitchell and van Aalst, 2008; Lavell, 2010).

Three key distinctions in methods may also inhibit the integration process.

Firstly, disaster risk management concepts, theory and learning from practice has tended to encourage a bottom up, grass roots approach, increasingly emphasizing local and community based risk management in the framework of national management systems (see chapter 5 and 6). Disaster risk is location-specific and disaster risk management concerns and responses will often begin at the local or community level. On the other hand, climate change adaptation has to date tended to be driven from the top down, in part due to the difficulty of predicting future changes at the local level. Disaster risk management is also more likely to promote the use of territory as a point of reference, whereas climate change adaptation has tended to have an orientation toward social and economic sectors and macro ecosystems (as does much agency-driven disaster risk management practice).

Secondly, disaster risk management has placed an increasing emphasis on the social conditioning of risk and the construction of vulnerability as a causal factor in explaining loss and damage. Climate change adaptation has tended to place emphasis on physical events and exposure; seeing vulnerability as what remains after all other factors have been considered. However, community based adaptation work in developing countries has helped move this position further towards social causation aspects (Beer and Hamilton, 2002; Brown *et al.,* 2006; Lavell and Lavell, 2009; UNISDR, 2009b and c).

A route to overcoming the two foregoing differences in approach is indicated by the body of work on the determinants of adaptive capacity that focus on the interaction of individual and collective action and framing institutions (McCray *et al.,* 2007; Schipper, 2009)

Thirdly, climate change adaptation has tended to focus considerable attention on extreme events in its deliberations and discussions, and less on the concatenation of small and medium sized events or on multihazard contexts. The notion of adaptation to extreme physical events is considered impractical by some disaster risk management specialists (Lavell, 2009; Lavell, 2010). Such stakeholders tend to favor ideas on adaptation, adjustment, prevention or mitigation to changing climate means and to the much more regular, non-extreme, but still potentially highly damaging events. On going work for the 2011 Global Assessment Report from the UN has taken up on the theme of different risk strata and the question of what levels of risk are manageable by governments.

Differences have been emphasized regarding the overall coverage and concern of the two practices. Disaster risk management covers a wide range of hazard events (e.g. earthquakes and volcanoes), while climate change adaptation involves concerns for adjustments, amongst others, to changing climate means, sea level rise and loss of polar and glacier ice as well as ongoing concerns for health related aspects. Moreover, it has been suggested that disaster risk management is short term and passing in its outlook, whilst climate change adaptation is more long term and permanent.

However, such differences are not absolute (Birkmann and von Teichman, 2010; World Resources Institute, 2007; ECA, 2009; Lavell, 2010). Climate change adaptation, in addressing a full range of climate-related decisions, can often benefit from a disaster risk management multi-hazard framework; for instance, that relocation responses to sea level change are synonymous with contexts already dealt with historically by disaster risk management when addressing persistent flooding, landslides, volcanoes and such, and the demand for post disaster relocation; that loss of glacial ice melt supplies of water and resulting increased water deficit or drought problems are just further manifestations of water access problems suffered historically under other drought stressors; and that disease vectors and ensuing increased health problems in areas affected by adverse climate conditions have arisen under normal, observed conditions of the climate variability associated, for example, with the occurrence of El Niño.

As regards the time scale involved, it is clear that disaster risk management in its most recent conception and practice aims to anticipate risks associated with physical event return periods of hundreds, if not thousands of years and involves significant forward-looking decisions on prevention, investment and structural solutions. Moreover, climate change adaptation is not only long, but also short term, given its concern for climate changes that are already manifest and local and regional effects which need to be managed immediately in reactive or corrective fashion.

The following areas, some of which have been pursued by governments, civil society actors and communities, are among those that could be pursued in order to foster integration:

- Development of a common lexicon and deeper understanding of the concepts and terms used in each field (Schipper and Burton, 2008).
- Implementation of government policy making and strategy formulation that jointly considers the two topics (see The Central American Integral Disaster Risk Management Policy and Climate Change Strategies and the Philippines and Bangladesh country cases, for examples);
- Evolution of national and international organizations and institutions and their programs that merge and synchronize around the two themes, such as: environmental ministries coordinating with development and planning ministries (see the National Environmental Planning Authority in Jamaica and the Peruvian Ministries of Economy and Finance, Housing and Environment).
- Merging and/or coordinating Disaster Risk Management and Climate Change Adaptation financing mechanisms through development agencies and NGOs ;
- Using disaster risk management local level risk and context analysis methodologies with strong civil society participation and government buy in (Lavell and Lavell, 2009; UNISDR, 2009 b and c);
- Implementing bottom-up approaches whereby local communities integrate climate change adaptation, disaster risk management, and other environmental and development concerns in a single, causally dimensioned, intervention framework (Moench and Dixit, 2004; Lavell and Lavell, 2009).

1.4. Coping and Adapting

Coping and adapting are central concepts for disaster risk management and climate change adaptation in both scholarship and practice. Despite this fact the meanings of these terms are muddled. Even after focused efforts to parse these (Davies, 1993), they are often used interchangeably and great “conceptual confusion” remains (Davies, 1996). In general usage, coping focuses on employing immediately available resources to address present needs, while adaptation focuses on making resources available to address emerging needs and those that may increase in the future. The confusion in the disaster risk management and climate change literature derives less from doubts as to how to define these terms as such than from the lack of a clear consensus regarding the relationships between the two processes over time. As a result, there is no clear specification of how the adaptation process can be managed to maximal effect, reducing the need for societies to cope with extreme impacts associated with climate change. Such lack of clarity has the potential to complicate the efforts of governments to establish policies in this arena.

The present discussion thus has three goals. The first is to explore the relationships between coping and adapting. The second goal is to consider barriers to effective adaptation. And, the third is to reframe the notions of coping and adaptation in terms of learning from experience (see box 1-3), to highlight the role of learning in facilitating short term recovery and promoting appropriate longer term adjustments, and to facilitate the development of effective policy.

_____ START BOX 1-3 HERE _____

Box 1-3. Adaptation to Rising Levels of Risk

Properly implemented or achieved adaptation can shift a society's capacity to live productively with significant natural hazards. This is particularly the case when the historical distribution of hazard intensity is well known and relatively stable. In such instances, adaptation efforts over time can match a society's coping range with the hazards it typically encounters. As the following example illustrates, this process both depends on and facilitates further economic development, but adjustment in response to shifting hazard distributions is important to avoid increasing and maladaptive hazard exposure.

Before 1000 AD, in the low lying coastal floodplain of the southern North Sea and around the Rhine delta, the inhabitants lived on dwelling mounds, piled up to lie above the height of the majority of extreme storm surges. By the 10th Century, with a population of what is now the Netherlands estimated as 300,000 people, inhabitants had begun to construct the first dykes and within 400 years ringed all significant areas of land above spring tide, allowing animals to graze and people to live in the protected wetlands. The expansion of habitable land encouraged a significant increase in the population exposed to catastrophic floods (Borger and Ligtendag, 1998). The weak sea dykes broke in a series of major storm surge floods through the stormy 13th and 14th Centuries (in particular in 1212, 1219, 1287, and 1362), flooding enormous areas (often permanently) and causing more than 200,000 fatalities, reflecting an estimated lifetime mortality rate from flood for those living in the region in excess of 5% (assuming a 30 year average lifespan; Gottschalk, 1971, 1975, 1977).

To adapt to increasing risk (reflecting long term delta subsidence), major improvements in the technology of dyke construction and drainage engineering began in the 15th Century. As the country became richer and population increased (to an estimated 950,000 by 1500 and 1.9 million by 1700), it became an imperative not only to provide better levels of protection but also to reclaim land from the sea and from the encroaching lakes, both to reduce flood risk and expand the land available for food production (Hoeksma, 2006). Examples of the technological innovations included: the development of windmills for pumping, and methods to lift water at least 4m whether by running windmills in series or through the use of the wind-powered Archimedes screw. As important was the availability of capital to be invested in joint stock companies with the sole purpose of land reclamation. In 1607 a company was formed to reclaim the 72km^2 Beemster Lake north of Amsterdam (twelve times larger than any previous reclamation). A 50km canal and dyke ring were excavated, a total of 50 windmills installed which after five years pumped dry the Beemster polder, 3-4m below surrounding countryside, and which, within 30 years, had been settled by 200 farmhouses and 2000 people.

Since the major investment in raising and strengthening flood defenses in the 17th Century, there was only one major flood, in 1717 (when 14,000 people drowned), since which time the total flood mortality has been around 1000 per century, (with two notable floods in 1825 and 1953), equivalent to a lifetime mortality rate (assuming a 50 year average lifetime) of around 0.01%, 500 times lower than that which had prevailed through the Middle Ages (Van Baars and Van Kempen, 2009). This change reflects increased protection rather than any reduction in storminess. Since 1953 the flood risk has been reduced at least an equivalent step further although this risk is considered now to be rising again due to climate change (Bouwer and Vellinga, 2007) and plans are being developed to manage further rises anticipated with increased inland and coastal flood hazard and again shift the coping range in anticipation of the new hazard distribution.

_____ END BOX 1-3 HERE _____

1.4.1. Definitions

While this section is concerned with coping and adapting in the contexts of disaster risk management and climate change adaptation, it is helpful first to look at the terms' dictionary definitions from which the thematic meanings derive. The *Oxford English Dictionary* defines *coping* as "the action or process of overcoming a problem or difficulty . . . or . . . managing or enduring a stressful situation or condition" and *adapting* as "rendering suitable, modifying" (OED, 1989). Contrasting the two terms highlights several important differences that are evident in their dictionary and even common usage definitions, relevant examples of which can be found in the literature cited:

- The first is exigency: coping implies survival in the face of immediate, unusually significant stress, when resources, which may have been minimal to start with, are taxed (Wisner, *et al.,* 2004), whereas adapting suggests reorientation in response to past or anticipated change, often without specific reference to resource limitations.
- The second is constraint: in coping, survival is foremost and bounded by available knowledge, experience, and assets, and reinvention is a secondary concern (Bankoff, 2004), while in adapting, adjustment is the focus and limits are not the primary concern.
- The third is reactivity: coping is tactical and used to protect basic welfare and provide for basic human security or survival after an event has occurred (Adger, 2000), while adapting is strategic and focused on anticipating change and addressing this proactively (Fussel, 2007), even if spurred by recent events seen as harbingers of further change.
- The fourth is orientation: coping is focused on past events that shape current conditions and, by extension, on previously successful tactics (Bankoff, 2004), while adapting is oriented toward future conditions and incorporates past tactics to the extent that they can facilitate adjustment, though according to some the two can overlap and blend (Chen, 1991).

Coping focuses on the moment, constraint, and survival; adapting focuses on the future where learning and reinvention are key, and short-term survival is less in question.

The definitions of coping and adapting used in this report reflect the connotations of the dictionary definitions. In particular, the glossary definition of coping emphasizes the use of available resources, skills, and opportunities to return to a basic standard of normality in the relatively near term after impact, while adaptation refers to adjustments, typically forward looking, in order to moderate future harm or exploit emerging opportunities. As an example, a community cannot adapt its way through the aftermath of a disastrous hurricane; it must cope instead. But adaptation in anticipation of the next hurricane can limit the coping that may be required. Importantly, in the aftermath, the use of certain coping mechanisms can limit the adaptation process, in ways that will be explored further below. It is also important to note that adaptation can (and often does) occur in the context of already changed climatic circumstances; the key is that those changed circumstances are expected to endure or, more commonly, to change further, necessitating a forward looking shift in disaster risk management. These relationships between the two concepts are not explicit in the definitions, but have been explored in the disaster and climate change adaptation literature.

1.4.2. Coping and Adapting in Current Usage

As noted above, the relationship between coping and adapting is unclear in both the disaster risk management and the climate change adaptation literature. This confusion extends to related terms such as coping capacity, coping range, and adaptive capacity. For instance, recent work on the topic has proposed various relationships between the two concepts, including synergy, in which coping is considered a means of advancing climate change adaptation (UNFCCC, 2003); recursive interactions, in which adaptation is seen to shift the coping range, or range of climate-related hazards that a society can successfully engage without incurring substantial losses (Smit and Pilifosova, 2001; Yohe and Tol, 2002; Jones and Mearns, 2004); temporal dependence, based on the assertion that coping occurs in the present and adaptation is a process that is realized over time (Brooks, 2003); and conditionality, as short term coping efforts are seen to erode the capital required for longer term adaptation (Adger, 1996). The imprecision that derives from these varying relationships is compounded when other terms whose meanings are contingent on a particular disciplinary connotation, such as resilience, are introduced.

Coping was first used in disaster work to refer primarily to survival strategies when practice was focused on reactive, response-based disaster or emergency management. As the disaster management community began to reorient its thinking toward disaster risk management in a development framework, in the 1980s, it embraced coping as a means to engage local populations and utilize indigenous knowledge in disaster preparedness and response (Twigg, 2004). Coping mechanisms were sometimes grouped with adjustment mechanisms useful for advancing development objectives (Clarke Guarnizo, 1992). There was concern, however, that this would divert attention away from addressing structural problems that could obviate the need for coping in the future (Davies, 1993), a focus on "surviving" instead of "thriving". Since then, there has been persistent discussion over where coping fits in the disaster risk management cycle and whether it is primarily *ex-post* or both *ex-ante* and *ex-post* disastrous events (UNISDR, 2008b; UNISDR, 2008c; UN, 2009) while the term has been used to refer both to strategies used to avoid risk (Ribot, 1996) and to strategies used to endure it, with an overall shift toward a focus on surviving a disastrous event. Thus, the current UNISDR definition of coping capacity is the 'ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters' (UNISDR, 2009d).

The climate change adaptation literature is primarily focused on the process of adaptation rather than on coping with discrete events. In this literature, coping is sometimes used as a standalone term in its conventional sense, i.e. as a means of surviving a shock, but equally often as part of the phrases coping capacity or coping range, synonyms that refer to the boundaries of a system's ability to survive and recover from a shock (Yoho and Tol, 2002). Coping range has been defined in part as a function of a system's prior adaptation (both autonomous and planned) (Hewitt and Burton, 1971; De Vries, 1985; De Freitas, 1989). The relationships between the use of coping strategies in response to a stress event, the recovery process, and the implications for long term development have received less attention in the climate change adaptation literature. The climate change literature does note the potential for coping strategies to deplete capital, with potential implications for future adaptation activities (Adger, 1996; Risbey *et al.,* 1999), and several other similar concerns have been discussed in regards to maladaptation (Barnett and O'Neill 2009). In contrast, however, some have suggested that coping mechanisms can be an initial if insufficient step in the adaptation process (Frankenberger and Goldstein, 1990). Summing the range of possibilities, Schipper and others (2011) note "while the ability to cope may suggest some resilience, the coping actions themselves may lead either to increased resilience, exposure and/or sensitivity over time". Overall, coping is acclaimed as tactical and noted to be a potential bridge to adaptation, in the sense that a community must survive in order to adapt. The resources put into building this bridge, however, would be more strategically deployed if used to enhance system adjustments.

1.4.3. Barriers to Successful Adaptation

Regardless of the terms used, there are interactions between coping and adaptation at several levels. While coping mechanisms facilitate survival, they also entail costs, and have the potential to shift a community into what has been termed transient poverty (Lipton and Ravallion, 1995). Rather than leaving resources for adaptation, communities forced to cope can become increasingly vulnerable to future risks (O'Brien and Leichenko, 2000). Successful adjustments can widen and shift a community's coping range, enabling it to absorb a wider range of future disaster risks (chapter 9). Thus there is a recursive relationship between past exposures, current coping range, adaptive capacity, and future risk. How this relationship is mediated and the impediments to successful adaptation are the focus of this sub-section.

1.4.3.1. Adaptation Failures and Maladaptation

While adaptation, particularly planned adaptation, has the potential to expand and shift the coping range into better alignment with anticipated new risks, not all adaptation efforts will be successful. Indeed it is difficult to arrive at one universally accepted approach to identifying a successful adaptation measure, as the impact of particular adaptation activities on disaster risk depends on the lens through which adaptation is viewed (Adger *et al.,* 2005). Deferring the process of defining successful adaptation, however, it is still possible to discuss adaptation failures, which fall into two broad categories: adaptation efforts that are derailed as a result of barriers that interrupt, delay, or stop the adaptation process; and adaptation efforts that achieve the stated objective but nevertheless increase overall risk. The two categories have similar causes, an issue to which we will return after briefly discussing these in more depth.

A host of barriers can undermine planned adaptation efforts. Moser and Ekstrom (2010) outline an adaptation process that includes understanding, planning and management (each containing several essential steps) and note that there are barriers at each step that can cause the adaptation process to fail. For instance, they note that adaptation efforts can fail before they begin as a result of barriers to understanding, including difficulty recognizing a changing signal due to difficulty with its detection, perception, and appreciation; preoccupation with other pressing concerns that divert attention from the growing signal; and lack of administrative and social support for making adaptive decisions. Other barriers can arise in the planning and management stages of the adaptation process in similar fashion, resulting from complex interactions between a wide range of actors, their perceptions, and the systems they manage, all over time. Planning barriers, for instance, can result from failure to adequately identify the full range of possible management options or from perceptions related to the feasibility of these, while management barriers may result from insufficient control over identified options, and lack of authorization, or insufficient material support to implement and monitor the chosen options.

In the climate change literature, maladaptation has been defined as “action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups” (Barnett and O'Neill, 2009). Barnett and O’Neill identified five types: adaptation activities that increase greenhouse gas releases; adaptation activities that burden vulnerable populations disproportionately; adaptation activities with relatively high opportunity costs; adaptation decisions and actions that reduce incentives for further adaptive action; and adaptation decisions that require excessive commitment to one path of action. Another type includes actions that offset one set of risks but increase others (perhaps unrelated to climate change), resulting in net risk increase, such as a dam that reduces flooding risk but increases the risk of certain vector-borne and zoonotic diseases and has an overall net negative impact on morbidity and mortality even after flood-related illness and death are taken into account.

Management of risk also may be maladaptive when it amplifies risks to those who remain exposed (or are newly exposed as a result of a maladaptive risk management strategy). There are abundant examples of this in the public health literature (Sterman, 2006) as well as literature from other fields and the issue frequently arises in managing large insurance systems. One common mechanism is the implementation of a risk management device that has the potential to provide false comfort if risks are not continuously reassessed, if risk management strategies and devices are inadequately maintained, or if other risk management strategies are not recruited as necessary. This was the case with the levees in New Orleans prior to Hurricane Katrina, termed the “safe development paradox,” wherein the levees were built to make a hazardous area safe but paradoxically a much larger population was exposed to catastrophic risk. As a result of multiple factors that have been termed the “local government paradox,” (Burby, 2006) crumbling levee infrastructure increased the risk of flooding but no other adequate risk reduction and management measures were implemented, resulting in catastrophic loss of life and property when the city was hit with the surge from a strong category 3 storm (Comfort, 2006).

Some have suggested that, as a result of the federal government’s historical approach to natural disasters, those whose property was at risk in New Orleans anticipated that they would receive federal recovery funds in the event of a flooding disaster, and that this distorted the risk management landscape, resulting in improper pricing of flooding risks, decreased incentives to take proper risk management actions, and thus exposure of a larger population to flood risk than otherwise might have been the case (Kunreuther, 2006). This instance illustrates the impact of maladaptive risk sharing and demonstrates the importance of considering how risks, in practice, are assumed and shared. The goal of risk sharing is to properly price risk so that, in the event risks are realized, there is an adequate pool of capital available to fund recovery. When risks are improperly priced and risk sharing is not adequately regulated, as can occur when risk-sharing devices are not monitored appropriately, an adequate pool of reserves may not accumulate. When risks are realized, the responsibility for funding the recovery falls to the insurer of last resort, typically the public (see also section 1.3.3).

This issue brings into relief the potential for large insurance systems to subsidize risk, moral hazard (see Section 1.3.3), and the issue of maladaptive risk management practices mediated through both public and private insurance programs. To design an insurance system that motivates adaptation requires that technical rates – rates that properly reflect empirically determined levels of risk – be established and accepted at the highest relevant resolution, a difficult prospect. Even in countries with free market flood insurance systems, insurers may be reluctant to charge the full technical rate for the risk in acknowledged high hazard flood plains, as consumers have come to assume that insurance costs should be relatively consistent by location, while the differential technical rates implied by flood risk, for example, may vary by an order of magnitude and more. Without charging technical rates for the risk, however, it is difficult to use pricing signals to motivate adaptation strategies such as flood proofing or elevating the ground floor of a new development (Lamond *et al.,* 2009). In such a case, barriers to adaptation (in both planning and management, in this case) result in a strategy with maladaptive consequences. In places where risk levels are rising, climate change may prompt reconsideration of these barriers to promote more adaptive risk management.

Ultimately, maladaptive processes run the risk of committing collective resources (public or private) to coping and recovery rather than adaptation; they sometimes also run the risk of forcing some segments of society to cope with higher levels of risk than they otherwise might. Ensuring an approximate match between a wide range of possible risks and their appropriate risk management strategies is complex, however, and faces its own set of issues, the focus of the next section.

1.4.3.2. The Role of Complexity

There are many sources of both maladaptation and the other barriers to effective adaptation. Many, at base, are the result of incomplete consideration and understanding of the complexity of dynamic systems as well as incomplete appreciation of the linkages between different risk management strategies and overall burdens of risk. There is often also a component of significant resource constraints and competition between multiple urgent priorities as well as insufficient linkage between costs and benefits across sectors and communities. In many settings, one major source of maladaptation results from incomplete awareness, appreciation, and acceptance of system complexity in the risk management process. In particular, as Sterman and others who have studied dynamic complexity have noted (Sterman, 2000), complexity can hinder evidence generation, learning from evidence, and evidence-based policy-making (Sterman, 2006) (these categories roughly parallel Moser and Ekstrom's (2010) framework regarding adaptation barriers.)

Each of these problems results in a different type of maladaptation. Complexity that hinders evidence generation (see section 1.3.2) limits knowledge of risk. In such instances, some risks are increased by incomplete understanding of the hazard universe (or the universe of relevant risk management strategies). This problem can be compounded by the issues of high specialization, narrow disciplinary focus, and short-term perspectives, each of which can undermine proper calibration of risk management decisions.

Complexity that limits learning from evidence is often the result of heuristics or mental models (Kahneman *et al.,* 1982) that lead to "systematically erroneous but strongly self-confirming inferences" (Sterman 2006; also see Section 1.3.2), complicate policy action among both experts and lay people (Cronin *et al.,* 2009). Complexity can lead to misunderstanding, for instance of the impact of flows in and out of a stock over time (e.g., the relationship between annual deficits and national debt). In regards to climate change, such errant mental models lend disproportionate reliance on a "wait and see" approach to mitigation (Sterman, 2008). This dynamic is also associated with the difficulty of weighing different levels of risk, (see section 1.3.2) some of which are more immediate but less devastating, while others feel more remote but potentially catastrophic, e.g. the risk associated with dwelling on a potentially unstable slope versus the risk of living far from one's crops and the center of economic and cultural activity in a given region.

Complexity that inhibits evidence-based policy making and implementation typically results from difficulty with message diffusion, risk communication, and public suspicion over experts' vested interests in the policy making process as well as complexity in confronting and managing the tradeoffs between different priorities and their impacts across sectors, populations, and generations. These issues can lead to paralysis and failure to engage in appropriate risk management strategies despite the availability of compelling evidence suggesting an appropriate risk management path. An example of this is the resistance to immunization policy recommendations among some subsets of the population, particularly regarding measles-mumps-rubella vaccination, which has been repeatedly correlated with disease outbreaks in communities with lower vaccination rates (Jansen *et al.,* 2003). Here again mental models and heuristics affecting risk perception come into play, complicating an evidence-based approach to risk management policy making as discussed in Section 1.3.2 and necessitating strategies for anticipating and addressing these barriers to adaptation policy formation.

Each source of maladaptation or policy resistance – complications with evidence generation, evidence interpretation, and evidence application – is relevant to the present discussion. The complexity of the climate system impeded accumulation of compelling evidence that the climate was changing until the second half of the twentieth century, and there remains significant lay skepticism despite widespread scientific consensus. Complexity also dogs the generation of estimates regarding how the frequency and severity of extreme events may shift with climate change as well as the process of deploying probabilistic risk management strategies using these estimates to promote appropriate adaptation efforts (section 1.3.2). Finally, conflicting perceptions and messages related to climate change impacts and distrust of expert opinion and consensus findings (Schrope, 2001) complicate development and action on a unified climate change risk management platform (see Section 1.3.2.2).

1.4.3.3. Adaptation with No Regrets

Disaster risk management decisions often pivot on thresholds: strategies that were conceived under one set of threshold assumptions can become maladaptive under another (Niemeyer *et al.,* 2005). For example, levees protecting established communities in flood prone areas might be adaptive for anticipated floods of a certain magnitude, but maladaptive when the maximum projected flood height for a given period shifts, unless new adaptation measures are taken, e.g. raising the levees. In such an instance, the (unchanged) levees exhibit both types of mal-adaptation: they represent a mismatch between projected risks and management strategies, and they promote assumption of greater risk by allowing for development in flood prone areas that feel safe but in fact are not (the “safe development paradox” noted above). The maladaptive nature of certain strategies can be further amplified by mal-distribution of risk associated with risk displacement and moral hazard (assumption of increased levels of risk when risk management schemes are in place).

In climate change adaptation literature the mismatch between adaptive strategies and needs has been characterized as the potential for regret, namely:

> The “regrets” that are experienced when planning for climate change in the present (*ex ante*) based on one set of climate expectations that later on (*ex post*) turns out to be “wrong”. … These regrets can be translated into economic opportunity costs, based on the losses that society incurs by not making the best *ex ante* choice. In situations where the range of possible climate changes that could occur becomes very broad (or very uncertain), then the decision-making framework needs to be changed so that the robustness of adaptation decisions (elaborated below) over a wide range of climates is more important (i.e. has lower economic regrets) than making a decision that is optimal for one or a small number of climate states. (Callaway and Hellmuth, 2007)

To address the challenge of risk management in the dynamically complex context of climate change and development, as well as under conditions where probabilistic estimates of future climatic conditions remain imprecise, the climate change adaptation literature has employed the concept of robustness. Robustness is a property of a plan or strategy that performs well over a wide range of plausible future scenarios even if it does not perform optimally in any particular scenario. Robust adaptation plans may avoid brittleness even if probabilistic assessments of risk prove wrong because they aim to address both expected and surprising changes, and may allow diverse stakeholders to agree on actions even if they disagree about values and expectations (Means et. al., 2010; WDR 2010; Brown and Lall, 2006, Dessai and Hulme; 2007; Lempert and Groves, 2010). Robust plans thus include ‘no regrets’ as a special case. To maintain their robustness over time, learning must be a central pillar of adaptation efforts.

1.4.4. Learning, Coping, and Climate Change Adaptation

The climate change adaptation literature emphasizes the importance of learning and plans that are explicitly designed to evolve over time in response to new information (Morgan et. al. 2009: NRC 2009). Learning has also been a long-standing focus in the resilience literature. For instance, adaptive management, an important framework in environmental management, rests on the notion that policy interventions should be viewed as experiments and learning opportunities for gathering additional information about the behavior of complex systems, including their response to management. That is, adaptive management addresses uncertainty about the future environment and human systems by consistently testing, monitoring, and revising policy assumptions. Well-conceived interventions designed to both improve conditions and provide information about the efficacy of various policy interventions, combined with systematic monitoring to track outcomes can in principle significantly improve responses over time. However, adaptive management has had a mixed history of implementation because organizations often find it difficult to design actual interventions as experiments, to spend resources on monitoring, and to document failures sufficiently well to facilitate learning (Gunderson *et al.,* 2010). Recent literature has also seen an emphasis on what is called adaptive governance (Olsson et. al., 2006; Scholtz and Stiffel 2005). This approach extends adaptive learning to the design and modification of institutions.

Of particular relevance is the distinction between different types of learning, including single-loop and double-loop learning processes (see Figure 1-2).

[INSERT FIGURE 1-2 HERE
Figure 1-2: Learning Loops: Pathways, outcomes, and dynamics of single, double, and triple loop learning (adapted from Sterman *et al.,* 2006; Folke *et al.,* 2009; and Argyris and Schön, 1978)]

In single-loop learning processes, like steering a car to correct its course when it veers, the rules are followed, i.e. data is integrated and acted on but the underlying mental model used to process the data is not changed. Single loop learning is often analogous to coping in response to hazard exposure: it can reduce risk if invoked quickly enough, or minimize and contain damage in the aftermath of a hazardous event. Double-loop learning, in contrast, is more analogous to adaptation. In double-loop learning the rules are changed, i.e. data are both acted on and used to change underlying mental models. Continuing the driving analogy, double-loop learning might entail regular examination of population-based crash location data and decisions to change road signage, speed limits, police patrols, and other interventions in order to reduce crash incidence. Such double loop learning may also include shifts in people's attitudes and practices in response to information about crash frequency and distribution. Single-loop learning is relatively static while double-loop learning is iterative and adaptive.

Some authors also distinguish triple-loop learning, or learning about learning, i.e. reflection on how we think about rules rather than on how to follow them or change them to better suit the circumstances. In triple-loop learning about risk, the social structures, cultural mores, and other structures that mediate constructions of risk (see section 1.3.2.2.3) are changed in response to evidence that these deep social structures are not serving a larger agreed upon goal, i.e. are maladaptive when assessed in a more comprehensive risk-benefit calculus. Extending the driving example further, triple-loop learning might entail a shift in urban design away from the automobile toward more dense development, public transit, and design principles that facilitate walking, cycling, and other forms of active transport. Such a shift would reduce not only the risk of injuries from motor vehicle crashes, but also the risks associated with obesity including cardiovascular disease and diabetes, reducing health care costs in the bargain, as demonstrated by several various analyses (Bell *et al.,* 2008; Younger *et al.,* 2008; Haines *et al.,* 2009; Rissel, 2009; Woodcock *et al.,* 2009).

For such triple loop learning to be translated into policy, however, requires not only articulation of a larger risk-benefit universe, but also mechanisms to identify, account for, and compare the costs associated with a wide range of interventions and their benefits and harms over various time horizons. Stakeholders must also collaborate to an unusual degree in order to collectively and cooperatively consider the wide range of risk management possibilities and their impacts. If single-loop learning is analogous to coping and double-loop learning to adaptation, then triple-loop learning may be analogous to what some have termed transformation (Kysar, 2004): triple-loop learning may lead to recasting social structures, institutions, and constructions that contain and mediate risk to accommodate more fundamental changes in world view (Pelling, 2010).

Without suggesting that coping mechanisms are unsophisticated or unschooled, and noting that coping can be necessary and protective in many circumstances, the distinction between single-, double-, and triple-loop learning highlights the limitations of over-reliance on coping as a strategy, particularly when circumstances are changing. In such instances, reliance on coping not only does not confer advantage but in fact may result in a behavioral mismatch for new environments and conditions. Of course, not all coping mechanisms are categorically reflexive; some are complex learned strategies that have developed over long periods of time and been tested against observation and experience. In this way, the role of learning and the equation of single-loop/coping - double-loop/adaptation - triple-loop/transformation provides a link to the Yohe and Tol (2002) discussion of coping and adaptation in which coping mechanisms and ranges can shift over time. Learning of all types is clearly pivotal to this process. Coping is occasionally necessary for survival but is a last resort. Prioritizing learning as part of the risk management process may facilitate careful consideration of the hazard landscape and the ways in which it is changing, reducing the need for coping strategies.

1.4.4.1. Learning from Disaster Risk Management Relevant to Overcoming the Barriers to Climate Change Adaptation

(To be completed for FGD)

1.5. Structure of this Report

Chapter 2 assesses literature on the key determinants of climate risk, namely hazard, exposure and vulnerability. A particular focus is the connection between near term experience and long-term adaptation. Key questions addressed include: whether adapting better to current hazards improves adaptation to longer-term climate change, how natural hazards research informs the question of how adaptation may address or reduce the risk of “dangerous” climate change, how near-term decisions and adjustments constrain or enable future vulnerability and capability to adapt, and what insights from hazard assessment and warning systems might apply to climate change.

Chapter 3 focuses on changes in climate extremes and the impacts of those extremes on the natural physical environment. The chapter reviews historical and expected changes in the frequency and intensity of heat waves, tropical storms, El Nino, monsoons, etc. The SREX builds on AR4 and updates the earlier assessments, which in some instances, due to new literature, leads to revisions. In addition, the chapter examines impacts such as extremes of sea level, drought, and flooding in order to provide a quantitative physical basis for the chapters that follow.

Chapter 4 explores how changes in such physical events assessed in Chapter 3 may translate into extreme impacts on and disaster in human systems and ecosystems. Impacts of extreme events depend on the interaction of the physical changes with exposure and vulnerability, both of which will also change over time. A key issue is the nature of both observed and expected trends in hazards, the latter resulting from trends in both physical and social characteristics. The chapter assesses these questions from both a regional and a sectoral perspective, and examines the economic costs of such changes.

Chapters 5, 6, and 7 assess disaster risk management and climate change adaptation from the perspectives of local, national, and international governance institutions and approaches, respectively, taking into consideration the roles of individuals, NGOs, the private sector, and other civil society institutions and arrangements.

Chapter 5 focuses on the local level of housing, buildings, land use, and warning systems, and evaluates the efficacy of current preparedness and responses to extremes and disasters to extract lessons for the future. Impacts and adaptation, and the cost of risk management, are assessed through the prism of diverse social aggregations and means for cooperation, as well as a variety of institutional arrangements. Chapter 6 explores similar issues at the national level, where the key elements include, *inter alia*, food and agriculture, forests, fisheries, and public health, and national institutional arrangements such as national budgets, development goals, and planning. Chapter 7 carries this analysis to the international level, where the emphasis is on institutions, organizations, knowledge generation and sharing, legal frameworks, and practices that characterize international agencies and cooperative arrangements. This chapter also discusses integration of responsibilities across all governmental scales, emphasizing the linkage between DRM, CCA, and development.

Chapter 8 assesses how disaster risk reduction strategies can advance climate change adaptation and promote a more sustainable and resilient future with a focus on the literature that considers whether an improved alignment between climate change responses and sustainable development strategies may be achieved.

Chapter 9 closes this report by presenting case studies in order to identifying lessons and best practices from past responses to extreme climate-related events and extreme impacts. Cases illustrate concrete examples of the disasters types, methodologies, and subsequent responses discussed in the other chapters in the context of specific applications, providing a key reference point for the entire report.

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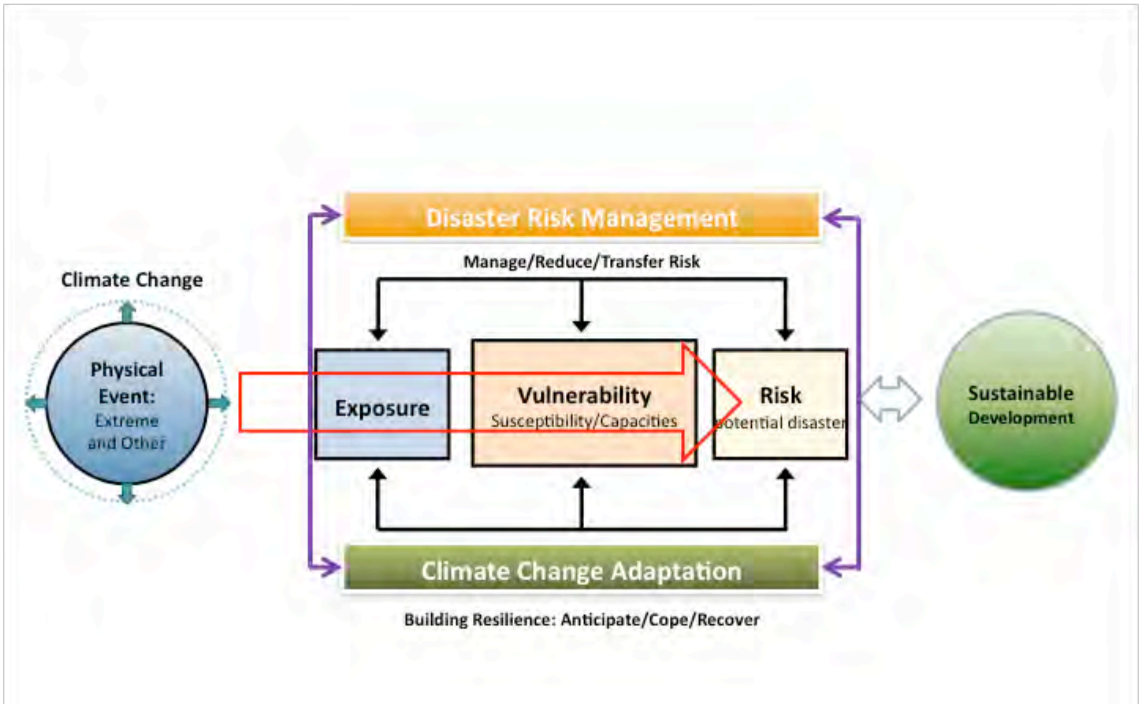

Figure 1-1: The key concepts and scope of this report. The figure indicates schematically key conceps involved in disaster risk management and climate change adaptation, and the interaction of these with sustainable development.

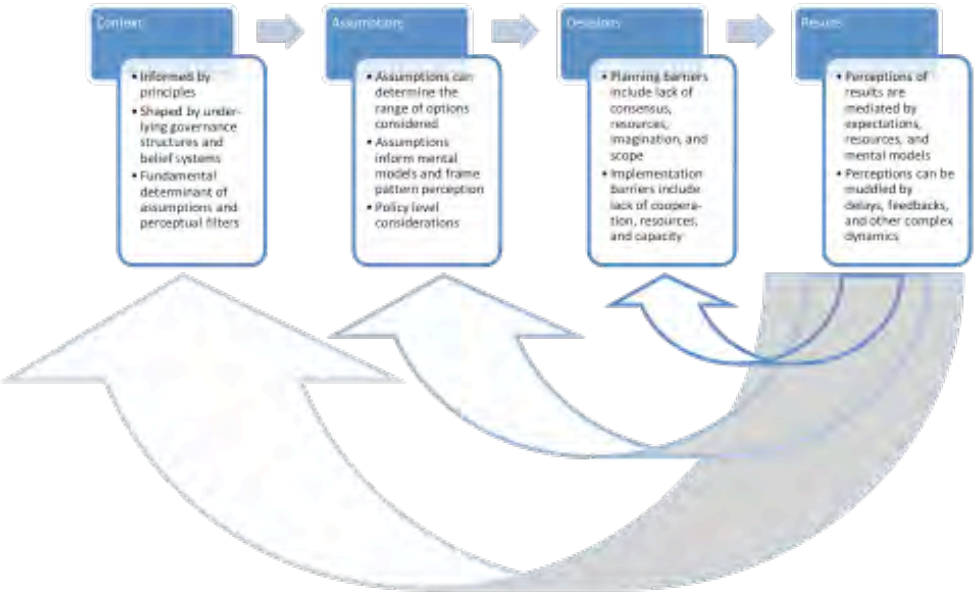

Figure 1-2: Learning Loops: Pathways, outcomes, and dynamics of single, double, and triple loop learning (adapted from Sterman *et al.,* 2006; Folke *et al.,* 2009; and Argyris & Schön, 1978).