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

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Contents

Executive Summary

This report addresses three major challenges associated with anthropogenic climate change and the management of disaster risk.

The first challenge is identifying and assessing the concepts, experiences, methods, strategies, and instruments used in disaster risk management that are likely to be most relevant and useful for climate change adaptation.

The second is identifying and assessing the modifications to current disaster risk management practice that climate change and climate change adaptation may require, and facilitating the required transition in concept, method, and practice.

The third challenge lies in consolidating the revisions in disaster risk management into climate change adaptation theory and practice.

This chapter lays out the conceptual premises, key notions, definitions and assumptions with which the climate change adaptation and disaster risk management communities, and sub-communities within them, operate. It seeks a more holistic, integrated, interdisciplinary approach than currently exists in order to bridge existing gaps.

A central concern is that climate change has introduced substantial non-stationarity into risk management decisions. Non-stationarity is the realization that past experiences may no longer be a reliable predictor of the future character and frequency of events; it applies both to hazards and to the response of human systems to same. As climate change is expected to change the frequency, magnitude, and other characteristics of extreme events, some of which are associated with extreme impacts, risk management strategies must accomodate a shifting distribution of the latter.

Extreme events do not bear a one-to-one relationship with extreme impacts. Some extreme events involving *extreme direct and indirect social and economic impacts* can be characterized as contributing in an important way to the occurrence of “disaster”. Disasters occur when extreme impacts cause a severe disruption of the normal, routine functioning of the affected society. However, depending on the context, physical extremes may or may not bring along extreme impacts and disasters.

Disaster may also arise from a concatenation of physical, ecological and social reactions to lesser physical events, or to moderate events superimposed onto a gradual trend. Disasters are predicated on the existence of vulnerability, which can be exacerbated by pre-existing social processes and events, such as financial crises, trade policies, wars, disease outbreaks, etc.

Climate change and its attendant additional risks and opportunities will inevitably be understood and responded to at multiple scales, from the individual household to the national and international level, and will likewise occur in the context of other economic, political, technological, and cultural shifts.

Disaster risk management and climate change adaptation policy, strategies and instruments will only be successful if understanding and intervention are based on multi-scale principles and if the complex interactions between phenomena and actions at local, sub-national, national and international scales are appreciated and anticipated.

Probabilistic risk analysis offers a powerful and elegant framework for addressing non-stationarity, but there exist numerous challenges to implementing it for disaster risk management and climate change adaptation. Many communities lack the training and data to implement this framework in practice. But even in the most favorable real-world situations, fundamental problems of estimating probabilities of both events and consequences, as well as problems of risk communication, markedly complicate implementation of a risk management framework.

In particular, the judgment and decision-making literature suggests various cognitive barriers that make it more difficult for individuals and organizations to properly assimilate and respond to information about low probability events. Effective risk communication requires a process of exchanging and integrating knowledge and information about climate-related risks among all stakeholder groups. Motivational factors also introduce differences in perceptions and reactions as the result of variations in values and beliefs.

Moreover, disaster risks do not exist in isolation, and ultimately cannot be separated from the ongoing, chronic or persistent social risk factors that typify everyday life for many individuals. Climate change introduces further complexity as a result of both shifting averages and shifting extremes.

Currently, most of the human losses (in absolute terms) and economic losses (in relative terms) due to extreme events are borne by developing countries. Climate change is expected to amplify this trend. Improving the management of extreme events and extreme impacts is often complicated by the lack of reliable and timely information on disaster risk, a lack felt most acutely in the developing world. Poverty also increases enormously the impacts of adverse exposures to hazards and extreme events, and significantly complicates risk prevention and reduction efforts.

The role of development is a key factor in climate change adaptation. Related to this line of inquiry is the contentious relationship between *coping* and *adapting* In the disaster risk management literature, the term coping appears to have derived from an interest in understanding *ex post* responses to disasters particularly amongst poorer populations, where few practical alternatives to achieve risk reduction or to bolster bottom-up approaches are readily available. As a result, coping has increasingly been comingled with adaptation, as disaster risk management practice has become more development oriented. Nevertheless, a tension remains because adaptation tends to emphasize *ex ante* approaches to risk management.

The synergistic relations between disaster risk, poverty, mismanagement of natural resources, lack of land use planning, and severe problems of governance in many countries and the challenge of climate change adaptation requires that intervention schemes assume a novel level of integration and coordination. The sectorialised views and actions of many government and international agencies are not currently well positioned for such an approach. Iintegrating disaster risk management and climate change adaptation thus presents an important opportunity for advanced learning processes that open up the possibility of significant revisions to both established theory and practice.

1.1. Introduction

1.1.1. Purpose and Scope

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, 2007). This change is very likely to be associated with an increase in disaster risk and the need for increased and improved disaster risk management and development planning processes.

Climate change refers to a long-term trend in the norms or averages of the characteristics of climate affecting particular geographical areas and the globe as a whole. Disaster risk refers to the potential future loss and damage associated with the impact of various types of physical events; disaster risk management refers to processes that anticipate or/and reduce disaster risk, respond to disasters, and manage recovery. Climate change adaptation refers to sustainable adjustments in society and ecosystems which moderate harm or exploit beneficial opportunities in response to existing or future predicted climate change.

This report addresses three major challenges associated with anthropogenic climate change and the management of disaster risk.

1) Assessing the relevance and utility for climate change adaptation, of the concepts, experiences, methods, strategies and instruments employed in the management of climate-related disaster risk under prior conditions of stationary or stable climate
2) Addressing the new challenges and requirements that climate change and climate change adaptation bring to the disaster risk management field and the modifications and transitions this requires in concept, method, and practice
3) Assessing the implications of such revisions in disaster risk management for climate change adaptation.

This first section of the current chapter attempts to lay out the conceptual and thematic basics of the present report. Later sections will delve deeper into various essential element in defining the problematic, whilst future chapters will carry these forward in more detailed and specific ways. Among the existing or projected consequences of climate change are alterations in the frequency, intensity, geographic scale and location of “climate or weather events” and associated hydrologic and oceanographic phenomena, characteristics that are projected to deviate from the historical averages associated with a “stationary” or stable climate. Amongst these one can identify a category referred to as “extreme physical events” (abbreviated here as “extreme events”, see Chapter 3). Extreme events have been a facet of normal climate variability under stable climate conditions but their characteristics are expected to undergo modifications with future climate change such as to increase their potential for contributing to damage and loss in society and increased physical impacts on natural ecosystems (IPCC, 2007).

Some extreme events involving *extreme direct and indirect social and economic impacts* can be characterized as contributing in an important way to the occurrence of “disaster”. Disasters may essentially be defined as a severe disruption of the normal, routine functioning of the affected society.

Where such physical extremes do not impinge on societies that are exposed to their effects or where such societies show adequate levels of social, physical or economic resistance and resiliance, extreme events will not be associated with disaster. In constrast, disasters may result from physical phenomena that are not extreme but which nevertheless trigger negative social outcomes due to prevailing social and structural conditions (see Section 1.2 and Chapter 2 for a discussion of so-called “vulnerability” and “exposure”).

Developing and implementing means to respond reactively to these phenomena and the risk they signify has been the objective of what has been known as “disaster” or “emergency” management for many years. More recently and comprehensively, the term “disaster risk management” has emerged as emphasis has turned from “disaster” to “disaster risk” as a central concept. Disaster risk management includes greater efforts to build resistance against the potential impacts of extreme events at many scales, from household and community to the nation and region (see Section 1.3 for details of this transition).

Learning from earlier experience is a critical feature of disaster risk management. However, in contrast with previous experience, not only are the characteristics of extreme events changing, but they occur in a context typified by gradual changes in the mean state of the climate and the presence of other related phenomena such as sea level rise and shifting species ranges. Small changes in the mean state may be associated with large changes in climate extremes. Under such circumstances, disaster risk patterns will be modified and new patterns will emerge affecting in differential and differentiated ways all communities, regions, zones and nation states.

A deeper understanding and more certain projection of these ongoing changes and of the relations between different types and levels of disaster- triggering events and the impacts associated with them is necessary for effective disaster risk management and climate change adaptation. Experience with recent changes in characteristics of extreme events and impacts already provides a limited basis for improving disaster risk management. However, a continuously changing climate increases the complexity of learning and the application of lessons to disaster risk management.

The changing characteristics of extremes will result in greater uncertainty as to their intensity and distribution in space and time. They may also modify the path of development processes that in turn will change or modify existing vulnerability patterns (Patt et al 2010) and risk scenarios. New challenges, related to both changing mean climate and climate and weather extremes, resulting in new, unpredictable, and more complex risk scenarios, will very likely arise and new patterns of geographical risk exposure will very likely appear. These may involve changes in the combinations of the varied types of potentially damaging physical events any given society may face. The emergence of new physical threats may affect areas with no previous experience of these, whilst other areas may experience a decrease in historical risk factors.

1.1.2. Climate Change Adaptation and the Role of Disaster Risk Management

A principle goal of the present report relates to bridging the gap between the disaster risk management and climate change communities as regards conceptions, objectives and approaches to managing risk, including development of a concerted multi- and interdisciplinary approach useful to both. This inevitably requires framing the challenges faced by disaster risk management in adjusting or widening its concept and practice to take account of new risk related climate change; and, at the same time, a modification and widening of the climate change community approach in order to more fully incorporate concepts and experience from disaster risk management.

Disaster or emergency management was formerly dominated by considerations of disaster response and preparedness and was focused predominantly on large-scale events. Over the past 30 years this approach has evolved in favour of a more balanced framework that includes development based risk reduction, risk prevision and disaster recovery strategies and instruments and a greater importance on smaller scale, but more recurrent events. The accommodation of climate change will be but the latest in a series of ongoing changes to disaster risk and disaster concepts and practice over time (see Hewitt, 1983; Smith, 1996; Tobin and Montz, 1997; Blaikie et al, 1996; Hewitt, 1997; Wisner et al, 2004, Lavell, 2005; Gaillard, 2010, for background and review of some of these historical changes).

Climate change policy, strategy and implementation already uses language and terminology with increasing emphasis on the need for adaptation in the face of changing average climate and climate and weather extremes (Schipper and Burton, 2009). Increasing demand exists for assessment and promotion of disaster risk management practice that can contribute to climate change adaptation. This requires increasing synergy, merging and complementarity between these two currently and still largely differentiated practices, both of which seek greater human and environmental security.

Despite the recognition of the need to bridge disaster risk management and climate change adaptation, progress on the ground in terms of tangible integration of adaptation projects and planning processes based on the concepts of disaster risk management and sustainable development has been very limited (German Committee for Disaster Reduction, 2009; Lavell, 2009; UNFCCC, 2008; Cristoplos, 2008; VARG, 2006; Mitchell and Van Aalst, 2008; Tear Fund, 2008; Adger et al 2007).

Contributing causes of this lack of integration include differing conceptual and definitional bases, differing institutional and organizational arrangements, differing scientific origins and baseline literature, and differing understandings of causal relations and the relative importance of different risk factors (see Schipper and Burton, eds, 2009; Tear Fund, 2008, Mitchell and van Aalst, 2008). While recognizing that disaster risk management and climate change adaptation employ concepts and have objectives and approaches that only partially overlap, this report aims at assessing the literature with a view toward developing an interdisciplinary approach, hence a robust bridge between the two practices. The present chapter lays out the conceptual premises, key notions, definitions and assumptions with which the climate change and disaster risk management communities, and the sub-communities within these, operate. It seeks to establish the challenges, the gaps, contradictions, similarities, convergences and divergences from a conceptual and practical viewpoint arising from consideration of the well-established and evolving disaster risk management theory and practice and the more recent science of climate change adaptation.

1.1.3. Key Concepts

Our starting point is the search to establish a commonly acceptable, conceptual and definitional framework that may be used throughout this report, while recognizing the valid historical and intellectual reasons for the distinct concepts, frameworks, and terms associated with and used by the disaster risk management and climate change adaptation communities and their respective sub-communities (see Figure 1-1). These differences have on many occasions impeded a free flow of understanding and exchange between and even within the two fields (Schipper and Pelling, 2006; O'Brien et al, 2006). Here only basic parameters and guidelines for definition will be established. Subsequent chapters will amplify and sharpen the basic notions here presented, and provide information on the range of different definitions used in the literature, allowing the richness of conceptual analysis to come forth without unnecessary rigidity being imposed from the outset.

[INSERT FIGURE 1-1 HERE
Figure 1-1: The key concepts and scope of this report.]

1.1.3.1. Risk

Both climate change adaptation and disaster risk management search to reduce factors and modify contexts that contribute to climate-related risk while enabling sustainability in social and economic development. Accordingly, a useful starting point for conceptual convergence is to assure clarity about the concept of **disaster risk**, which is used in this study to refer probabilistically to the level of damage and loss associated with the future occurrence of a forecasted physical phenomenon or event (or sequence of events) and which is determined by the convolution of hazard and vulnerability factors (Cardona, 2004; Carter et al 2007; Schneider et al 2007; see the following sub-section for definition of these terms). This contrasts with other commonly used definitions where risk is defined as the probability of the occurrence of a particular type of physical event as is the case when referring to seismic, flood or hurricane "risk", for example.

1.1.3.2. Social Conditioning of Loss and Damage

Loss and damage are themselves a result of the magnitude, intensity and physical and temporal extent of a physical event interacting with socially constructed or determined conditions that commonly go under the name of "**vulnerability**", conditions that may be evaluated according to a variety of quantitative and qualitative metrics (Schneider et al 2007).

Exposure, widely used in disaster risk management studies but not defined in the more commonly used climate change glossaries (IPCC, 2007)**,** refers to the location of social and economic elements, population, infrastructure, production, culture, etc. in areas where physical events may be predicted to occur. Such physical events are typically denoted "**hazards**". That is to say, physical events per se are transposed into "**hazards"** where social elements are exposed to their potential damaging impacts. (see Smith, 1996; Tobin and Montz, 1997). This means that hazard is the latent threat associated with any type of physical event that may occur in a particular context, rather than the event itself. It is one of the defining components or factors of risk, a latent condition that announces future loss and damage.

The usage here reflects an emerging understanding that disaster risk, while embodying an objective, physical aspect, is fundamentally a "social construction", the result of social choice, constraints, social action and inaction. An example would be the decision or not to operate in a particular manner, to locate in a particular place and build in a particular fashion which is the product of varied and differing political, economic, cultural and psychologically induced considerations, perceptions and actions (see Section 1.3.x; Wisner et al., 2004; Douglas and Wildavsky, 1983; Weber 2006). While physical aspects help define the disaster risk problem, it is only through concerted human action and social decision making that risk may be managed.

Exposure as such is not risk. Exposure to potentially damaging physical events where not accompanied by so-called "vulnerability" of the exposed social elements will not lead to loss and damage. Differential levels of "vulnerability" will lead to differential levels of loss, even under similar conditions of exposure to physical events of a given magnitude.

Vulnerability originated in disaster risk management, as opposed to climate change adaptation, in the 1970s (see Baird et al, 1975; O'Keefe et al, 1976; Wisner et al 1977, quoted in Gaillard, 2010) and can be defined in terms of the susceptibility of humans, their livelihoods, assets and infrastructure to suffer loss and damage when faced with physical events of varying magnitudes. It highlights the conditions in society which pre-dispose particular groups of people to loss and harm. As Gaillard (2010) points out, despite a broad agreement amongst authors as to the basic definition, significant divergences of approach exist when applying the notion of vulnerability to analysis. Thus, in its earlier interpretation the concept referred to the social relations, processes and structures that lead people to be susceptible to loss or harm in the face of hazards or food shortage and examined macro scale structural and societal constraints. By contrast, engineers and earth scientists used the term vulnerability in computations of quantitative indices of potential losses to built structures (so-called structural vulnerability).

The fundamental importance of vulnerability to the disaster risk management and disaster risk communities may be seen in the way it helped reveal 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 what he referred to as the "physicalist" interpretation of disaster).

In contrast, the 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". This definition sees vulnerability as an outcome of climate change factors operating in a particular setting. Some authors have criticized this definition as leading to an emphasis on physical events as opposed to social factors in understanding vulnerability and risk (Kelman and Gaillard, 2008; Gaillard, 2010).

Underlying this tension is the recognition that characterizations of physical events by statistical distributions for specific periods of time (see Section 1.2 and Chapter 3 for details), are necessary but not sufficient for understanding disaster. The explicit recognition of the political, economic, social, cultural, and psychological elements of risk explains the use in this report of the phrase "extreme impacts" in addition to "extreme events" as a way to denote a key aspect of the problem. Depending on the context, physical extremes may or may not bring along extreme impacts; likewise, some extreme impacts may follow from events which in purely physical terms and in isolation from social context would not be defined as extreme. For example, the vast majority of disasters registered annually in particular disaster data bases are not associated with extreme physical events as defined probabilistically (see Section 1.2.x), but many have important and even extreme impacts for local and regional societies (see ISDR, 2009). These data bases include EM-DAT at the Centre for the Epidemiology of Disasters, University of Louvain (Centre for the Epidemiology of Disasters, 2008), and the DESINVENTAR data base used by ISDR and others to examine small and medium scale disaster occurrences and "extensive risk" in Latin America and Asia in particular (see ISDR, 2009; Corporación OSSO, 2008)

1.1.3.3. Recovering from Disaster Loss and Damage

The consequences of disaster and aspects relating to recovery following disaster are characterized by diverse concepts including coping, capacity, and resilience. Coping will be dealt with in some detail in Section 1.4.

As Gaillard (2010) points out**, resilience** has been used in disaster contexts since the 1970s (Torry, 1979) and has its origins in engineering (Gordon, 1979), ecology (Holling, 1973) and child psychology (Werner et al, 1971).

Common to its various uses, resilience refers to characteristics of society, social groups and individuals which, following trauma or initial crisis and impact, allow certain sectors and populations to recover with greater facility than others. In this sense it is related to the notion of elasticity or malleability, and maintenance of essential functions (see Section 1.4.3.2).

Although now commonly employed, the term is however subject to very diverse interpretations. These range from a more strict use in post impact situations through to its usage for depicting conditions at any point of the risk or disaster continuum, before, during, or post hazard impact. This confusion and the “borrowing” of concepts from other thematic and disciplinary areas has in fact led to the decision by some outstanding disaster risk experts to obviate its use and to consider “vulnerability” and “lack of capacities” as sufficient in explaining differential success in recovery (Wisner et al., 2004: 12). Under this formula, vulnerability both potentiates original loss and also impedes recovery. Finally, resilience, “bouncing back”, and its conceptual “cousin”, coping (see Section 1.4), or “getting by” have been criticized as emphasizing a status quo, often unjustifiable prior situation, i.e., “surviving”, as opposed to “bouncing forward” and “thriving”.

Capacity and capacity building are important concepts for climate change adaptation and also for disaster risk management. Capacity involves access to and use of social, economic/ livelihood related and natural resource-based, psychological, cultural resources, conditions and characteristics that permit society at large, organizations and institutions and groups of people to reduce susceptibility to loss and harm from extreme events and extreme impacts. Introduced into disaster management work in the late 1980s by Anderson and Woodrow (1989) as a means of shifting analytical balance from negative aspects of vulnerability to positive actions by people, the notion of capacity is fundamental to imagining and designing a positive movement in favour of risk reduction and adaptation. Capacity may be used in the context of pre-impact risk reduction, response, coping, and recovery.

1.1.3.4. Approaches or Concepts for Understanding and Intervening in Risk

In establishing the boundaries of phenomena and social processes that concern disaster risk management and climate change adaptation, two key questions arise: 1) to what degree should the focus be on exceptional events (a physicalist approach) as distinct from the routine, daily occurrences (emphasizing social context); and 2) what is the appropriate territorial scale that ought to be considered?

1.1.3.4.1. Exceptionality, extremity, and the every day or quotidien

Schemes and interpretations based on physical causes of loss and damage have been referred to as “physicalist” (see Hewitt, 1983) whilst notions developed around normal, everyday-life risk factors, which are much favoured by many disaster risk specialists can be considered “comprehensive” (embracing the physical and the social). The latter were a major contributing factor in the development of the so-called “vulnerability paradigm” for understanding disaster (Wisner et al, 2004; Hewitt, 1983, 1996). Additionally, the more recent discussion on the role of small and medium scale disasters and so-called “extensive risk” (ISDR, 2009) provides a further argument for the need to deal integrally with the problem of loss and damage, looking across the different scales of experience both in human and physical worlds, in order to advance adaptation. The design of mechanisms and strategies based on the removal of every day or chronic risk factors (Sen, 1983; World Bank 2001), as opposed to actions based solely on the “exceptional” and “extreme” is one obvious corollary of this approach. The ability to deal with risk, crisis, and change is influenced by an individual’s life experience with smaller scale occurrences. Climate change and its attendant additional risks and opportunities will inevitably be understood and responded to at the scale of the individual household in the context of many other changes, including economic, political, technological, and cultural ones (see Box 1-1 and Section 1.4.3.1).

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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. 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 plane, 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."

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1.1.3.4.2. Scale and disaster risk

According to one view, disaster risk or, in the case of this study, climate related risk is most adequately depicted, measured and monitored at the local or micro level where the concrete interaction of hazard and vulnerability are worked out “on the ground” (Lavell, 2005). At the same time it is accepted that risk construction processes are not limited to specifically local or micro processes but, rather, are related to diverse environmental, economic and social and ideological influences whose sources are to be found at scales from the international through to the national, sub-national and local levels, each in constant flux (Wisner et al, 2004). Thus disaster risk management and adaptation policy, strategies and instruments will only be successful where understanding and intervention is based on multi-scale principles and where phenomena and actions at local, sub-national, national and international scales are construed in interacting ways (Lavell, 2002) (see Section 1.5 and Chapters 5-9).

1.1.4. A Basis for Advancing Holistic, Integrated, and Interdisciplinary Understanding

It can be concluded from the earlier discussion that a more holistic, integrated, interdisciplinary approach to assessment than currently exits is needed to bridge the gap between the (at times) different approaches and visions provided by the climate change adaptation and disaster risk management communities. This refers to both the ways physical extremes and non-extremes are viewed and the manner in which vulnerability and changes and challenges in everyday life are depicted and the way exceptional circumstances are characterized. Such an approach would probably recognize the participatory methods and basic decentralization principles inherent in both climate change adaptation and disaster risk management while transcending the tendency to divide the world up for analytical and intervention ends, which has very limited utility.

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

1.2.1. Extreme Events, Extreme Impacts, and Disasters

The objective of this section is to amplify on the outlined definitions and distinctions among extreme events, extreme impacts, and disasters given in Section 1.1 and discussed further in Chapter 3, with a view toward clarifying the role and interactions of physical versus social processes.

Discussion and definitions of "extreme 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 definition of measured physical attributes of phenomena used by natural scientists (see Chapter 3) to a concern with the deterioration of social systems often expressed qualitatively by social scientists (see Chapters X). In attempting to align both perspectives, a U.S. National Science Foundation (NSF) "Workshop on Extreme Events: Developing a Research Agenda for the 21st Century" concluded in 2000 that any successful effort to conceptualize "*extreme events" as a researchable issue will rest on an explicit awareness of the context…*" The context reflects an agenda focused around improving human welfare.

The definition of "extreme event" offered at the same NSF workshop covers both physical attributes of an initial event and its social and physical impacts:

> "*...an occurrence (physical, author's note) that with respect to some class of related occurrences, is eithernotable, rare, unique, profound, or otherwise significant in terms of its impacts, effects, or outcomes*."

And, also bridging the divide between extreme events and extreme impacts, Easterling et al. (2000) define extreme climate events *as "those climate events causing extraordinary economic and social (loss of life or livelihood) damage*".

In contrast, the IPCC definitions in the Working Group I, Working Group II, and Synthesis reports of the Fourth Assessment Report are purely physical and focused on the initial event, although slightly different in each case. For example, the glossary of the Synthesis report defines an extreme weather event as follows:

> '*An event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense...When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season).*'

This tension between the purely physical and social impact perspectives was emphasized in social science literature in the 1970s and 1980s as articulated by Kenneth Hewitt (1983) who "*castigated hazards researchers for the overwhelming attention devoted to geophysical processes and the neglect of societal forces*" (Tobin and Montz, 1997). In considering the food deficit problem, Wisner et al (2004) note that analysts still grant a significant role "*to 'extreme' natural events which focuses attention on unpredictable nature… meaning (they) can avoid the analysis of how the history of vulnerability….operates to provide the context for the triggering event*".

The general definition of a weather or climate extreme and its link with an 'extreme impact' depends strongly on context, reflecting both the degree to which populations or ecosystems are located in the path of the extreme (exposure) and the underlying vulnerability or susceptibility to damage of these populations. 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 climate change may affect our understanding of extreme events and extreme impacts, and how these should be considered and communicated.

1.2.2. Extreme Events Defined in Physical Terms

Weather can be defined as '*the state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity, and barometric pressure*' while **climate** is '*the meteorological conditions, including temperature, precipitation, and wind, that characteristically prevail in a particular regiŏn* (http://www.thefreedictionary.com)'.

In addition to providing a long-term mean of weather, 'Climate' characterizes the full spectrum of means and extremes associated with 'unusual' and unusually persistent weather. In probabilistic terms, the outer tail of this annual variance (i.e., extending beyond the 90^{th} or 10^{th} - percentiles of the underlying distribution) reflects the infrequent extremes, the weather events, and the climate states that by virtue of their scarcity may have damaging impacts on human settlements, infrastructure, lives, and ecosystems which lack adequate resilience and resistance to them. Scarcity is specific to location and climate contexts: a month of temperatures corresponding to the expected Spring climatological daily maximum in Chennai would be termed a heat wave in France; the precipitation of a monthly maximum tropical afternoon in Kuala Lumpur would lead to a flash flood in Mongolia; a snow storm expected every year in New York would provoke a disaster when it occurs in southern China.

Out of the simple raw materials of precipitation, winds, and temperatures emerges a wide range of potential extreme 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 can also be a climate extreme (McKee et al., 1993). 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, presents a spectrum of size, forward speed, and intensity that, in the tail of the distribution of such characteristics, drives damaging extremes of wind and precipitation.

The full range of climate extremes reflects the interactions of atmospheric temperatures, motions, and precipitations over a very wide range of timescales, spanning up to eight orders of magnitude, from the short-lived passage of an intense tornado to a multi-year drought. The behavior of the atmosphere is also highly interlinked with that of the hydrosphere, ocean, and terrestrial environment so that extreme (or sometimes non-extreme) atmospheric events may cause (or contribute to) other rare physical events such as extreme sea levels, river levels, landslides and avalanches. Of course they also can lead to non-rare or non-extreme manifestations of such events.

Here the distinction between the initial physical event and its impact becomes critically important. Whether climate and weather extremes cause extremes of physical surface phenomena, like landslides, avalanches, and river levels, depends on the physical and ecological context in which the initial event occurs, and often the pre-existing human management and reconfiguration of that context. Some literature (Easterling et al.,2000) reserves the term "extreme event" for the initial physical phenomenon; some includes the physical impacts, like flooding, which follow from the initial event even though the latter can also include a human factor; and some literature uses this term to refer to the entire spectrum of outcomes including the initial event and its effects on humans, society, and ecosystems. In this report, we use "extreme event" to refer to physical phenomena including some, like flooding, which may have a human component to causation. We contextualize "impact" to include: a) changes in the natural physical environment, like flooding, 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) human or societal loss and damage. An "extreme impact" reflects highly significant consequences.

Among the more important physical extremes or physical impacts deriving from climate and weather interacting with the hydrosphere, cryosphere, and other aspects of the geosphere and biosphere, the following are particularly relevant to this report:

- Exceptionally high or low sea surface temperatures affecting sea ice formation (Gordon et al., 2000) and biological systems like coral reefs (Brown, 1997).

- Large cyclonic storms, with their reduced central pressures and persistent winds, generating positive and negative storm surges in both the sea and large lakes which become amplified on long shoaling coasts (Xie et al., 2004).
- Rivers reflect the most volatile component of the hydrosphere (Henshaw et al., 2000). Flows exceeding the 1- or 2-year maximum typically expand beyond the natural channel to produce 'floods' (Gurnell and Petts, 1995). Extreme flows arise from intense precipitation, spring thaw of accumulated winter snowfall, or an outburst from an ice, landslide or artificially dammed lake. River systems are tuned to react to particular durations of intense precipitation, with steep short mountain streams responding to rainfall totals over a few hours, while peak flows on major continental rivers reflect precipitation extremes of weeks (Wheater, 2002). Here the history of human management is an additional contributory cause of extremity, in particular in the urban environment, where impermeable surfaces lead to rapid run-off with little infiltration (Wheater, 2002).
- Long term reductions in precipitation, exacerbating human groundwater extraction, reduce ground water levels, causing spring-fed rivers to disappear (Konikow and Kendy, 2005).
- For glacial rivers, rising temperatures lead to increased summer meltwater flow until a glacier finally dwindles, after which flow will be significantly reduced in hot dry seasons (potentially creating unprecedented low flow extremes), as anticipated in regions such as Bolivia and central Asia (Rees and Collins, 2006).
- At the interface of the hydrosphere and geosphere, landslides (Dhakal and Sidle, 2004) are triggered by raised ground water levels after excess rainfall or melting permafrost and glacial retreat.

A variety of feedbacks and other interactions connect extreme events and ecological responses in a way that may amplify such extremes events or lead to additional physical impacts. For example, reductions in soil moisture intensify heat waves (Seneviratne 2006), while droughts following rainy seasons turn vegetation into fuel that can be consumed in wildfires (Westerling and Swetman, 2003).

1.2.3. Extreme Impacts

Extreme impacts to human, biological or physical systems, can be the result of a single extreme event, a compound of extremes or non-extremes, or simply the persistence of conditions, such as those that lead to drought. Whether an extreme event results in extreme impacts to physical, human, and ecological systems depends, as has been said previously, on the degree of exposure and vulnerability and lack of resilience or resistance, in addition to the intensity of the physical event (see Box 1-2). Similarly, the human, societal, physical and ecological context in which non-extreme events occur determines whether or not extreme impacts result (see Section 1.1 and Box 1-1).

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Box 1-2. Impact Determined by Previous State of the Environment

The impact of an extreme event can be strongly determined by the prevailing condition of the environment. Since the late 1990s Gangwon Province in South Korea has experienced several severe wildfires as a result of droughts, as in 1996, 2000 and 2005 (NEMA, 2009). These resulted in deforestation, especially on the steep mountainsides. Therefore, those areas were left with a high potential for landslide risk in case of heavy rainfalls.

In 2006, Typhoon Ewiniar struck Korea. As the typhoon filled and weakened, heavy and persistent rainfall continued in the mountainous northeastern part of the country, especially in Gangwon Province, with 90mm of hourly rainfall at Pyeongchang (NEMA, 2007). The rainfall led to severe landslides, which brought a great amount of debris into streams, and consequently resulted in significant flooding.

In contrast, other neighboring areas with similarly intense precipitation suffered from much less secondary mass movement or consequential flooding, because they had not had the previous degradation of the landscape or were better prepared after experiencing severe typhoons such as Rusa in 2002 and Maemi in 2003 (NEMA, 2007).

Since the damaged areas were neither highly populated, nor farmed, the total quanitifable damage was not high enough for the event to be classified as a major disaster. However, damage to the natural ecosystem and to infrastructure were very severe: rivers, hill slopes, and roads were devastated, and the rural population lost its means of livelihood. The Korean government was prevailed upon to amend the law for disaster and safety management and to declare the affected region a major disaster area, thereby facilitating financial assistance. After this compound disaster, the government and the local people worked diligently toward recovery of the damaged areas, starting a program to control soil erosion and to build dams in areas of potential risk to prevent debris from flowing downstream (Gangwon Province, 2007).

_____ END BOX 1-2 HERE _____

In the climate change and adaptation literature, extreme events are often considered in strictly physical terms (Easterling et al., 2000). In contrast, in the disaster risk community, "extreme" refers to levels of damage and loss, and the notion of "event" increasingly takes on a social connotation (Thomalla et al., 2006).

Metrics to quantify extreme impacts may include, among others (Below et al., 2009):

i) human casualties and injuries
ii) numbers of permanently or temporarily displaced people
iii) impacts to properties, measured in terms of numbers of buildings damaged or destroyed
iv) impacts to infrastructure and lifelines
v) financial or economic loss
vi) duration of the above impacts.

Both human and natural systems will be largely unaffected by a wide spectrum of weather. Extreme impacts arise due to the lack of resistance and resilience in the face of the rarest individual extremes and more common smaller scale events, or to a concatenation of less extreme events. Trees, like indigenous building styles, have evolved (or grow) to withstand extremes expected every 10-50 years, but not extremes that lie beyond their average lifespan of 100-500 years, reflecting the inherent cost-benefit ratio of developing additional levels of protection (Ostertag et al., 2005). Tree susceptibility to being uprooted or felled by extreme winds, for example, is strongly species dependent, with evidence that indigenous species adapted to a particular climatology of extreme winds are more resilient than species imported from lower wind hazard regions (Canham et al., 2001).

Human systems are also explicitly designed to withstand expected extremes. On the island of Guam, within the most active and intense zone of tropical cyclone activity on Earth, buildings are built to the the most stringent ordinary building wind design code in the world, requiring a bunker style construction able to withstand wind speeds of 76metres/second as expected in this location every few decades (International Building Codes, 2003). However, even for the same return period of an extreme (e.g., a 100-year storm return period), climate conditioning may vary from place to place (reflecting the relationship between extreme wind and return period). In the tropics, without any source of high wind speeds other than rare tropical cyclones, indigenous vernacular building practices are less likely to be resilient than at mid latitudes (Minor, 1983).

Communities accustomed to periodic droughts employ wells, boreholes, pumps, dams and irrigation systems. Those with houses exposed to excessive seasonal heat have developed passive cooling systems, or acquire 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 2003 (Vandentorren et al., 2004).

1.2.4. Distinguishing Disasters from Extreme Events and Extreme Impacts

Disasters are defined in Section 1.1.1 as extreme impacts associated with a severe disruption of the normal, routine functioning of the affected society. Some definitions of 'disasters' for the purposes of tabulating occurrences rely only on exceedances of thresholds of numbers of killed or injured, or repair costs (see Below et al., 2009). More contextually, societal impacts resulting from weather or climate events become a disaster when 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 the capacity of the society to repair itself; Alexander, 1993). For example, Tobin and Montz, (1997) contrast everyday or chronic risk with "*threats and levels of damage that can overwhelm whole communities or cripple aspects of every day life-such are the features of disasters and catastrophes"*. While extreme physical events may be the principle trigger of many disasters, a disaster may also arise from a concatenation of physical, ecological and social reactions to lesser physical events (see Box 1-2). Disasters may be exacerbated by pre-existing social processes and events, such as financial crises, trade policies, wars, disease outbreaks etc. Evacuation or migration away from the site of one disaster can leave a population much more vulnerable to further disasters. 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'.

The term "event" also does not capture the full range of characteristics of impacts and disasters, because it does not reflect the compounding of outcomes from successive physical phenomena, e.g., footprints from a succession of serial storms tracking across the same region which can generate disasters. The circulation in an entire hemisphere can lock into a stable configuration (teleconnect) for periods up to 6 weeks, as in August and September 2004, when both the western equatorial North Atlantic hurricane track and the western Pacific typhoon track became set, leading to four major hurricanes making landfall on Florida and four typhoons striking Japan (Kim et al., 2005; Bell et al., 2004). Atmospheric teleconnections also relate to the principal drivers of oceanic sea surface temperatures, in particular ENSO. Sometimes locations affected in the same weather event can be far apart, as for example when extreme precipitation fell in the headwaters of different river systems (see European floods of 2002 Ulbrich et al., 2003).

The aftermath of one extreme may precondition successor events, leading to disaster. High groundwater levels and river flows can persist for months, increasing the probability of a later storm causing flooding. The 1997-1998, El Nino, that led to heavy rains across Honduras causing saturated soils, ahead of the arrival of the stalled intense 1998 Hurricane Mitch that in turn triggered massive landslides and destructive floods (Smith et al., 2002). Periods of high rainfall followed by droughts create the conditions for wildfires, 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 and for the next month, any cyclone whose path follows too closely will tend to lose intensity (Emanuel, 2001).

1.2.4.1. Extremes in a Changing Climate

Climate change is expected to alter both the intensity and frequency of extreme (and non-extreme) events, and thereby alter their distribution and concentration in space and time (see Section 1.2.5, Box 1-3, and Chapter 3). Potential outcomes in terms of particular extreme impacts and disasters are discussed in succeeding chapters. A key issue to bear in mind is that an extreme event or a disaster may result from a succession of smaller events, or a moderate event superimposed onto a gradual trend, such as would occur in a changing climate. For example, in the future, a storm surge with a ten year return period superimposed on a higher sea level could have the same consequences as a disastrous storm surge flood with a hundred-year return period occurring today (see Section 1.2.5), depending on the level of learning and adaptation in the interim. Even without the additional contribution of sea level rise, disasters 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 sea levels, compounding such extremes. Novel combinations of events, such as an earthquake occurring coincident with high groundwater levels, or a tsunami superimposed on higher sea level, may also cause unprecedented outcomes.

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Box 1-3. Example of Complex Ways in which Extreme Events, Long-Term Trends, and High Vulnerability Interact to Produce Extreme Impacts

Sahel is located on the southern margins of the Sahara desert, where the ecology and the climate start to make settlement possible again (Nyong et al., 2007). Drought in Sahel dates back to early times, reflecting the fact that the southern boundary of the desert fluctuates. The most prominent and severe recent drought was in the early 1970s (Hulme, 1992, 1996, 2001, Batterbury and Warren, 2001) when hundreds of thousands of people and millions of animals died (Mortimore, 1998). The prolonged period of reduced rainfall (down by 20-30%) that began in the early 1970s is still in progress (Le Houérou, 1996, Nicholson, 1986, 1989, 1993) and reflects regional shifts in rainfall patterns also affected by ENSO (Folland et al., 1986; Ward, 1998). . At the same time, the population in the area has increased rapidly with an average annual growth of 2.6 percent (UNPP, 2006). This increase, along with social conditioning and social deficit,, combined with the persistent droughts, appears to be a main cause of degradation of ecosystems, by humans over-using natural resources in the region through overgrazing**,** deforestation, overcultivation, intensive irrigation, and poor land management (Olssona et al. 2005, Ezra, 2001, Nicholson, et al. 1998). The loss of vegetation has been linked to increased surface albedo, increased dust generation, and reduced productivity of the land (Nicholson, et al. 1998). The combined pressures on the fragile environment and severe droughts made the society and ecosystems more vulnerable to impacts from extreme events.

According to the report of Africa Committee on Sustainable Development under the aegis of United Nations Economic Commission for Africa (UN-ECA Report, 2007), drought and floods induced 80 percent of loss of life and 70 percent of economic losses linked to climate hazards in Sub-Saharan Africa. The drought of 2001–03 resulted in a food deficit of 3.3 million tons, with an estimated 14.4 million people in need of assistance in the sub-region. Major rivers and lakes highly sensitive to rainfall variability are severely affected by water stress, weakening the potential for hydropower generation. The population threatened by migration in response to desertification is estimated at 135 million people, 60 million of whom are in Sub-Saharan Africa, the Sahel and the Horn of Africa. Migration paths are expected to be towards Northern Africa and Europe**.**

During recent decades, eastern Africa has experienced high rainfall variability, (Schreck and Semazzi, 2004). The persistent and severe droughts of the 1970s and 1980s and those occurring during 2001-2003 have been associated with socioeconomic and environmental disasters including loss of life, poverty, famine, mass migration of pastoralists and farmers, environmental refugees, shortage of food, water and energy (UNEP, 2002, UNECA, 2007)

_____ END BOX 1-3 HERE _____

1.3. Disaster Risk Management, Reduction, and Transfer

The disaster risk management community has developed key concepts and methods for managing, reducing, and transferring or sharing risk. These concepts must evolve in order to take account of the ways changing climate and other environmental and social conditions such as the state of development, income levels, and distribution of resources within a society may affect management schemes and challenges.

This section will first review and critique the probabilistic risk analysis framework that provides the conceptual underpinnings for much of the literature on risk management, reduction, and transfer. It will then summarize how risk management, reduction, and transfer are addressed in both the literature and practice of disaster risk management and climate change adaptation, and suggest how considerations of climate change might affect disaster risk management. This section emphasizes conceptual frameworks, not because they are necessarily commonly implemented in pure form nor currently available to all practioners, but rather because they support a more thorough understanding of current practice and potential improvements. The section does conclude with a review of such current practice in both developed and developing countries.

1.3.1. Probabilistic Risk Analysis

Probabilistic Risk Analysis (Beford and Cooke, 2001) provides an important set of 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 also use this framework. In its simplest form, the approach defines risk as the product of the probability that some event will occur and the probability of adverse consequences of some magnitude resulting from the interactions of that event with humans, their societies, and their physical artifacts. For instance, the risk a community faces from flooding from a nearby river might be calculated as the likelihood of the river rising high enough to inundate the town multiplied by the likelihood that such flooding would kill and injure a certain number of people, cause a particular amount of damage to the community's buildings and possessions, and disrupt the community's economic livelihood for a particular period of time. The community could also evaluate various options for reducing risks by comparing their effect on the likelihood and magnitude of the adverse consequences from any given flood.

A community will typically face many types of events and potential consequences. Thus, the community's overall risk can be written as

$$\text{Total Risk} = \sum_{\substack{\text{All Events} \\ \text{All Consequences}}} \text{Prob(Event)} \times \text{Prob(Consequence)} \qquad (1)$$

The disaster risk management literature focuses on actions communities can take to reduce and manage risk by lowering the probability of adverse consequences from events (the second term on the right-hand side of Eq 1), and by transfering or sharing risks through mechanisms such as insurance. In the context of Eq 1, such risk transfer or sharing would reduce the net consequences to a particular individual or community of some event while increasing it for others. As will be discussed in more detail below and throughout this report, disaster risk management generally regards the probability of events– such as hurricanes, droughts, and heavy rainfall -- as beyond human control. In general, anthropogenic climate change may affect the probability of such events, though it is important to note that the relation between greenhouse gas emissions and the probabilities over space and time of particular types of events, e.g., intense precipition, tropical storms, or droughts, remains uncertain (IPCC 2007, Table SPM-3). In the broadest context, policies to address climate change can reduce risk both by limiting atmospheric concentrations of greenhouse gases (mitigation) and taking actions that limit the consequences of such events (adaptation). However, this report focuses only on the latter set of actions.

1.3.2. Challenges in Implementing the Probabilistic Risk Framework

Probabilistic risk analysis offers a powerful and elegant framework, but there exist numerous challenges to implementing it for disaster risk management and climate change adaptation. As will be described throughout this chapter and report, many communities lack the training and data to implement this framework in practice. But even in the most favorable real-world situations managing the risks created by extremes and disasters poses fundamental problems of estimating probabilities of both events and consequences as well as of risk communication. This subsection will address these two challenges.

1.3.2.1. Challenge of Imprecise Probabilities

The probabilistic risk management framework applies to events and their consequences of all types and of all magnitudes. This report focuses on reducing and managing the risks associated with extreme events and the extreme consequences of less extreme events. Such extremes pose a particular set of challenges for the probabilistic risk analysis framework because their relative infrequency often makes it difficult to obtain adequate data to estimate the probabilities used in Eq (1).

The likelihood of extreme events is most commonly described by the mean interval expected between one such event and its recurrance. 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 exceedence 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, though this translates into a 63% chance of occurring within any 100-year period because probabilities are not strictly addiive.

The larger question of the return period of an event cannot be answered without providing some additional spatial context. A typhoon has just made landfall in Vietnam. What is the 'events' return period? Is it the 20 year return period for an intense tropical cyclone making landfall somewhere on the coast of Vietnam, or the 200 year return period for a particular intensity storm making landfall within 50km of Hanoi? Or is it the ten-year return period for an event of this magnitude of loss? Furthermore across the footprint of a spatially extensive event, the extreme will likely have different point return periods.

These procedures still leave estimates of the probability of extreme events more imprecise than estimates of the probability of less extreme events. In addition, the probability of such extreme events will in general change over time in ways that may prove difficult to predict. For example, paleoclimate evidence suggests that before any anthropogenic climate change the frequency of large Atlantic hurricanes changes over time periods of decades and centuries. Anthropogenic climate change significantly exacerbates this already difficult estimation challenge, since it may generally alter such frequencies, intensities, and consequences in difficult-to-predict ways (Chapter 3; IPCC 2007; NRC 2009; TRB 2008).

There are, however, two ways of substituting for the absence of a suitable data time series: either by pooling independent observations (see Milly et al, 2002) or by inferring that changes at short return periods mimic changes in extremes (although the absence of evidence for a change at short return periods does not prove that the tail of extremes remains unaltered; Frei and Schar, 2001).

In addition, there are perhaps even more difficult challenges in estimating the probabilities of extreme consequences since these involve predicting the behavior of complex human systems under stressful and potentially novel conditions. Section 1.4.4.1 describes some of the challenges system complexity may pose for effective risk assessment.

The disaster risk management and climate change communtities 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 for climate change adaptation(Parson et. al. 2007) and DRM. As described in Section 1.3.5.1, the probabailistic 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. Cognitive Barriers to Effective Communication about Extremes

A second fundamental challenge is that the key concepts underlying probabilist risk analysis – probabilies and risk – often prove difficult for people to communicate and understand. In particular, the judgment and decision-making literature suggests various cognitive barriers that make it more difficult for individuals and organizations to properly assimilate and respond to information about low probability events. Effective disaster risk management and climate change adaptation must thus address these barriers. Effective risk communication requires a process of exchanging, integrating and sharing knowledge and information about climate-related risks among all stakeholder groups: scientists, policy makers, private firms, non governmental organizations, media, and the public.

As described in the judgment and decision-making literature, the concepts of disaster, risk, and disaster risk management have very different meanings and interpretations for scientists and nonscientists. Experts in the private and public sectors often use the probabilitistic risk analysis framework. Within this framework, disasters are a statistical concept that combines probability and consequences, in conjunction with conditions of vulnerability. In contrast, the general public, politicians, and the media are more likely to focus on the concrete adverse consequences of such events, absent from the probabilistic context. 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. The understanding of risks and extreme events by climate scientists are based in large part on analytic processing, as these experts have been trained in the necessary analytic tools and have the necessary input required for these tools.

Nonscientists, on the other hand, rely more on more readily available and more easily processed information. These gaps between scientist and nonscientist understanding of extreme events present important communication challenges (Weber and Stern, 2010).

1.3.2.2.1. Nonscientists' estimations of risk and extremes

Climate scientists use careful observations of phenomena to collect data over time, which are incorporated into models to project future states of the system. The average person predicts 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 people's past experience and thus will be relatively unavailable. They will essentially be ignored unless and until they do happen to occur, as in the case of a hundred-year flood (Hertwig et al., 2004). For extreme events with severe and thus memorable consequences, people's estimates of their risks will, at least temporarily, become inflated (Weber, Shafir, Blais, 2004).

Nonscientists' judgments of risk are 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 people with predictions about extreme events, in part to circumvent the problem that such events may not be available in the public's attention because of a paucity of past personal experience with them, 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).

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.

1.3.2.2.3. Influence of culture and ideology

The perceptions of risks and extremes by nonscientists are not only influenced by the cognitive shortcuts with which unaided and untrained human information processors circumvent limited attention and processing capacity (Kahneman and Tversky, 1979), but also by motivational factors that can introduce differences in perceptions and reactions as the result of variations in values and beliefs. Which extreme events are seen as threats or risks worthy of attention and reaction, and which extreme events are essentially ignored often differs between groups. People's worldview and political ideology guide attention towards events that threaten their desired social order (Weber, 2010). They also influence which sources of expert forecasts of extreme climate events will be trusted. Different groups put their trust into different organizations, from national meteorological services to independent farm organizations to the IPCC.

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). Evidence from the health literature, the social psychological literature, and the risk communication literature suggests that these social and cultural risk amplification processes modify perceptions of risk in ways that may generally be socially adaptive, but can also bias reactions in socially undesirable ways in specific instances (American Psychological Association, 2009).

1.3.3 Current Framework for Disaster Risk Management

Disaster risk management primarily addresses the complex mix of social, economic, political, cultural, technical, and others factors that affect the consequences of a given event or events as well as efforts to reduce and manage those consequences. The field has evolved significantly over recent decades and offers a range of strategies, approaches, definitions and concepts which are briefly reviewed here.

Consistent with Eq (1) and following on from the basic definition given in Section 1.1, disaster risk itself is defined as "the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions."

The word disaster, when used to describe contexts associated with the impact of damaging physical phenomena, has been defined in many different ways (Sections 1.1 and 1.2 provide elements for defining disaster). The International Strategy for Disaster Reduction (UNISDR) refers to contexts where there is:

> "*a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources*" (UNISDR, 2009).

ISDR also presents the important clarification that a *"disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk."*

Despite criticisms that have been made of this and other disaster definitions, and complexities and redundancies raised by concepts like "hazard", "vulnerability" and "coping" (see Sections 1.1 and 1.4), the ISDR approach is sufficiently explicit and comprehensive to serve an an acceptable starting point for consideration of disaster risk management and reduction goals and processes.

Over the last fifty years the disaster intervention problematic has undergone very significant changes, increasingly adopting a probabilistic risk management framework, as opposed solely to a focus on specific occurances and reactions and responses to disasters, and increasingly emphasizing proactive in addition to reactive responses to these risks, favouring risk reduction, prevention and mitigation and with increasingly stronger, if as yet insufficient, links to development planning. Reactive approaches based on disaster management and response principles were captured under the terminology "Disaster" or "Emergency Management". This movement and transformation, which is differentiated in its level of advance on a regional and national level, and which is still more developed conceptually than on the ground, has led to the gradual, ongoing disappearance of the Disaster Management term as such and the emergence of the more comprehensive notion of Disaster Risk Management. Risk and its reduction or mitigation or prevision and prevention is increasingly becoming the central concern and this risk is present in pre impact and post impact contexts.

The UNISDR defines disaster risk management as "*the systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards.*"

A myriad of alternative if complimentary definitions also exist. As one illustrative example, the Central American Coordinating Centre for the Prevention of Natural Disasters (CEPREDENAC), the official Central American intergovernmental organization for disaster reduction and response, and the Andean Committee for Disaster Reduction (CAPRADE), two of the more long standing, experienced intergovernmental, regional organizations located in some of the most risk prone areas of the world, have defined disaster risk management as "*a social process that searches for the prevision and permanent control of disaster risk in manners that are consonant with and integrated into the planning of sustainable human, economic, environmental and territorial development. In* *principle this allows for different intervention levels from the global and integral, sectoral and macro-territorial through to local, communitarian and family based".*

Disaster risk management is seen by CEPREDENAC and CAPRADE to be a process and not simply a series of concatenated and related actions, whilst also considering the full range of activities and aspects associated with risk and disaster from prevention through to recovery and reconstruction. Risk is seen to be ever present in differing forms and dimensions.

Both definitions provide for a further delimitation of disaster risk management practice, distinguishing clearly between what is called corrective or compensatory disaster risk management where the interest is in reducing existing risk and risk factors, and prospective or proactive risk management where the interest is in avoiding new risk factors in the future through risk controls and considerations introduced in the development of new private and public sector projects and programs (see Lavell, 2005 for a thorough presentation and discussion of these concepts).

Disaster risk management clearly focuses on a general notion of "risk reduction" which has been defined by the ISDR as "*the conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of risks, within the broad context of sustainable development* (UNISDR 2002; also see Section 1.3.7).

Seen from the angle of the relations between disaster risk reduction and such other prevailing challenges as the need to reduce poverty and the need to adapt to climate change, the recent Global Assessment Review of the UNISDR (UNISDR, 2009) in its discussion of what it calls "risk drivers" has clearly established that the reduction of environmental services depletion, improvements in urban land use and territorial organization processes, the strengthening of rural livelihoods and overall and specific advances in governability are indispensable in order to achieve that triple agenda. They are strategies that cut across problems and serve to clearly link poverty reduction, adaptation and risk reduction strategies and instruments.

The concept of risk transfer has also gained increased interest and salience. Also described as "risk sharing" (see Section 1.4.), this approach refers to mechanisms that permit risk to be transferred to third parties or shared among a larger group. For instance, insurance policies ask for regular payment of premiums and in return will provide monetary compensation for losses if and when risks materialize. Insurance mechanisms may allow many of those affected by similar risks to pool resources that can then flow to those who suffer particular losses. 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 corrective and proactive risk management, for instance when insurance rates are calibrated to the level of existing risk—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). For instance, actions to reduce risk of flooding might include structural measures such as building levees and non-structural measures such as land use changes or restoring wetlands that can absorb flood waters (see Section 1.4.4).

The evolution of disaster policy and the goals of intervention in favor of increased concern for risk reduction and control as a necessary complement to disaster response and rehabilitation aspects has inevitably placed the previously existing institutional and organizational arrangements under scrutiny.

In many parts of the world -- whether it be with the Federal Emergency Management Authority- FEMA- in the USA or former disaster management organizations in Colombia, Nicaragua or Ecuador, South Africa, Mozambique or Angola, India, Bangladesh or the Philippines -- the increased importance given to risk reduction in a development framework has meant the need to search to diversify and increase the complexity of their institutional arrangements. The dominance of response-based organizations from government or civil society has been complemented with the increasing incorporation of sector and territorial development agencies, Ministries of Planning and Finance. Land use planning and environmental services agencies have now become indispensable components of more modern risk management systems. Systems as opposed to single agency approaches are now evolving all over the world. Synergy, collaboration, coordination, multidisciplinary and multiagency schemes are now seen to be required to guarantee risk reduction and risk management in a sustainable development framework **(CITE).** A classic case of institutional evolution can be found in the early Colombian evolution from a single civil defense type structure to the creation of its multi-institutional, multi-disciplinary, decentralized Disaster Prevention and Response System in 1989 after the impact of the Nevado de Ruiz eruption and lahar which killed 20,000 persons in Armero. This model served as an example in much of Latin America for years after and many countries built on it with their institutional transformations (Ramírez and Cardona, 1996).

The notions of hazard and risk, the latent danger associated with diverse non-routine physical events that range from extreme and rare to recurrent, and the potential for loss, are key to understanding disaster risk management. The level of the risk is determined both by the intensity and magnitude of the physical event as such and the differential levels of exposure and vulnerability of the diverse social and economic elements. The overall objective of disaster risk management is to limit the losses associated with such non-routine events in contexts where prevalent environmental norms and averages are the basis and fundamental factor in explainingongoing social productivity and economic gains and accumulation. This objective can be achieved by reducing the levels of exposure and social vulnerability to events, that is, all the factors that contribute to consequences in the probabilistic risk analysis framework. An understanding of, and the values people place on various potential consequences (see Section 1.3.5), along with expectations about the potential likelihood of the triggering events, can help inform decisions about the allocation of resources to reduce and manage the various risks a community faces. Positively managing such risks with a full portfolio of process and actions is what disaster risk management does and should help to do.

The management of non-routine events and the risk associated with them cannot be dealt with in isolation from the ongoing, normal context of every day life and the chronic or persistent social risk factors that typify it for many individuals (ill health, unemployment, lack of incomes, addiction and alcoholism, family and social violence, etc) (see Section 1.1). The idea that disaster and disaster risk are exceptional conditions counter-posed to normal life was convincingly debunked many years ago by amongst others Wisner et al (1976), Hewitt (1983), Blaikie et al (1994) and Wisner et al (2004). The only way of understanding disaster risk is to understand the ongoing social processes associated with every day life that lead to its existence and, on the other hand, the only way to be able to enact risk management principles is by framing and bedding these in a thorough understanding of the ongoing social demands of the population, particularly the poor who must deal with risk at all levels on a daily basis (Maskrey, 1987).

Managing the risk of extreme impacts includes managing the risk associated with non-extreme, but also non-routine events that affect the same areas on a more permanent and persistent basis, all within the framework of ongoing chronic risk, associated with poverty, lack of incomes, ill health, lack of hygiene etc. Managing extreme events and disasters is most usefully accomplished as one component of managing risk in general.

The concept of totality in dealing with risk is further developed on the understanding that the risks associated with climate variability and change can only be realistically dealt with if they are also considered in the light of other pervasive and permanent hazards associated with the natural and non natural environment—geological, geomorphologic, oceanic, technological etc. In other words, total integrated risk management requires holistic visions of environments, both human and natural. The lack of holistic visions will also be a cause of “mal-disaster risk management” and maldaptation as discussed in Section 1.4

1.3.4. Climate Change Adaptation Framework

Clmate change may change the disaster and other risks faced by communities. Climate change adaptation (see Section1.4) addresses actions taken to reduce and transfer such risks. In some cases climate changes may prove beneficial; climate change adaptation also aims to take advantage of such opportunities.

From their very beginning, human societies have faced and responded to climate variability and weather extremes Burroughs, 2005). But the literature on climate change adaptation dates largely from the mid- 1990s and is thus more recent than disaster risk management and its disaster management and emergency management predecessors. Working Group II of the Fourth IPCC Assessment Report defines adaptation as:

> *“The adjustment in natural or human systems in response to actual or expected climate stimuli or their effects,which moderates harm or exploits beneficial opportunities.”*

The term climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity, so that climate change adaptation refers to responses taken in anticipation or response to changes of any mix of natural or anthropogenic origin.

Climate change adaptation rests on the key recognition that the risks to human and natural systems can vary as climate changes. Most germane to this report, climate change may affect the frequency and magnitude of extreme events in a region and the consequences of those events. In general, these systems face changes of two types: 1) chronic, gradual, long-term changes such as trends in climate averages, sea level rise, and shifts in ecosystems and 2) changes in the frequency and character of extremes of weather and climate such as droughts, floods, and storms. In any particular region, climate change may shift the frequency and character of extreme events, may contribute to changing conditions that can lead to extreme impacts and disasters as the physical and biological environment responds to non-extreme events,-or may introduce types of events and conditions new to that region but common elsewhere, such as forest fires or severe flooding in regions where such events were previously unknown. If global mean temperature rises high enough, some regions may begin to experience impacts outside the range of any previous human experience.

From its beginnings, the climate change adaptation literature has employed the concepts of vulnerability and adaptive capacity to capture the ways in which changing climate conditions can affect human and natural systems. These terms are also found in disaster risk management literature, though the exact definitions may differ (see Section 1.1.3.2 for controversies over these definitions).

The early climate change adaptation literature focused on identifying and characterizing vulnerabilities to various human and natural systems (IPCC ,1995). In recent years, however, communities worldwide have begun to take actions to reduce these vulnerabilities (see World Development Report 2010; IPCC 1990; US National Academy of Science 2010). Accordingly, the climate change adaptation literature has increasingly focused on the identification and evaluation of alternative options that can reduce vulnerability and increase adaptive capacity. In many cases, such actions are identical to those that might be considered by disaster risk management. For instance, a climate change adaptation analysis might suggest how a community can reduce vulnerability by moving populations away from regions that may in the future see more frequent floods, by improving its ability to monitor and evacuate when floods prove imminent, and by building and retrofitting buildings so they suffer less damage in floods. The community could increase its adaptive capacity by insuring against its economic losses, improving forms of social organization and collaboration, and improving its capability to rapidly repair and rebuild after any flooding.

Similarly to disaster risk managment, the climate change adaptation literature pays significant attention to the potential for *ex ante* action. Given its focus on the impacts resulting from temporal changes in climatic conditions, ideally climate change adaptationwill prove more effective the more it can anticipate future change. In some cases, *ex ante* actions may be necessary to an effective response. In other cases, it may prove less important. Irrespective of its importance, in some cases communities may be unable or unwilling to take *ex ante* actions and in other cases, as described in Section 1.4.4, attempts at anticipatory action may increase future risks. Accordingly, the IPCC distinguishes three types of adaptation to climate change that incorporate varying degrees of foresight (IPCC, 2001):

- *Anticipatory adaptation* – Adaptation that takes place before impacts of climate change are observed, also referred to as proactive adaptation. This is seen to be undertaken by persons and communities in the normal development of their lives as opposed to being incited by government intervention and plan.
- *Planned adaptation* – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.
- *Autonomous adaptation* – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems and also referred to as spontaneous adaptation.

Other taxonomies have also been proposed. For instance, in a survey of 135 claimate change adaptation efforts in developing countries, The World Resources Institute describes "serendipidous adaptation" in which activities taken to enhance development objectives also decrease risks due to climate change, "climate proofing" in which ongoing development activities are augmented by actions to reduce risks due to climate change, and "discrete adaptation" in which actions are taken specifically to reduce risks due to climate change (McGray et. al. 2007).

In recent years the climate change adaptation literature has increasingly adopted an iterative risk management framework. This framework recognizes that the process of implementing the probabilistic risk analysis of Section 1.3.1 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. The importance of such an iterative risk management framework is emphasized in the IPCC's Fourth Assessment Report, which states:

> *Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation, and takes into account climate change damages, co-benefits, sustainability, equity and attitudes to risk. (IPCC 2007).*

One exemplar process for implementing an iterative risk management climate change adaptation approach is shown in Figure 1-2. This 8-stage iterative process, developed by UK Climate Impacts Program (Willows and Connell 2003), is designed to help decisionmakers identify and manage their climate risks in the face of uncertainty and encourages users to consider climate risks alongside non-climate risks. While this approach provides a good example of the state of the art in the climate change adaptation literature, many communities have not adopted this or similar practices (as described below and elsewhere in this report).

[INSERT FIGURE 1-2 HERE
Figure 1-2: One example of an iterative risk management approach, developed and widely applied by the UK Climate Impacts Program (Willows and Connell 2003).]

1.3.4.1. Iterative Risk Management under Deep Uncertainty

As emphasized in several recent reports (NRC 2009; Morgan et. al. 2009) 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 often unknown. Such deep or severe uncertainty (see Lempert and Collins 2007 for a discusion of various terms used in the literature for this type of uncertainty) 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 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). For instance, governments at the December 2009 climate negotiations in Copenhagen set a goal of preventing temperatures from rising beyond 2°C above preindustrial levels. Climate science research may reveal previously unanticipated impacts if global mean temperature increases grow beyond this target, thus increasing the range of potential risks.

Overcoming these challenges require augmenting the basic iterative risk management framework in two important ways (NRC 2009, Morgan et. al 2009):

1) Recognize and manage the deep uncertainties facing many climate related decisions.
2) Embed iterative risk management in a broader process of institutional learning and adaptive governance in a manner which captures the full range of knowledge available including from local, indigenous experiences and other sources, and corresponding variations in experience and perception of risk from group to group (see Section 1.3.5).

In response to such deep uncertainties, many climate-related decisions should seek to be robust, that is, to perform well compared to the alternatives across a wide range of plausible future scenarios, even if they do not perform optimally for any particular scenario. The iterative risk management framework can implement this concept by characterizing probabilities by a range of plausible values or by a set of plausible probability distributions (Morgan et. al., 2009). Although many risk assessment tools provide optimal strategies, such strategies may prove brittle if the probabilistic expectations on which they are based are sufficiently imprecise (Lempert and Collins 2007). They may also prove overly contentious if different stakeholders have sufficiently different expectations about the future. Robust uncertainty management strategies may address some of these difficulties by performing adequately and enabling multiple decision makers to agree on a portfolio of actions, even if they disagree about values and expectations (see Section 1.3.5). Example applications of such ideas are beginning to appear in the climate change adaptation literature (Means et. al. , WDR 2010; Brown and Lall 2006, Dessai and Hulme 2006).

An iterative risk management framework also emphasizes the importance of learning and adaptive strategies, those explicitly designed to evolve over time in response to new information (Morgan et. al. 2009: NRC 2009). The learning theme has also been a long-standing focus in the literature on resilience. For instance, adaptive management, an important theme in environmental management, rests on the notion that policy interventions should be viewed as experiments and learning opportunities. 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. Nonetheless, recent literature has also seen an emphasis on what is called adaptive governance (Olsson et. al. 2006; Scholtz and Stiffel 2005). This approach suggests that a key uncertainty is often the efficacy of alternative institutional arrangements and design, and thus extends adaptive learning approach to the design and modification of institutions. The particular challenges relevant to applying such frameworks to the vast range of conditions in least developed countries is discussed in Section 1.3.6.

The climate change adaptation literature recognizes that many barriers exist to effective adaptation. These include the difficulty in recognizing gradual changes and changes in the frequency and character of rare events, and understanding and turning them into actionable information. Many societies also have trouble expending near-term resources to address longer-term issues, even when those actions are clearly cost effective in the long-term. Some societies lack the resources to address any but their most immediate needs. Richer societies often face political or cognitive barriers for such investments **(CITE)**.

1.3.5. Integrating Disaster Risk Management and Climate Change Adaptation

Disaster risk management has evolved over the last decades under the stimulus of changing concepts, circumstances, approaches and social and economic demands. The complementary nature of reactive disaster response and proactive risk reduction and prevision stances, including the move from reactive mitigation to proactive risk prevention, is but one of these, and is increasingly prevalent, if not as yet mainstream, at the practical level. Climate change will pose a new challenge and lead to new changes, driven by the key concepts of non-stationarity, that is, the realization that past experiences may no longer be a reliable predictor of the future character and frequency of events and of the responses of human systems to these. A further useful concept is complexity, including the changing interrelationships between factors, scales and territories.

Non-stationarity and complexity can affect disaster risk management in several ways:

- Climate change will directly affect the frequency and character of extreme events. What had previously been considered a five hundred year event may become a hundred, fifty, or even a thousand year event. Events may occur with no analogue in the historical record, such as wildfires in areas previously too wet to burn or extended drought combined with extreme temperatures.
- The effects of climate change on physical, biological, and other systems may affect patterns of exposure and vulnerability, changing the relationship between extreme *events* and extreme *impacts*. For instance, rising sea levels may affect the vulnerability of coastal communities to storm surges. Changes in agriculture may induce migrations that affect the vulnerability of both the places that lose and gain new populations.
- Attempts to adapt to climate change may also affect patterns of exposure and vulnerability. For instance, communities might make changes in water and agricultural systems in anticipation of climate change and

unknowingly create new vulnerabilities in those systems. This dynamic is not new. Commentators have described the "levee effect" in actions designed to reduce certain risks can create other, even larger, risks **(CITE)**. Climate change may increase the potential for such mal-adaptation, including displacement of risk from one location or time or population to another (see Section 1.4.4.1).

Based on this assessment, we conclude that the major foreseeable topics that will demand new or modified approaches and responses from the disaster risk management community are:

- The need to deal with greater levels of uncertainty as to magnitude, intensity and return periods of potentially damaging events, ranging from extreme to typical.
- The need to consider the changing relationships between consequences of events with a range of characteristics. Climate change may affect differentially the occurrence of small, medium, large scale and extreme events and their balance in any one area or region. These changing relationships will be critical in the design of disaster risk management and development strategies in general and fundamental for considering the adaptation problematic. Changes in the relationships among non-routine events merit particular attention.
- The need to consider both non-routine extreme and more routine climate events and their impacts in the framework of changing climate averages and norms and their effects. Unlike conditions under historical stationary or stable climate where climate averages or typical weather has not been a source of stress but rather the basis of development in many zones and regions, the future new and even unpredictable averages of temperature, rainfall, humidity etc will in some circumstances be themselves a source of additional tension and stress and the basis of potential new disaster. This will increase the importance of learning and of adopting more holistic processes as regards development and disaster risk management and the integration of concerns for averages and extremes in a single planning framework from the beginning (see Lavell, 2009).
- While areas historically affected by extreme and non routine events will continue to be affected in different proportions and measures, new areas will suffer unfamiliar processes and events for which they are not accustomed (and some may suffer fewer). This will require new processes and procedures. Distinguishing between anomalous, extraordinary and potentially recurring events will be extremely difficult over short and medium time periods.
- Climate change will simultaneously localize and globalize effective disaster risk management. The climate adaptation literature emphasizes that adaptation decisions are fundamentally place-based. However, climate change may create correlations among increasing risks that affect resiliency and risk sharing regionally and globally. For instance, all coastal areas globally evcentually will be affected by sea level rise. An entire region may experience a change in the frequency of storms, which may stress the resiliency of regional disaster response and the solvency of any insurance mechanisms. In addition, climate change may introduce human agency into changing hazards that were previously viewed as arising solely from acts of god or nature. Any future ability, for instance, to attribute an increased frequency of severe storms to increased concentrations of greenhouse gases may affect views about the responsibility some nations bear for disasters that strike other nations (Allen, 2003).

1.3.6. How These Frameworks are Implemented in Practice

The agendas of policy-makers and practitioners working on climate change adaptation and disaster risk reduction have converged in recent years, and it has been recognized that the capacity to manage extreme events more effectively is an essential aspect of adaptation to a more volatile and unpredictable climate. The Hyogo Framework for Action 2005-2015 under the United Nation's International Strategy for Disaster Reduction (UNISDR) promotes the integration of disaster risk reduction associated with today's climate variability and future climate change into national strategies, and includes risk identification, design of risk reduction measures and an operational use of climate risk information by planners, engineers and other decision-makers (Pilot Program Year?). In developing countries, the Global Facility for Disaster Risk Reduction – a partnership of The World Bank and UNISDR - supports the integration of disaster risk reduction through country risk assessments and capacity building, policy advice and strategy formulation, and rapid technical and financial response and recovery in post-disaster situations. Similarly, climate change adaptation and disaster risk management have become a strategic priority for multi-lateral development banks, bi-lateral development agencies and non-government organizations, and programs to increase climate resilience are being pilot tested in a number of vulnerable developing countries (NRC 2006) Also, many development agencies have started to systematically screen their investment portfolio for climate risk, and consider climate risk and vulnerabilities in project identification and design. But also rich countries are changing their risk management practices in light of recent extreme events that revealed short-comings in preparedness and response (as the 2002 floods in Germany, the 2003 heat wave in France, or Hurricane Katrina in 2005 in the USA), and are making efforts in improving geo-spatial risk information, early warning and communication system, public awareness, and the understanding of the human dimension of disasters (Birch, Wachter 2006).

1.3.6.1. Good Practices

Understanding risk is essential to promote action and requires investment in scientific, technical, and institutional capacity to observe, record, research, analyze, forecast, model, and map natural hazards and vulnerabilities. While rich countries generally have systems to routinely collect and analyze information pertaining to risk and provide such information as a public good (e.g. flood zoning program, land tenure records), many low- and middle-income countries have only recently started to build their capacity to perform basic (i.e. generally low-cost, ad hoc and simple) risk assessments, improve risk management practices (e.g. through better inter-agency coordination), and put policy frameworks in place to reduce disaster risk. But ubiquity of information and high capacity to model and analyze risk does not necessarily result in systematic risk reduction, as in the case of New Orleans where many of the same fundamental risk patterns continue to prevail after the destructive hurricane Katrina (FEWS).

Still, an important activity is the development of capacity to systematically collect and disseminate information pertaining to risk and vulnerabilities, e.g. to map key physical assets, household characteristics and physical hazards. Good practice can involve both high-tech and low-tech solution, such as the mapping of high risk areas (e.g. coinciding high population density and physical hazards) by integrating satellite remote sensing data of urban structure with ground-based, geo-referenced surveys (see Box 1-4). For instance, the Central American Probabilistic Risk Assessment uses state-of-the-art observation systems, geo-spatial modeling and risk analysis to improve the understanding of disaster risk in the region, and uses web-based communication to provide decision support to local decision-makers. But equally important are low-tech actions at the community-level in low-capacity environments such as systems of basic indicators that monitor *inter alia* seasonal weather characteristics, food prices and grain reserves to track poor rural communities' propensity to suffer from seasonal droughts (ECLAC 2003). Having a clear framework to methodically estimate post-disaster losses and assess sector impacts using empirical techniques is an important step to improve the knowledge base about key risks and vulnerabilities, in particular in poor countries that have little and often unreliable statistical information on disasters (the methodology for estimating the socio-economic an environmental effects of disasters originally developed by the Economic Commission for Latin American and the Caribbean is now widely used and adapted internationally; Hoeppe and Gurenko 2006).

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Box 1-4. Spatial Modeling

Spatial modeling provides an important tool for disaster risk management. Spatial risk modeling approaches can facilitate the development of disaster risk management action plans by helping to identify the level of disaster risk in different locations and to prioritize areas for disaster risk prevention, preparedness, reduction or mitigation. Spatial modeling can assess potential damages from disasters, locate potentially damaged infrastructure and emergency shelters, and design evacuation routes for emergency, to name a few. Spatial modeling can also effectively display changes in vulnerability to disaster over a specific area and time. Therefore, it can be effectively used for raising awareness. It can incorporate diverse thematic maps such as land use maps or topological maps with data regarding social, natural, and economic aspects, and consequently provide a comprehensive understanding of disasters.

Such spatial analysis reveals that the spatial and temporal pattern of vulnerability to disaster in the US during the past four decades,1960-2000, has changed (Cutter and Finch, 2008). A study on flood vulnerable areas of North Korea identified prioritized areas for disaster risk reduction (Myeong et al, 2008). A climate change vulnerability assessment of Southeast Asia (Arief and Francisco, 2009) provided information on areas most vulnerable to climate change, using maps of hazard, sensitivity, and adaptive capacity. With the spatial model of risk vulnerable areas shown in each of these case studies, it is possible to identify areas most vulnerable to a certain type of extreme events including those whose risk may increase due to climate change. Such a model would be useful to decision makers involved in setting development goals or targets.

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Also, many countries have taken legislative and institutional reform measure to address the joint challenge of adaptation and disaster management. In the Philippines, one of the most disaster-prone countries, the recently created Presidential Climate Change Commission coordinates climate policy across different sectors and in Mozambique, the government has strengthened its institutional coordination, communication systems and support to local communities after the devastating floods in 2000. Further, a key aspect of effective disaster risk mitigation is the active inclusion of local governments and a national risk management framework supportive of local action. Local government plays a key role in coordinating and sustaining a stakeholder process, engaging local citizens and communities in risk reduction, pilot-testing innovative tools for disaster risk, management of infrastructure, and the design and execution of development plans. Respectively, national risk management strategies need to be informed by practices and knowledge at the local level.

Poor countries are increasingly using risk management instruments to prepare themselves financially for extreme events and to be able to respond rapidly and effectively after disasters (World Bank, 2008) as the 16 Caribbean countries that pool their resources in a contingency fund to provide liquidity to maintain essential government services in the immediate aftermath of extreme hurricane or earthquake events reveal (Mahul amd Stutley 2010) Similarly, after several years of pilot-testing farmers in India now can purchase weather-index insurance, a simplified form of insurance based on observations, that provides rapid compensation during seasonal droughts. In both (and in many other similar) cases the private sector is an important partner to spread and diversify catastrophic risk domestically and internationally. These innovative projects provide important lessons for developing countries to access financial markets to more effectively manage disasters risk and develop their own insurance markets using simplified products that are adapted to a situation characterized by small and often poor households in the developing world, and a nascent private sector for financial services.

It is important to note, that while risk financing (insurance) has emerged as important climate risk management tool, it can only be effective and sustainable as part of a broader risk management framework that promotes systematic risk reduction and preparedness. An important concept is the layering of risk, whereby communities and households make arrangement to buffer against smaller losses, the private sector provides insurance products for insurable (i.e. not too frequent) losses, and the government makes provisions to prepare for catastrophic losses that exceed the capacity of households or private insurers (Mahul and Skees 2007). Such concepts of risk layers have for instance been put in practice in Mongolia to protect herders against livestock losses due extreme cold episodes(Convenient Solutions year?).

Management of natural systems is fundamentally important to risk management (World Resources Institute 2008) Coastal mangrove forests protect against storm surges partly by absorbing the flows and partly by keeping human settlements behind the mangroves farther from the sea. Similarly, forested catchments buffer water flows from moderate rains far better than non-forested catchments. Vegetated wetlands buffer water flows, but wetlands converted to agriculture or urban settlements and simplified drainage systems inevitably fail, resulting in flooding. Thus, a comprehensive response to flood management includes maintaining ecosystems services by managing vegetation cover in the catchment areas, managing wetlands and river channels, and siting infrastructure and planning urban expansion appropriately. Similarly, carefully managed production landscapes increase water storage and soil fertility and increase resilience to protracted periods of drought (World Bank 2009).

1.3.6.2. Issues Particular to Developing Countries

Developing countries are expected to experience the effects of climate change most severely (World Bank 2008) Most of the human losses (in absolute terms) and economic losses (in relative terms) due to extreme events are borne by developing countries today. Improving the management of extreme events and extreme impacts is often complicated by the lack of reliable and timely information on disaster risk, whilst the acute combination of increasing exposure and vulnerability associated in many instances with poverty increases enormously the complexities of risk reduction and risk prevention strategies and instruments.

Sparse and dated observations systems hamper the operation of risk monitoring, early warning, and post-disaster loss assessments. Many national hydro-meteorological services struggle to maintain a basic network of observational infrastructure as well as to develop services that translate basic data into information useful for decision-makers and planners (IRICS, 2006; Balk et al, 2008).

The synergic relations between disaster risk, poverty, mismanagement of natural resources, lack of land use planning, severe problems of governance in many countries and the challenge of climate change adaptation requires integral internvention schemes that belie the options and are compounded by the sectorialised views and actions of many government and international agencies (see ISDR, 2009 for a detailed revision and consideration of these aspects). The combination of encroachment in hazardous zones due to urban development (Balk, D.G, McGranahan and B. Anderson) lack of enforcement of building codes, and degradation of natural systems contribute to a relatively high degree of physical vulnerability in the developing world. The lack of service provision – access to financial services, water, education, communication – further amplifies the vulnerabilities of the poorest segments of society in particular.

Governments bear an implicit liability in relation to disasters and historically have acted as ‘insurer of last resort’ (Kunreuther and Michel-Kerjan, Linnerooth-Bayer and Mechler2006). Yet, many small economies have little capacity to absorb disaster losses (e.g. Grenada lost 200% of its GDP during hurricane Ivan), and even donor contributions generally fall short of covering the extent of disaster losses (OECS 2004; Melcher 2009). A challenge thus is to provide rapid and targeted financing to allow governments to re-establish government services and rebuild critical infrastructure to avoid longer-term economic losses. Similarly, insurance markets in developing countries are relatively thin and as of today provide little risk protection for households and businesses through the private sector.

1.4. Coping and Adapting

Coping and adapting are significant terms for disaster risk management and climate change adaptation in both scholarship and practice. From a historical perspective, coping came into favor in development work in the 1960s – at times closely associated with the notion of survival strategies amongst the poor and later, in the 70s, in response to famine conditions in Africa (**CITE- PELLING**)– and was taken up bydisaster risk management specialists from the ‘90s onwards in particular. In the first decade of the 21st century, for instance, the ISDR stated that disaster occurs in part because a community’s ability to cope has been exceeded. The disaster risk management community is currently divided, however, on the role of coping in both theory and practice.

Adaptation, in turn, has been a central term for the climate change adaptation community since the IPCC’s First Assessment Report (FAR) in 1990, and has been progressively incorporated into disaster risk management frameworks and terminology since the FAR was published. In recent years the climate change adaptation community, alongside their disaster risk management colleagues, has taken up the discussion of how coping and adaptation relate. Even more recently, both camps have struggled to integrate these terms with the notions of resilience and maladaptation in efforts to advance climate change adaptation theory and practice.

While the terms are used frequently, their meanings have not been rigorously discussed since Davies in 1993 (Davies 1993) and there is great “conceptual confusion” surrounding the two terms (Davies 1996). The terms are often co-mingled or used interchangeably such that their meanings are confused, and until recently there have been no definitive reviews of their relationship. In the last decade there have been some gestures toward a unifying approach in which coping experience can be seen as a means of strengthening, promoting, or advancing climate change adaptation, as attempted by a United Nations Framework Convention for Climate Change- UNFCCC- Delhi workshop in 2003 (UNFCCC 2003) and a more recent reflection on the terms and the utility of the two strategies (Schipper, et al. 2010). These efforts have uncovered both friction and synergy, however, and the issues remain unresolved. The debate is not merely semantic, as the conceptions of coping and adaptation have implications for programming and funding. Emphasis on coping, for instance, tends to cast efforts in terms of recovery and integration of loss, while emphasis on adaptation focuses on transformation.

The present discussion has two goals. First, it is an attempt to assess the definitions of these notions and discern between differing views by examining usage across time and disciplines. This explication is in service of distinguishing the two terms, identifying acceptable common ground, and identifying any mutually reinforcing relationships. Ultimately, it seems that a key distinction is whether a process is pre- or post-impact: both coping and resilience are primarily post-impact notions that reinforce recovery from a disaster, if incompletely. Adaptation is primarily pre-impact, anticipatory, and potentially transformative. Both are necessary to facilitate climate change adaptation, but as the hazard landscape is increasingly dynamic, and many extreme impacts are becoming more severe and less reliably predictable (see Chapter 3), adaptation is likely to be increasingly important. The process is fraught with pitfalls, however, that can result in maladaptation. This leads to the second goal of this section: to assess the notion of maladaptation and to reframe the notions of coping and adaptation as approaches to learning from experience. This vantage point deemphasizes the tension between coping and adapting and reframes the issue as one of maximizing learning, both to facilitate recovery in the short term and to promote appropriate transformations over longer time horizons.

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Box 1-5. Adaptation to Rising Levels of Risk

Before 1000 CE, 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, as the population of what is now the Netherlands rose to an estimated 300,000 people, the first dykes had begun to be constructed 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 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 lifetime; Gottschalk, 1971, 1975, 1977).

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), so 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 is considered a result of increased protection rather than any reduction in storminess. Since 1953 the flood risk has been reduced at least an equivalent step further.

_____ END BOX 1-5 HERE _____

1.4.1. Denotations and Connotations

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 disciplinary 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, 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, 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, are taxed (Wisner, Blaikie et al. 2004), whereas adapting suggests reorientation in response to change, often without specific reference to resource limitations.
- The second is entrenchment: in coping, survival is foremost and bounded by available knowledge, experience, and assets, and reinvention is a secondary concern (Bankoff 2004), while in adapting, creative flexibility is a necessity.
- The third is reactivity: coping is tactical, managerial, and used to protect basic welfare or survive when after an event has occurred (Adger 2000), while adapting is strategic, transformative, and focused on anticipating a situation or changing pattern and addressing the anticipated change proactively (Fussel 2007).
- 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 possibilities and incorporates past tactics to the extent that they facilitate adaptation to changing future conditions, though according to some the two can overlap and blend (Chen 1991).

Overall, in coping the focus is on the moment, constraint, and survival; in adapting, the future is the focus, learning and reinvention are key, and survival is less in question.

These common meanings have implications for the themes discussed in the remainder of this section. Principally, coping emphasizes survival or getting by post-event, "surviving but not thriving", and is by default more oriented toward the status quo. Schipper et al. point out that coping's goal is in fact to return to normal, if not necessarily optimal, function (Schipper et al. 2010). Adaptation, in contrast, is closer to the notion of development. Coping has been used in the disaster-related literature for decades and its meaning has changed over time, but it was originally developed and used when the field's focus was on reactive, response based *disaster or emergency management* (CITE). Since then, the disaster theme has evolved to focus much more on integral *disaster risk management* (see Section 1.1) and become more development oriented and adaptation focused (CITE). However, coping and related terms are still used in the disaster risk managment literature and have been integrated into the climate change adaptation literature as well, leading to a significant interpretation problem that is the subject of the next several subsections.

One possible hypothesis then regarding the current uses of the term coping is that its use has not kept pace with this evolution in disaster risk management, i.e. that there has been gradual drift from the word's original use and meaning as disaster risk management has moved ever further toward a holistic, proactive, transformative approach. This definitional drift now muddles the role and potential utility of coping strategies in the larger climate change adaptation effort, which is also focused on proactive interventions. Box 1-6 traces the evolution of coping, adaptation, and related terms and recasts their meaning in light of the current state of the disaster risk management and climate change adaptation fields to provide explication of their changing meaning over time as background to the current state of affairs discussed in the next section.

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Box 1-6. Coping Historically

General trends in usage of the term coping can be teased out, though there has been significant controversy among disaster risk management and climate change adaptation theorists and practitioners regarding coping's role. Following is a review of the evolution of the term coping in the specialist literature.

Origins in the Disaster Risk Management Literature

The dictionary definitions of coping and adapting are in play in the disaster risk management literature but there are some important definitional nuances. These evolved over time in response to two changes in the field. The first was the need to make disaster risk managment more bottom-up by including local and indigenous practices: "the application of indigenous knowledge in the face of hazards and other threats is referred to as 'coping mechanism' or 'coping strategy' . . . (and in some circumstances as a 'survival strategy')" (Twigg 2004). Twigg also noted the potential for coping to serve as a point of entry rather than an end unto itself. In this he highlighted the association between disasters and development first systematically discussed by Cuny in 1983 (Cuny 1983).

The second trend in disaster risk management that influenced the evolution of the term coping was its progressive reorientation toward proactive risk management with emphasis on disaster risk reduction as sustainable development (broadly construed to include socio-cultural development, political stability, economic growth, land use planning and ecosystem protections). Development and disaster risk management began their more formal integration in the late '80s when coping and adjustment mechanisms (technological, social, organizational, and cultural) were first discussed in 1992 (Clarke Guarnizo 1992). In this line of disciplinary discussion, the term coping became more elastic in comparison with dictionary definitions, particularly regarding orientation and reactivity. Specifically, coping's relation to a hazardous event was expanded to include both processes occurring *ex post* a hazardous event as well as in anticipation or *ex ante* during periods of relative normalcy, perhaps in order to retain its utility as a way to emphasize bottom up practice while also allowing for more of a development orientation.

These trends have prompted the question of where coping strategies sit in the disaster risk management cycle. As disaster risk managment has evolved, some practitioners have preferred to equate coping with the response phase (see Figure 1-3), while others have preferred to integrate the term into other phases to emphasize the importance of indigenous practices (UNISDR 2008; UNISDR 2008; UNISDR 2009).

[INSERT FIGURE 1-3 HERE
Figure 1-3: ______________________ (Keim, 2008).]

At the same time, others in the disaster risk management community criticized the use of coping capacity as a strategy. In particular, practitioners in the global South felt that coping, with its connotative emphasis on survival and on getting by, did not place enough emphasis on addressing structural problems and thereby avoiding the need to cope in the future (Davies 1993). The common theme between these schools, it would seem, is the need for a framework that allows for proactive, anticipatory action while recognizing the value of indigenous knowledge and practice where applicable, but also highlighting the importance of learning and deliberately transforming in response to changing conditions.

Coping in Early Climate Change Adaptation Literature

The climate change adaptation community inherited the confusion and tension associated with coping when it began to use the term (and the related "coping capacity") in its literature. For instance, Adger explored the possibility that migration could be considered either coping or adaptation (Adger 2000). Efforts to merge the terms from disaster risk management and climate change adaptation were rare, however, until a 2003 conference on coping and climate change adaptation sponsored by the UNFCCC where the topic was discussed explicitly. While not primarily a scholarly meeting, this conference was a noteworthy attempt to bring together different lines of theory and practice. Echoing disaster risk management's interest in building on local expertise, the conference participants emphasized the value of "local knowledge" that "embodies a wide variety of skills . . . closely linked to community survival and subsistence . . . blending many knowledge streams to solve local problems", and highlighted successful coping strategies including indigenous forecasting and early warning systems, flood and drought management, mutual support, livelihood switching, and evacuation and migration (UNFCCC 2003). Participants noted the limits of coping, as well, and the difference between "thriving versus surviving."

Participants also highlighted an important consequence of coping strategies, i.e. that coping as an ex-post activity often promotes deep debt and thus exacerbates vulnerability. This echoes others' work on the topic (Risbey, Kandlikar et al. 1999). They also distinguished coping from recovery whereby external resources are introduced to facilitate return to pre-disaster function, emphasizing that coping is only part of a larger risk management strategy. Finally, they noted pitfalls of relying on coping strategies to deal with climate change, as the lack of stationarity (Milly, Betancourt et al. 2008) may result in some events falling outside the "historical coping range." They recommended that the climate change adaptation field examine coping strategies for similarities across contexts (UNFCCC 2009) and further research on coping strategies with an emphasis on risk communication and evaluation. Ultimately, however, the participants concluded by emphasizing that development should serve as the primary climate change adaptation strategy: "Perhaps what should be done is to look at local communities that are facing climate-related risks, then address their development needs while incorporating climate change concerns into these interventions … This approach provides greater sustainability because it uses existing structures and community concerns" (UNFCCC 2003).

_____ END BOX 1-6 HERE _____

[INSERT FIGURE 1-4 HERE
Figure 1-4: Evolution of climate change adaptation and disaster risk management.]

1.4.2. Coping as Currently Construed

In more recent literature the terms coping, coping capacity, and coping range have been used in various ways. Comparing and contrasting recent usage in light of the dimensions noted above (exigency, entrenchment, reactivity, and past orientation) helps highlight continuing themes as well as substantial differences in the way the terms continue to be employed.

1.4.2.1. Recent Disaster Risk Management Literature

As noted above, there is ongoing debate in the disaster risk management community regarding the strategic value of coping. Nevertheless, the term and its variants continue to figure prominently in recent publications such as the 2008 ISDR *Indigenous Knowledge for Disaster Risk Reduction*, where coping mechanisms and strategies are prominent and divided into three categories: social (including institutions and other forms of social capital), functional (including building and land use practices), and sequential (including strategies to protect livelihoods such as dietary changes and migration) (UNISDR 2008). The ISDR emphasizes the importance of coping mechanisms as part of priority 3 of the Hyogo Framework for Action focusing on education and knowledge (UNISDR 2005), but acknowledges that coping mechanisms are primarily entertained under periods of significant stress and that effective disaster risk management also includes a strong emphasis on development (UNISDR 2008). Even in disaster risk management publications focused on development, however, coping mechanisms figure prominently and are framed in a relatively positive light, and poverty or lack of development are seen as undermining coping capacity.

Coping, per se, is not defined in the IPCC, UNFCCC, or ISDR glossaries, but the ISDR does define coping capacity. It's most recent (2009) glossary definition is:

> *The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters. The capacity to cope requires continuing awareness, resources*

and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Compared with earlier ISDR definitions of coping capacity, the 2009 definition places more explicit emphasis on management. It seems to situate coping as a post-event process, but also acknowledges the importance of "continuing awareness" during 'normal times as well as . . . crisis", suggesting that coping is an ongoing risk reduction strategy. These aspects of the definition help establish a bridge between coping and accepted processes of climate change adaptation and disaster risk management, including land use planning and livelihood security schemes, and harmonize the definition with current development practice focused on longer term adjustment, adaptation or risk reduction and control goals. Similar trends are apparent in definitions from other organizations, glossaries, and journal articles discussing the overlap between disaster risk managment and climate change adaptation(Schipper, Pelling et al. 2006; Thomalla, Downing et al. 2006; van Aalst 2006; see also Section 1.1.3.4 for the related discussion of the integrated view of the extreme and the every-day experiences).

1.4.2.2. Recent Climate Change Adaptation Literature

While coping has been peppered throughout climate change adaptation literature since the FAR through the AR4, the term is not nearly as prominent as adaptation. For instance, in AR4 Chapter 17 on adaptation mechanisms and processes, coping is only briefly referred to twice in the written text and a very limited number of times in the quoted references. In more recent papers on climate change adaptation, coping appears somewhat more frequently, but more commonly coping capacity and related terms such as coping range are used, and then almost always in conjunction with adaptive capacity. Kelly and Adger examined the terms in a 2000 paper on vulnerability and adaptation (Kelly and Adger 2000) and Saldana-Zorrilla recently offered explicit definitions (referring to Kelly and Adger's work), defining coping capacity as "the ability of a unit to respond to an occurrence of harm and to avoid its potential negative effects," and adaptive capacity as "the ability of a unit to gradually transform its structure, functioning or organization to survive under hazards threatening its existence" (Saldana-Zorilla 2008). Here the meanings of the two terms are closer to their common meanings, though the dimension of exigency has been extended to adaptation as well as coping, underlining the severity of the climate change threat.

In a recent contribution, Schipper et al. parse the meanings of both coping and adapting, concluding that the central distinction between coping and adaptation is that "coping actions do not imply any adjustment to new conditions" and that "coping strategies are more about avoiding facing risk or change than about adjusting to its presence" (Schipper et al.2010). They conclude that coping strategies may have a place in longer term adaptation efforts, primarily to ensure survival by "helping avoid that a hazard turns into a disaster." To help clarify the difference between coping and adapting, they propose an analytical tool composed of a series of questions related to the intervention. The parameters of their tool roughly parallel the dimensions discussed at the beginning of this section (exigency, entrenchment, reactivity, and orientation), focusing on whether the intervention is primarily short term, resource intensive, a part of normal activities, and whether it is abandoned when normal activities resume. The tool also assesses the degree to which the intervention reduces the exposure to a hazard or a population's sensitivity to it, whether the intervention has worked well in the past, and whether it is focused on improving well-being in the long term (Schipper et al. 2010). Overall, their piece is a significant step toward systematic, methodical distinction between the two terms, though their approach is primarily descriptive and does not resolve the question of how the notion of coping should be used in disaster risk management and claimate change activities.

Despite increasing clarity regarding the term coping, dangling threads remain, particularly in relation to certain related terms that have acquired their own disciplinary meanings in recent years, such as the term "coping range." Neither the UNFCCC, the IPCC, nor the ISDR has defined the term explicitly, though by inference in the 2003 UNFCCC conference proceedings, coping range appears to have been defined as the historical context within which a particular coping mechanism had been effective at maintaining essential functions during periods of severe stress. Others, particularly Yohe and Tol, have a different perspective. They assert that coping range is "a range of circumstances within which, by virtue of the underlying resilience of the system, significant consequences [of change and variability in a system] are not observed"; they also characterize the coping range by its boundaries, i.e. the "thresholds beyond which the consequences of experienced conditions become significant" (Yohe and Tol

2002). Importantly, they deemphasize both entrenchment and past orientation by asserting that coping ranges are not static and can shift over time. They develop a formula through which adaptation supports coping capacity, maintains or extends coping range, and thus enables maintenance of a system's essential function (resilience). In this framework there is no discussion of thriving versus surviving and the dimensions of exigency and entrenchment appear to have been minimized if not eliminated entirely. Moreover, differently than others' aproaches, for Yohe and Tol adaptation supports coping and thereby "advances" disaster risk management strategies.

Yohe and Tol's definition of coping range refers to resilience, as do the ISDR definitions cited above. Effort to parse the definitions further quickly becomes cyclical, however, as the following ISDR definition of resilience illustrates:

> *… the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures. (UNISDR 2009)*

1.4.2.3. Summary

Coping and adapting and associated terms such as coping capacity, coping range, and adaptive capacity are used relatively frequently and often interchangeably in both the disaster risk management and climate change adaptation literature. Coping in the disaster risk management literature appears to have derived from an interest in understanding responses to disasters particularly amongst poorer populations, where little real alternative is seen for real risk reduction and development, and for bolstering bottom-up practice, and has increasingly been comingled with adaptation as disaster risk management practice has become more development oriented. Climate change adaptation has emphasized coping as a means of survival, but has not clearly distinguished coping mechanisms from other adaptation strategies or clarified the relationship between the two. The terms' meanings have evolved somewhat in recent years, but there have been no exhaustive efforts to disentangle their meanings.

That said, certain themes are relatively stable, particularly if coping is considered to be post-event (at least primarily): First, coping capacity and resilience are primarily concerned with the ability of a system to remain intact and maintain (or soon resume) normal function in the face of extreme stress. Normal function, it should be said, is not necessarily optimal function but merely connotes status quo prior to a disastrous event. Neither coping nor resilience necessarily transmit the idea of progress or getting out of the status quo, but instead both are primarily focused on returning to normalcy. Second, coping mechanisms are of greatest utility during the response phase of the disaster risk management cycle, and the processes of recovery, prevention, mitigation, and preparedness are not contained in coping capacity. The relationship between coping capacity and resilience has been characterized variably by different authors and remains unclear. Third, in contrast to coping, it seems most authors consider adaptation to be longer-term, more future oriented, and transformative. Overall, in the literature adaptation has a complex relationship with coping depending on whether coping is considered to be solely *ex* or both *ex* and *post ante*.

1.4.3. Adaptive and Maladaptive Risk Management and Insurance

The relationship between coping, adaptation, and the types of strategies that are truly adaptive under different climate change scenarios is garnering increasing attention (Lorenzoni, Pidgeon et al. 2005). There is concern that relying on certain coping strategiesmay not contribute substantially to adaptation over time and may undermine adaptive capacity given that coping often depletes resource stores. Adaptive decisions are those in which strategies are properly matched with changing risk distributions over a specified period of time and those that do not protect one population at the expense of another. Conversely, maladaptation occurs when risks and management strategies for a given period are not well matched, when a strategy increases other risks and ultimately undermines its own effect, when adaptation strategies shift unacceptable levels of risk onto other populations, or when cost-benefit horizons are too narrowly construed or short-sighted leading to bad risk management decisions. Many maladaptive strategies are also unsustainable, given the resource intensity of certain coping strategies and the depletion of capital and other stores (Risbey, Kandlikar et al. 1999). Most if not all types of maladaptation result from 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. As such, maladaptation can be construed as incomplete awareness and appreciation of system complexity in the risk management process.

1.4.3.1. Types of Maladaptation

There are several types of maladaptation, each correlated with a particular wrinkle in the interface between complex systems and risk management decisions. 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). Each of these problems results in a different type of maladaptation. Complexity, such as the difficulty in providing downscaled climate projections, limits knowledge of risk in risk management, so that some risks are increased by incomplete understanding of the hazard universe (or the universe of relevant risk management strategies). Also related to this is the issue of narrow disciplinary focus and short term perspectives, both of which can undermine proper calibration of risk management decisions.

Complexity that limits learning from evidence, often the result of heuristics or mental models that lead to "systematically erroneous but strongly self-confirming inferences" (Sterman 2006; also see Section 1.3.2.2), complicate policy action, even among experts. This has been observed in regards to flows of greenhouse gases into atmospheric stocks, which can drive misunderstanding of the costs and benefits of a "wait and see" approach to mitigation (Sterman 2008). This dynamic is also associated with the difficulty of weighing different levels of risk, some of which are more immediate but not catastrophic, 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. This suspicion can lead to paralysis and failure to engage in appropriate risk management strategies despite the availability of compelling evidence. An example of this is the resistance to immunization policy recommendations, particularly regarding measles-mumps-rubella vaccination, which has been repeatedly correlated with disease outbreaks in communities with lower vaccination rates (Jansen, Stollenwerk et al. 2003). Altogether, those who have studied system dynamics term these maladaptive influences "policy resistance" and cite abundant examples, from the paradoxical increase in traffic often seen when roads are built or expanded (Sterman 2000) to the increase in forest fires seen with forest fire suppression (USDA Forest Service 2003).

Each source of maladaptation or policy resistance – complications with evidence generation, evidence interpretation, and evidence application – is relevant to the present discussion. The world's climate is an exceedingly complex system with multiple feedbacks that are difficult to study and model. Attribution of observed climate changes to warming is challenging (see Chapter 3). This complicates generation of evidence relating climate change with its impacts, from injuries to property loss, and thus constrains identification of appropriate management strategies.

The World Health Organization's estimate of the global burden of disease attributable to climate change is an example: as a result of methodological limitations in our ability to project extreme exposures and to confidently link certain climatic exposures with health outcomes, it focuses on only five major health outcomes (cardiovascular conditions exacerbated by increasing average temperatures, injuries and death associated with floods, illness and death from malaria, morbidity and mortality from diarrheal disease, and health impacts associated with malnutrition including disability and death). Given difficulties in modeling and projecting extreme event exposure, the study is limited to only a handful of important climate-health associations and does not evaluate others, e.g. excess mortality from severe heat waves, focusing instead only on health impacts of increases in temperature averages (McMichael 2004).

Finally, conflicting perceptions and messages related to climate change impacts and distrust of expert opinion and consensus findings related to climate change adaptation (Schrope 2001) complicate development and diffusion of a unified climate change risk management platform (see Section 1.3.2.2). The need to integrate indigenous coping mechanisms with conventional risk management strategies serves as another instance of this last complication. For example, modern early warning systems may fail if they do not integrate traditional mental models tied to indigenous coping mechanisms. This was the case in one unnamed country where local communities would not heed conventionally generated flood forecasts, instead waiting for their usual signal of flooding (UNFCCC 2003).

It should be noted that these sources of policy resistance do not map directly to specific categories of risk mismanagement, e.g. of inappropriate risk retention when risk might better be shared, reduction of risks that might be avoided, etc. Neither do they directly map to other common problems such as risk displacement, wherein adoption of a risk management strategy results in behaviors that increase overall risk exposure, or risk shifting, a related concern wherein risk management decisions reduce risk within one domain but increase risk outside of it. These types of mismanagement arise in many instances from centralization of power and lack of transparency in decision making, particularly in the case of risk shifting where international regulations are weak. The international trade in toxic waste, while not related to climate change, provides an excellent example of risk shifting and political failure in risk management secondary to global power differentials (Menkes 1998; Schmidt 1999; Hess and Frumkin 2000; Orloff, Falk et al. 2003).

1.4.3.2. Risk Amplification

Mismanagement 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. The worldwide recession of 2008-2009 is an example from the financial sector, which had complex origins (Caballero, Farhi et al. 2008), including that risk managers (financial regulators in this case) failed to adequately enforce regulations relevant to a wide range of financial products designed to hedge against investment risks (Congleton 2009). Because risks were neither properly priced into financial transactions nor retained by the institutions that were making risky transactions, moral hazard occurred at multiple levels and losses were distributed widely over the public sector while gains had been distributed much more narrowly to private interests (Brill 2009; Okamoto 2009). Regulators are still struggling to find ways to reduce moral hazard and prevent similar risks from undermining the financial system in the future (Morgenson 2010). This instance illustrates the impact of maladaptive risk sharing and demonstrates the importance of 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).

Risk management decisions related to catastrophic events often pivot on thresholds: strategies that were conceived under one set of threshold assumptions can become maladaptive under another (Niemeyer, Petts et al. 2005). For example, levees protecting established communities in flood prone areas may be adaptive for anticipated floods of a certain magnitude, but maladaptive when the maximum projected flood height for a given period shifts. In such an instance, the 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 feels safe but in fact is not. 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). This is the case in coastal development, wherein property insurance for beachfront properties is effectively subsidized by inland residents, as discussed further below.

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 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)

Identifying "no regrets" adaptation policies in response to climate change can, as a result, become a dizzyingly complex exercise in comparative risk assessment involving many assumptions that complicate the policy making process and introduce substantial potential for policy resistance. Certain approaches such as social risk management have been advanced as useful lenses to facilitate no-regrets adaptation (Heltberg, Siegel et al. 2009), though the potential for several types of policy resistance remains even with many types of intentional adaptation planning (Urwin and Jordan 2008).

1.4.3.3. Mal-Adaptation and Insurance

In many countries a principal justification for catastrophe insurance is to provide social 'solidarity' or risk sharing without adequate consideration of the underlying risk differentials. A classic example of this is the French Cat Nat system (de Marcellis-Warn and Michel Kerjan, 2001), where all property insured pays an additional fixed percentage to support a central State Backed Reinsurer fund. The fund pays out for claims when a Cat Nat event is announced (by ministerial decree) in a municipality. One progressive feature of the system is that the deductible is raised after a claim has been made so that a claimant will have to pay progressively greater proportions of each subsequent loss. However, by virtue of the fact that any new property will be covered under a flat rate arrangement, the system effectively subsidizes further development in risky locations such as river flood plains, another example of moral hazard discussed above (see Section 1.3.3).

Inadvertent risk subsidies are also facilitated in regulated insurance systems in which the rating resolution is too coarse to adequately account for the underlying gradients of risk, as for example in Florida (Grace and Klein, 2007, Klein, 2007, Grace and Klein, 2009). The greatest beneficiaries of insurance rates averaged over larger areas are those with beach front properties, which tend, for the acknowledged amenity value, not only to have the highest risk but also to be the most expensive.

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). As mechanisms to incentivize adaptation become even more important in places where levels of risk are rising, climate change may prompt reconsideration of structures and policies that promote maladaptive risk management processes.

1.4.4. Learning, Coping, and Climate Change Adaptation

Pursuing a "no regrets" approach to climate change adaptation and development can be remarkably complex. Similar to *"primum non nocere"* ("first do no harm") in medicine, "no regrets" serves as a first principle but in fact provides little guidance for generating, interpreting, and applying evidence in service of enlightened policy, particularly in the dynamically complex context of climate change and development. In practice, identifying and implementing "no regrets" strategies requires an enhanced approach to managing complexity, particularly regarding feedback mechanisms, learning promotion, and evidence interpretation as noted in 1.4.4.1 above. The new methods for developing robust uncertainty management strategies noted in 1.3.4.1 are beginning to address some of these challenges (Lempert 2002).

Of particular relevance to the topic of coping and adapting is the distinction between different types of learning, including single-loop and double-loop learning processes (see Figure 1-5; Argyris and Schon, 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. 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. 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 are changed in response to evidence that these deep social structures are not serving a larger agreed upon goal. Extending the example still further, triple loop learning could, for example, 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 human-powered forms of transit.

[INSERT FIGURE 1-5 HERE
Figure 1-5: __________________________ (Sterman, 2006).]

There are clear parallels with coping, adaptation, and what some have termed transformation (Kysar 2004). Single-loop learning, like coping, tends to be reflexive, survival oriented, and occurs over a relatively brief period of time. Double-loop learning, like adaptation, tends to be anticipatory, future-oriented, and most effective (in a dynamic context) when the process is reiterated repeatedly over time. In some instances, triple-loop learning may lead to a more transformative change wherein social structures, institutions, and constructions that contain and mediate risk are recast 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. While they do not refer to learning loops or to transformation, these processes are operative in shifting coping range according to their analysis. Extending their analysis, over time, as iterative adaptation shifts the coping range, societies may come to inhabit a categorically distinct sustainability basin as a result of third-loop learning.

Focusing on learning and the role of coping and adaptation in the learning process suggests that there may yet be room for a productive association between the two that can facilitate climate change adaptation. In particular, to the extent that coping mechanisms can be catalogued along with the contexts in which they are most applicable, they may inform climate change adaptation activities by enabling survival in the face of extreme stress and allowing for a return to relatively normal function, wherein more aspirational, development oriented processes would prevail. Understanding historical coping mechanisms can also provide fundamental insight into how societies perceive and act on risk, i.e. how they filter the complexity associated with risk assessment and risk management. Such insight is a key component of the process of learning to manage dynamic complexity, which is at the heart of climate change adaptation.

1.5. Structure of this Report

This report is organized into three major sections. 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 section 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, a chapter on case studies focuses on experience gained from specific instances of extreme impact and disaster.

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 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 expected changes in the frequency and intensity of heat waves, tropical storms, El Nino, monsoons, etc, based on literature assessed by WGI during AR4, and revises this assessment based on literature published subsequently. 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 impacts 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 ask a common set of questions: What is the appropriate distribution or allocation of responsibility for the management of the risks from climate extremes and disasters? Is the present allocation of tasks and responsibilities at the local, national, and international levels satisfactory or are there options that might facilitate improved performance? Who does and who could shoulder which activities and which roles? At the same time, the discussions recognize the importance of other levels of government (e.g., village, community) as well as individual, non-governmental, private sector, and other civil society institutions and arrangements. These three chapters explore these questions from 7 perspectives: subsidiarity, the social contract, systematic risks, economic efficiency, legal obligations, development as disaster reduction, and harmonization.

Chapter 5, focusing 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, and practices which characterize international agencies and cooperative arrangements. This chapter also discusses integration of responsibilities across all governmental scales.

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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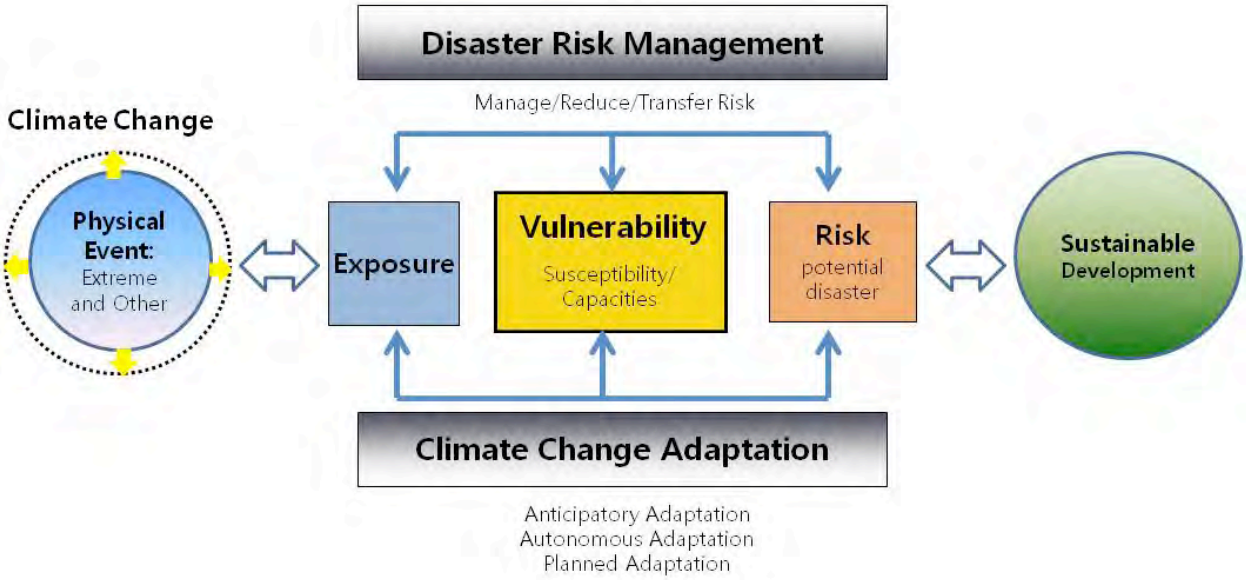


Figure 1-1: The key concepts and scope of this report.

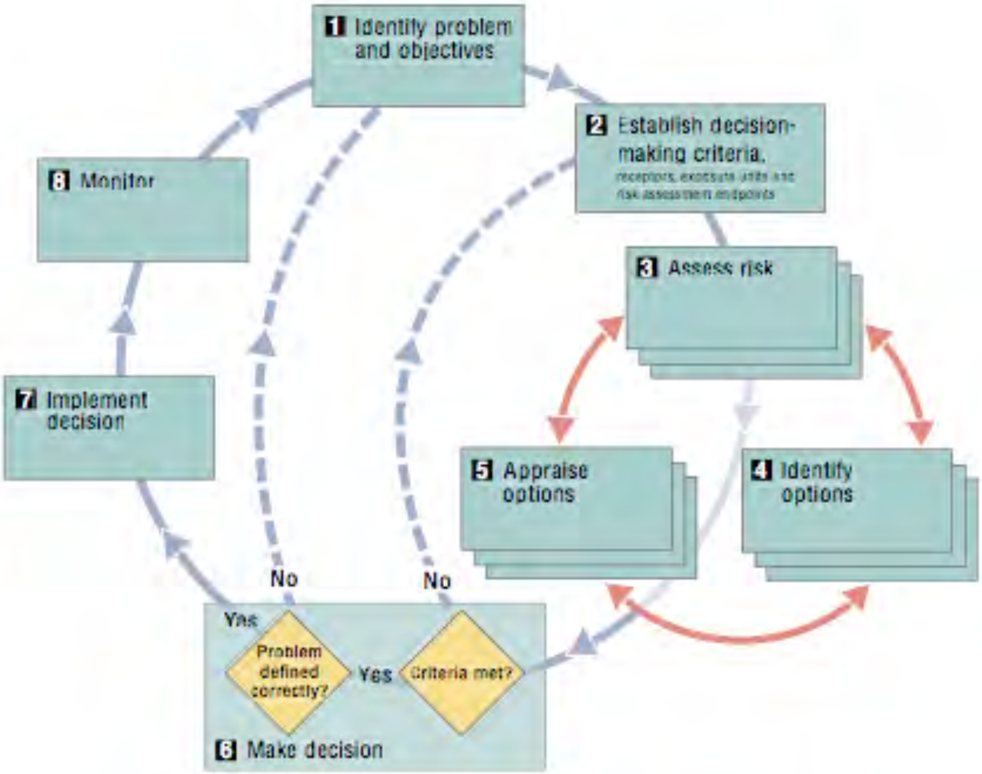


Figure 1-2: One example of an iterative risk management approach, developed and widely applied by the UK Climate Impacts Program (Willows and Connell 2003).

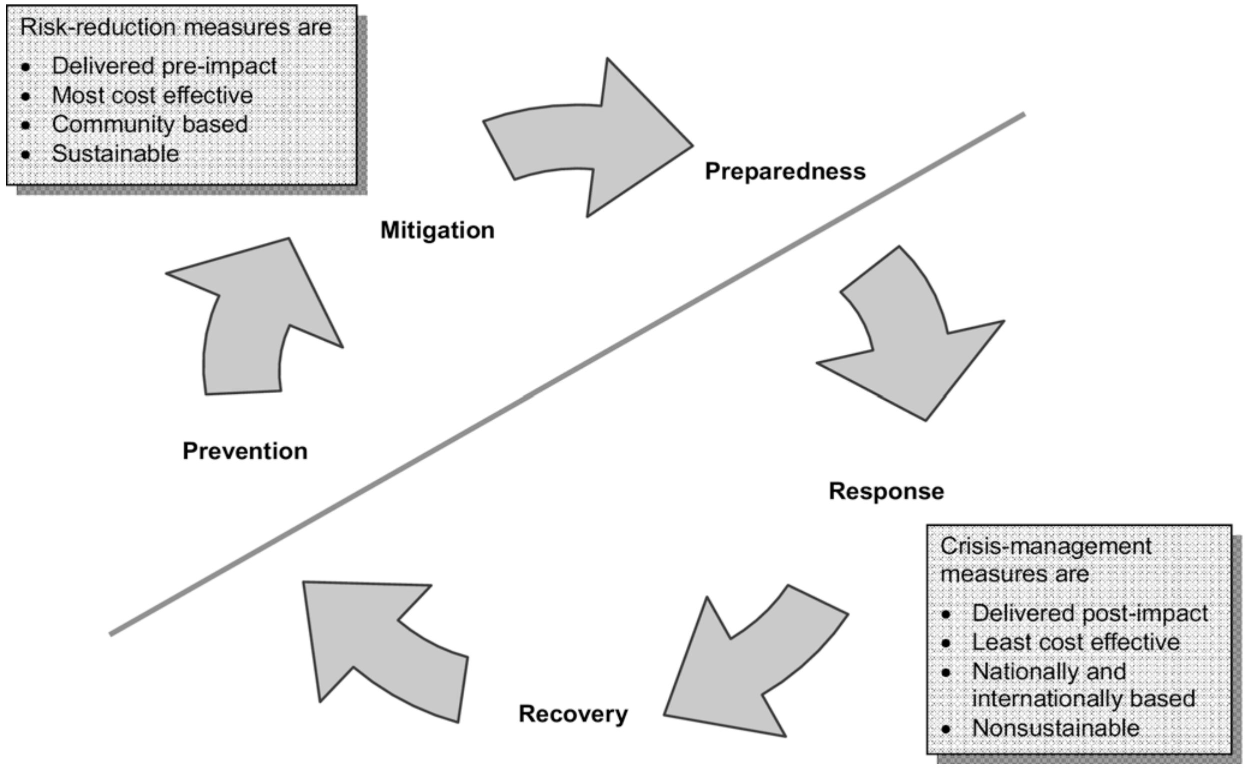
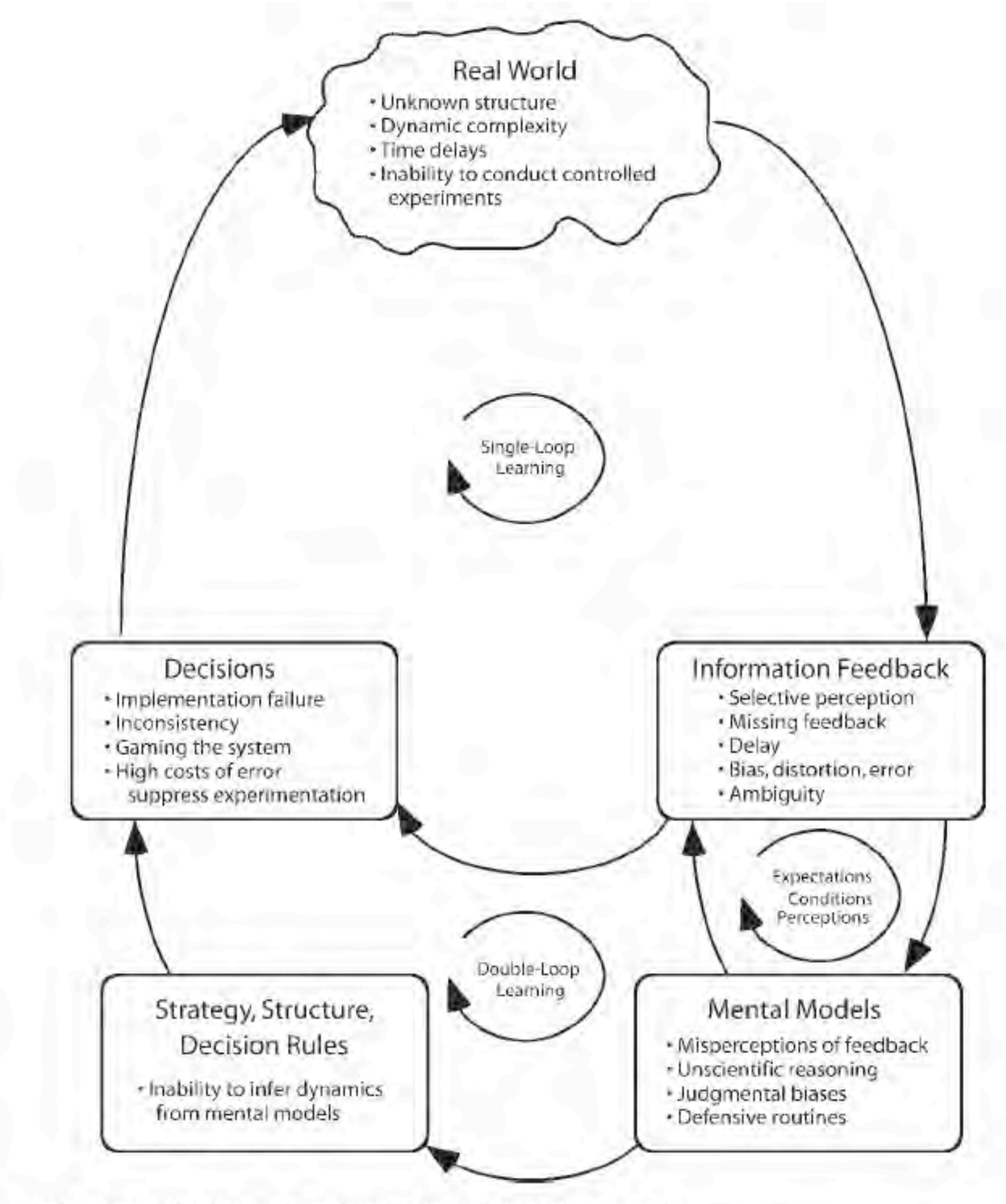


Figure 1-3: ______________________ (Keim, 2008).

Figure 1-4 Evolution of climate change adaptation and disaster risk management.

PLACEHOLDER: Figure will be a timeline of disaster risk management and climate change adaptation that illustrates significant dates for both disciplines / communities and highlights recent overlapping activities, conferences, and significant dates in the development of shared principles and practice.



Note. The diagram shows the main impediments to learning. Arrows indicate causation.

Figure 1-5: ________________________ (Sterman, 2006).