6

National Systems for Managing the Risks from Climate Extremes and Disasters

Coordinating Lead Authors:
Padma Narsey Lal (Australia), Tom Mitchell (UK)

Lead Authors:
Paulina Aldunce (Chile), Heather Auld (Canada), Reinhard Mechler (Germany), Alimullah Miyan (Bangladesh), Luis Ernesto Romano (El Salvador), Salmah Zakaria (Malaysia)

Review Editors:
Andrew Dlugolecki (UK), Takuo Masumoto (Japan)

Contributing Authors:
Neville Ash (Switzerland), Stefan Hochrainer (Austria), Robert Hodgson (UK), Tarik ul Islam (Canada), Sabrina McCormick (USA), Carolina Neri (Mexico), Roger Pulwarty (USA), Ataur Rahman (Bangladesh), Ben Ramalingam (UK), Karen Sudmeier-Reiux (France), Emma Tompkins (UK), John Twigg (UK), Robert Wilby (UK)

This chapter should be cited as:

Lal, P.N., T. Mitchell, P. Aldunce, H. Auld, R. Mechler, A. Miyan, L.E. Romano, and S. Zakaria, 2012: National systems for managing the risks from climate extremes and disasters. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 339-392.

Table of Contents

Executive Summary

This chapter assesses how countries are managing current and projected disaster risks, given knowledge of how risks are changing with observations and projections of weather and climate extremes [Table 3-2, 3.3], vulnerability and exposure [4.3], and impacts [4.4]. It focuses on the design of national systems for managing such risks, the roles played by actors involved in the system, and the functions they perform, acknowledging that complementary actions to manage risks are also taken at local and international level as described in Chapters 5 and 7.

National systems are at the core of countries' capacity to meet the challenges of observed and projected trends in exposure, vulnerability, and weather and climate extremes (*high agreement, robust evidence*). Effective national systems comprise multiple actors from national and sub-national governments, private sector, research bodies, and civil society, including community-based organizations, playing differential but complementary roles to manage risk according to their accepted functions and capacities. These actors work in partnership across temporal, spatial, administrative, and social scales, supported by relevant scientific and traditional knowledge. Specific characteristics of national systems vary between countries and across scales depending on their socio-cultural, political, and administrative environments and development status. [6.2]

The national level plays a key role in governing and managing disaster risks because national government is central to providing risk management-related public goods as it commonly maintains financial and organizational authority in planning and implementing these goods (*high agreement, robust evidence*). National governments are charged with the provision of public goods such as ensuring the economic and social well-being, safety, and security of their citizens from disasters, including the protection of the poorest and most vulnerable citizens. They also control budgetary allocations as well as creating legislative frameworks to guide actions by other actors. Often, national governments are considered to be the 'insurer of last resort'. In line with the delivery of public goods, national governments and public authorities 'own' a large part of current and future disaster risks (public infrastructure, public assets, and relief spending). In terms of managing risk, national governments act as risk aggregators and by pooling risk, hold a large portfolio of public liabilities. This provides governments responsibility to accurately quantify and manage risks associated with this portfolio – functions that are expected to become more important given projected impacts of climate change and trends in vulnerability and exposure. [6.2.1]

In providing such public goods, governments choose to manage disaster risk by enabling national systems to guide and support stakeholders to reduce risk where possible, transfer risk where feasible, and manage residual risk, recognizing that risks can never be totally eliminated *(high agreement, robust evidence).* The balance between reducing risk and other disaster risk management strategies is influenced by a range of factors, including financial and technical capacity of stakeholders, robustness of risk assessment information, and cultural elements involving risk tolerance. [6.2.1, 6.2-6.5]

The ability of governments to implement disaster risk management responsibilities differs significantly across countries, depending on their capacity and resource constraints *(high agreement, robust evidence*). Smaller or economically less-diversified countries face particular challenges in providing the public goods associated with disaster risk management, in absorbing the losses caused by climate extremes and disasters, and in providing relief and reconstruction assistance. [6.4.3] However, there is *limited evidence* to suggest any correlation between the type of governance system in a country (e.g., centralized or decentralized; unitary or federal) and the effectiveness of disaster risk management efforts. There is *robust evidence* and *high agreement* to suggest that actions generated within and managed by communities with supporting government policies are generally most effective since they are specific and tailored to local environments. [6.4.2]

In the majority of countries, national systems have been strengthened by applying the principles of the Hyogo Framework for Action to mainstream risk considerations across society and sectors, although greater efforts are required to address the underlying drivers of risk and generate the political will to invest in disaster risk reduction *(high agreement, robust evidence).* The Hyogo Framework for Action has encouraged countries to develop and implement a systematic disaster risk management approach, and in some cases has led to strategic shifts in the management of disaster risks, with governments and other actors placing greater attention on disaster risk reduction compared to more reactive measures. This has included improvements in coordination between actors, enhanced early warning and preparedness, more rigorous risk assessments, and increased awareness. However, there is *limited evidence* and *low agreement* to suggest improvements in integration between efforts to implement the Hyogo Framework for Action, the United Nations Framework Convention on Climate Change, and broader development and environmental policy frameworks. [6.4.2]

A set of factors can be identified that make efforts to systematically manage current disaster risks more successful (all *high agreement, robust evidence*). Systems to manage current disaster risk are more successful if:

- Risks are recognized as dynamic and are mainstreamed and integrated into development policies, strategies, and actions, and into environmental management. [6.3.1]
- Legislation for managing disaster risks is supported by clear regulations that are effectively enforced across scales and complemented by other sectoral development and management legislations where risk considerations are explicitly integrated. [6.4.1]
- Disaster risk management functions are coordinated across sectors and scales and led by organizations at the highest political level. [6.4.2]
- They include considerations of disaster risk in national development and sector plans, and, if they adopt climate change adaptation strategies, translating these plans and strategies into actions targeting vulnerable areas and groups. [6.5.2]
- Risk is quantified and factored into national budgetary processes, and a range of measures including budgeting for relief expenditure, reserve funds, and other forms of risk financing have been considered or implemented. [6.4.3]
- Decisions are informed by comprehensive information about observed changes in weather, climate, and vulnerability and exposure, and historic disaster losses, using a diversity of readily available tools and guidelines. [6.5.1]
- Early warning systems deliver timely, relevant, and accurate predictions of hazards, and are developed and made operational in partnership with the public and trigger effective response actions. [6.5.1]
- Strategies include a combination of hard infrastructure-based options responses and soft solutions such as individual and institutional capacity building and ecosystem-based responses, including conservation measures associated with, for example, forestry, river catchments, coastal wetlands, and biodiversity. [6.5.2]

While there is robust evidence and high agreement on efforts to tackle current disaster risks, the assessment found *limited evidence* of national disaster risk management systems and associated risk management measures explicitly integrating knowledge of and uncertainties in projected changes in exposure, vulnerability, and climate extremes. The effectiveness of efforts to manage projected disaster risks at the national level are dependent on a range of factors, including the effectiveness of the system for managing current risks, the ability of the system to flexibly respond to new knowledge, the availability of suitable data, and the resources available to invest in longer-term risk reduction and adaptation measures. Developed countries are better equipped financially and institutionally to adopt explicit measures to effectively respond and adapt to projected changes in exposure, vulnerability, and climate extremes than developing countries. Nonetheless, all countries face challenges in assessing, understanding, and then responding to such projected changes. [6.3.2, 6.6]

Measures that provide benefits under current climate and a range of future climate change scenarios, called low-regrets measures, are available starting points for addressing projected trends in exposure, vulnerability, and climate extremes. They have the potential to offer benefits now and lay the foundation for addressing projected changes (*high agreement, medium evidence*). The assessment considered such 'low' regrets options across a range of key sectors, with some of the most commonly cited measures associated with improvements to early warning systems, health surveillance, water supply, sanitation, and drainage systems; climate proofing of major infrastructure and enforcement of building codes; better education and awareness; and restoration of degraded ecosystems and nature conservation. Many of these low-regrets strategies produce co-benefits; help address other development goals, such as improvements in livelihoods, human well-being, and biodiversity conservation; and help minimize the scope for maladaptation. [6.3.1, Table 6-1]

Ecosystem-based solutions in the context of changing climate risks can offer 'triple-win' solutions, as they can provide cost-effective risk reduction, support biodiversity conservation, and enable improvements in economic livelihoods and human well-being, particularly for the poor and vulnerable *(high agreement, robust evidence)*. The assessment found that such ecosystem-based adaptation strategies, including mangrove conservation and rehabilitation, integrated catchment management, and sustainable forest and fisheries management, also minimize the scope for maladaptation in developed and developing countries. In choosing amongst ecosystem-based adaptation options, decisionmakers may need to make tradeoffs between particular climate risk reduction strategies and other valued ecosystem services. [6.5.2]

Insurance-related instruments are key mechanisms for helping households, business, and governments absorb the losses from disasters; but their uptake is unequally distributed across regions and hazards, and often public-private partnerships are required (*high agreement, robust evidence*). Disaster insurance and other risk transfer instruments covered about 20% of reported weather-related losses over the period 1980 to 2003. Distribution, though, is uneven, with about 40% of the losses insured in high-income as compared to 4% of losses in low-income countries. Existing national insurance systems differ widely as to whether policies are compulsory or voluntary, and importantly in how systems allocate liability and responsibility for disaster risks across society. With changing weather and extreme events, vulnerability, and exposure, extended and innovative private-public sector partnerships are required to better estimate and price risk as well as to develop robust insurance-related products, which may be supported in developing countries by development partner funds. [6.5.3]

Pooling of risk by and between national governments contributes to reducing the fiscal and socioeconomic consequences of disasters (*medium agreement, medium evidence*). As national governments hold a large portfolio of public liabilities (infrastructure, public assets, and the provision of disaster relief), risk aggregation and pooling are expected to become more important given projected impacts of climate change and trends in vulnerability and exposure. In addition, particularly for small, low-income, and highly exposed countries, risk transfer of public sector assets and relief expenditure recently have become a cornerstone of disaster risk reduction. Key innovative and promising applications recently implemented comprise sovereign insurance for hurricane risk, insurance for humanitarian assistance following droughts, and intergovernmental risk pooling. [6.4.3, 6.5.3]

Flexible and adaptive national systems are better suited to manage projected trends and associated uncertainties in exposure, vulnerability, and weather and climate extremes than static and rigid national systems (*high agreement, limited evidence*). Adaptive management brings together different scientific, social, and economic information, experiences, and traditional knowledge into decisionmaking through 'learning by doing.' Multi-criteria analysis, scenario planning, and flexible decision paths offer options for taking action when faced with large uncertainties or incomplete information. National systems for managing disaster risk can adapt to climate change and shifting exposure and vulnerability by (i) frequently assessing and mainstreaming knowledge of dynamic risks; (ii) adopting 'low regrets' strategies; (iii) improving learning and feedback across disaster, climate, and development organizations at all scales; (iv) addressing the root causes of poverty and vulnerability; (v) screening investments for climate change-related impacts and risks to minimize scope for maladaptation; and (vi) increasing standing capacity for emergency response as climatic conditions change over time. [6.6.1, 6.6.2, 6.6.4]

6.1. Introduction

The socioeconomic impacts of disaster events can be significant in all countries, but low- and middle-income countries are especially vulnerable, and experience higher fatalities even when exposed to hazards of similar magnitude (O'Brien et al., 2006; Thomalla et al., 2006; Ibarraran et al., 2009; IFRC, 2010). The number of deaths per cyclone event in the last several decades, for example, was highest in low-income countries even though a higher proportion of population exposed to cyclones lives in countries with higher income; 11% of the people exposed to hazards live in low human development countries, but they account for more than 53% of the total recorded deaths resulting from disasters (UNDP, 2004a). At the same time, while in absolute terms the direct economic losses from disasters are far greater in high-income countries, middle- and low-income states bear the heaviest burden of these costs in terms of damage relative to annual gross domestic product (GDP: UNDP, 2004a; DFID, 2005; O'Brien et al., 2006; Kellenberg et al., 2008; Pelham et al., 2011). This burden has been increasing in the middle-income countries, where the asset base is rapidly expanding and losses over the period from 2001 to 2006 amounted to about 1% of GDP. For the low-income group, losses totaled an average of 0.3% and for the high-income countries amounted to less than 0.1% of GDP (Cummins and Mahul, 2009). In some particularly exposed countries, including many small island developing states, these wealth losses expressed as a percentage of GDP can be considerably higher, with the average costs over disaster and non-disaster years close to 10%, such as reported for Grenada and St. Lucia (World Bank and UN, 2010). In extreme cases, the costs of individual events can be as high as 200% of the annual GDP as experienced in the Polynesian island nation of Niue following cyclone Heta in 2004, or in the Hurricane Ivan event affecting Grenada in 2004 (McKenzie et al., 2005).

In terms of the macroeconomic and developmental consequences of high exposure to disaster risk, a growing body of literature has shown significant adverse effects in developing countries (Otero and Marti, 1995; Charveriat, 2000; Crowards, 2000; Murlidharan and Shah, 2001; ECLAC, 2002, 2003; Mechler, 2004; Hochrainer, 2006; Noy, 2009). These include reduced direct and indirect tax revenue, dampened investment, and reduced long-term economic growth through their negative effect on a country's credit rating and an increase in interest rates for external borrowing. Among the reasons behind limited coping capacity of individuals, communities, and governments are reduced tax bases and high levels of indebtedness, combined with limited household income and savings, a lack of disaster risk transfer and other financing instruments, few capital assets, and limited social insurance.

This body of evidence emphasizes that disasters can cause a setback for development, and even a reversal of recent development gains in the short- to medium-term, emphasizing the point that disaster risk management is a development issue as much as a humanitarian one. Poor development status of communities and countries increases their sensitivity to disasters. Disaster impacts can also force households to fall below the basic needs poverty line, further increasing their vulnerability to other shocks (Owens et al., 2003; Lal, 2010). Consequently, disasters are seen as barriers for development, requiring ex-ante disaster risk reduction policies that also target poverty and development (del Ninno et al., 2003; Owens et al., 2003; Skoufias, 2003; Benson and Clay, 2004; Hallegatte et al., 2007; Raddatz, 2007; Cardona et al., 2010; IFRC, 2010). However, some literature suggests that disasters may not always have a negative effect on economic growth and development and for some countries disasters may be regarded as a problem *of*, and not *for* development (Albala-Bertrand, 1993; Skidmore and Toya, 2002; Caselli and Malthotra, 2004; Hallegatte and Ghil, 2007). Disasters have also been considered to increase economic growth in the short term as well as spur positive economic growth and technological renewal in the longer term, depending on the domestic capacity of nations to rebuild and the inflow of international assistance (Skidmore and Toya, 2002). This observation may be partially attributable to national accounting practices, which positively record reconstruction efforts but do not account for the immediate destruction of assets and wealth in some cases (Skidmore and Toya, 2002).

To better respond to the impacts of disasters on human livelihoods, environment, and economies, national disaster risk management systems have evolved in recent years, guided in some cases by international instruments, particularly the Hyogo Framework for Action (HFA) 2005-2015 and more recently as part of the adaptation agenda under the United Nations Framework Convention on Climate Change (UNFCCC; see Section 7.3). Increasing knowledge, understanding, and experiences in dealing with disaster risks have gradually contributed to a paradigm shift globally that recognizes the importance of reducing risks by addressing underlying drivers of vulnerability and exposure, such as targeting poverty, improving human well-being, better environmental management, and adaptation to climate change as well as responding to and rebuilding after disaster events (Yodmani, 2001; IFRC, 2004, 2010; Thomalla et al., 2006; UNISDR, 2008a; Venton and LaTrobe, 2008; Pelham et al., 2011). While governments cannot act alone, the majority are well placed and equipped to support communities and the private sector to address disaster risks. Yet recent reported experiences suggest that countries vary considerably in their responses, and concerns remain about the lack of integration of disaster risk management into sustainable development policies and planning as well as insufficient implementation at different levels (CCCD, 2009; UNFCCC, 2008b).

It is at the national level that overarching development policies and legislative frameworks are formulated and implemented to create appropriate enabling environments to guide other stakeholders to reduce, share, and transfer risks, albeit in different ways (Carter, 1992; Freeman et al., 2003). National-level governments in developed countries are often the de facto 'insurers of last resort' and used to be considered the most effective insurance instruments of society (Priest, 1996). Governments also have the ability to mainstream risks associated with climate variability and change into existing disaster risk management and sectoral development, policies, and plans, albeit to differing degrees depending on their capacity. These include initiatives to assess risks and uncertainties, manage these across sectors, share and transfer risks, and establish baseline information and research priorities (Freeman et al., 2003; Mechler, 2004; Prabhakar et al., 2009). Ideally, national-level institutions are best able to respond to the challenges of climate extremes, particularly given that when disasters occur they often surpass people and businesses' coping capacity (OAS, 1991; Otero and Marti, 1995; Benson and Clay, 2002a,b). National governments are also better placed to appreciate key uncertainties and risks and take strategic actions, particularly based on their power of taxation (see Sections 6.4.3 and 6.5.3), although particularly exposed developing countries may be financially challenged to attend to the risks and liabilities imposed by natural disasters (Mechler, 2004; Cummins and Mahul, 2009; UNISDR, 2011a).

Changes in weather and climate extremes and related impacts pose new challenges for national disaster risk management systems, which in many instances remain poorly adapted to the risks posed by existing climatic variability and extremes (Lavell, 1998; McGray et al., 2007; Venton and La Trobe, 2008; Mitchell et al., 2010b). Nonetheless, valuable lessons for advancing adaptation to climate change can be drawn from existing national disaster risk management systems (McGray et al., 2007; Mitchell et al., 2010b). Such national systems are comprised of actors operating across scales, fulfilling a range of roles and functions, guided by an enabling environment of institutions, international agreements, and experience of previous disasters (Carter, 1992; Freeman et al., 2003). These systems vary considerably between countries in terms of their capacities and effectiveness and in the way responsibilities are distributed between actors. Countries also put differential emphasis on integration of disaster risk management with development processes and tackling vulnerability and exposure, compared with preparing for and responding to extreme events and disasters (Cardona et al., 2010).

Recent global assessments of disaster risk management point to a general lack of integration of disaster risk management into sustainable development policies and planning across countries and regions, although progress has been made especially in terms of passing legislation, in setting up early warning systems, and in strengthening disaster preparedness and response (Amendola et al., 2008; UNISDR, 2011b; Wisner, 2011). Closing the gap between current provision and what is needed for tackling even current climate variability and disaster risk is a priority for national risk management systems and is also a crucial aspect of countries' responses to projected climate change. With a history of managing climatic extremes, involving a large number of experienced actors across scales and levels of government and widespread instances of supporting legislation and cross-sectoral coordinating bodies (Section 6.4.2), national disaster risk management systems offer a promising avenue for supporting adaptation to climate change and reducing projected climate-related disaster risks.

Accordingly, this chapter assesses the literature on national systems for managing disaster risks and climate extremes, particularly the design of such systems of functions, actors, and roles they play, emphasizing the importance of government and governance for improved adaptation to climate extremes and variability. Focusing particularly on developing country challenges, the assessment reflects on the adequacy of existing knowledge, policies, and practices globally and considers the extent to which the current disaster risk management systems may need to evolve to deal with the uncertainties associated with and the effects of climate change on disaster risks. Section 6.2 characterizes national systems for managing existing climate extremes and disaster risk by focusing on the actors that help create the system – national and sub-national government agencies, bilateral and multilateral organizations, the private sector, research agencies, civil society, and community-based organizations. Drawing on a range of examples from developed and developing countries, Sections 6.3 through 6.5 describe what is known about the status of managing current and future risk, what is desirable in an effective national system for adapting to climate change, and what gaps in knowledge exist. The latter parts of the chapter are organized by the set of functions undertaken by the actors discussed in Section 6.2. The functions are divided into three main categories – those associated with planning and policies (Section 6.3), strategies (Section 6.4), and practices, including methods and tools (Section 6.5), for reducing climatic risks. Section 6.6 reflects on how national systems for managing climate extremes and disaster risk can become more closely aligned to the challenges posed by climate change and development – particularly those associated with uncertainty, changing patterns of risk and exposure, and the impacts of climate change on vulnerability and poverty. Aspects of Section 6.6 are further elaborated in Chapter 8.

6.2. National Systems and Actors for Managing the Risks from Climate Extremes and Disasters

Managing climate-related disaster risks is a concern of multiple actors, working across scales from international, national, and sub-national and community levels, and often in partnership, to ultimately help individuals, households, communities, and societies to reduce their risks (Twigg, 2004; Schipper, 2009; Wisner, 2011). Comprising national and sub-national governments, the private sector, research bodies, civil society, and community-based organizations and communities, effective national systems would ideally have each actor performing to their accepted functions and capacities. Each actor would play differential but complementary roles across spatial and temporal scales (UNISDR, 2008a; Schipper, 2009; Miller et al., 2010) and would draw on a mixture of scientific and local knowledge to shape their actions and their appreciation of the dynamic nature of risk (see Figure 6-1). Given that national systems are at the core of a country's capacity to meet the challenges of observed and projected trends in exposure, vulnerability, and weather and climate extremes, this section assesses the literature on the roles played by different actors working within such national systems.

Figure 6-1 encapsulates the discussions to follow on the interface and interaction between different levels of actors, roles, and functions, with the centrality of national organizations and institutions engaging at the international level and creating enabling environments to support

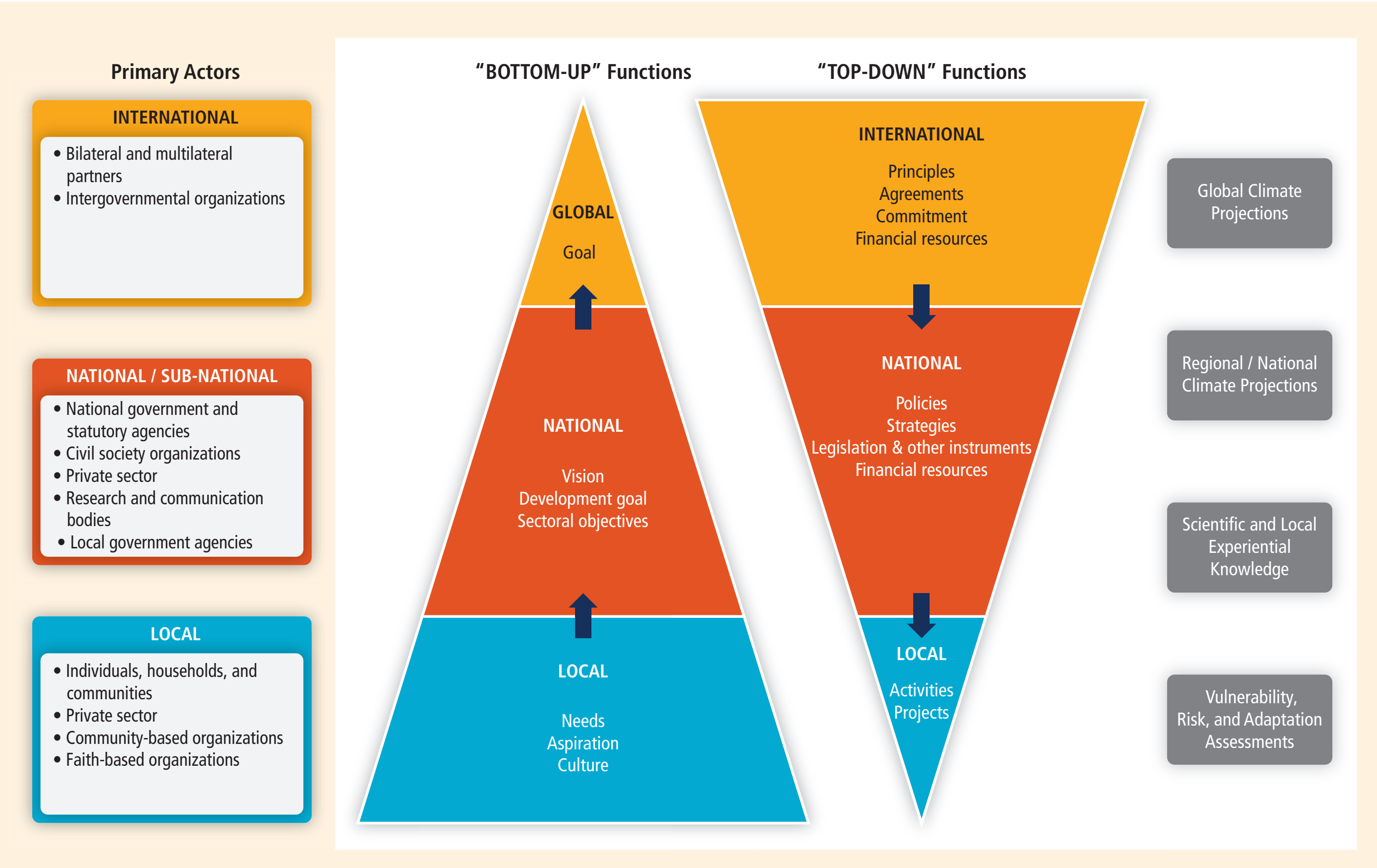

Figure 6-1 | National system of actors and functions for managing disaster risk and adapting to climate change.

actions across the country, supported by scientific information and traditional knowledge.

6.2.1. National and Sub-National Governments

The national level plays a key role in governing and managing disaster risks because national governments are central to providing risk management-related public goods as they maintain organizational and financial authority in planning and providing such goods. National governments have the moral and legal responsibility to ensure economic and social well-being, including safety and security of their citizens from disasters (UNISDR, 2004). It is also argued that it is government's responsibility to protect the poorest and most vulnerable citizens from disasters, and to implement disaster risk management that reaches all (McBean, 2008; O'Brien et al., 2008; CCCD, 2009). In terms of risk ownership, government and public disaster authorities 'own' a large part of current and future extreme event risks and are expected to govern and regulate risks borne by other parts of society (Mechler, 2004). Various normative literature sources support this. As one example, literature on economic welfare theory suggests that national governments are exposed to natural disaster risk and potential losses due to their three main functions: provision of public goods and services (e.g., education, clean environment, and security); the redistribution of income; and stabilizing the economy (Musgrave, 1959; Twigg, 2004; White et al., 2004; McBean, 2008; Shaw et al., 2009). The risks faced by governments include losing public infrastructure, assets, and national reserves. National-level governments also redistribute income across members of society and thus are called upon when those are in need (Linnerooth-Bayer and Amendola, 2000), or when members of society are in danger of becoming poor, and in need of relief payments to sustain a basic standard of living, especially in countries with low per capita income and/or that have large proportions of the population in poverty (Cummins and Mahul, 2009). Finally, it can be argued that governments are expected to stabilize the economy, for example, by supply-side interventions when the economy is in disequilibrium.

National-level governments are often called 'insurers of last resort' as the governments are often the final entity that private households and firms turn to in case of need, although the degree of compliance and ability to honor those responsibilities by governments differs significantly across countries. Nonetheless, in the context of a changing climate, it is argued that governments have a particularly critical role to play in relation to not only addressing the current gaps in disaster risk management but also in response to uncertainties and changing needs due to increases in the frequency, magnitude, and duration of some climate extremes (Katz and Brown, 1992; Meehl et al., 2000; Christensen et al., 2007; also refer to Chapter 3).

Different levels of governments – national, sub-national, and local level – as well as respective sectoral agencies play multiple roles in addressing drivers of vulnerability and managing the risk of extreme events, although their effectiveness varies within a country as well as across countries. They are well placed to create multi-sectoral platforms to guide, build, and develop policy, regulatory, and institutional frameworks that prioritize risk management (Handmer and Dovers, 2007; UNISDR, 2008b; OECD, 2009); integrate disaster risk management with other policy domains like development or environmental management, which often are separated in different ministries (UNISDR 2004, 2009c; White et al., 2004; Tompkins et al., 2008); and address drivers of vulnerability and assist the most vulnerable populations (McBean, 2008; CCCD, 2009). Governments across sectors and levels also provide many public goods and services that help address drivers of vulnerability as well as those that support disaster risk management (White et al., 2004; Shaw et al., 2009) through education, training, and research (Twigg, 2004; McBean, 2008; Shaw et al., 2009).

Governments also allocate financial and administrative resources for disaster risk management, as well as provide political authority (Spence, 2004; Twigg, 2004; Handmer and Dovers, 2007; CCCD, 2009). Evidence suggests that successful disaster risk management is partly contingent on resources being made available at all administration levels, but to date, insufficient policy and institutional commitments have been made to disaster risk management in many countries, particularly at the local government level (Twigg, 2004; UNISDR, 2009d). It is argued that governments also have an important role to guide and support the private sector, civil society organizations, and other development partners in playing their differential roles in managing disaster risk (O'Brien et al., 2008; Prabhakar et al., 2009).

6.2.2. Private Sector Organizations

The private sector plays a small, but increasingly important role in disaster risk management and adaptation, and some aspects of disaster risk management may be suitable for nongovernmental stakeholders to implement, albeit this would often effectively be coordinated within a framework created and enabled by governments. Three avenues for private sector engagement may be identified: (1) corporate social responsibility (CSR); (2) public-private partnerships (PPP); and (3) businesses model approaches. CSR involves voluntary advocacy and raising awareness by businesses for disaster risk reduction as well as involving funding support and the contribution of volunteers and expertise to implement risk management measures. PPPs focus on enhancing the provision of public goods for disaster risk reduction in joint undertakings between public and private sector players. The business model approach pursues the integration and alignment of disaster risk reduction with operational and strategic goals of an enterprise (Warhurst, 2006; Roeth, 2009). While CSR and PPP have received substantial attention, business model approaches remain rather untouched areas, one very important exception being the insurance industry as a supplier of tools for transferring and sharing disaster risks and losses.

In terms of business model approaches, insurance is a key sector. In exchange for pre-disaster premium payments, disaster insurance and other risk transfer instruments in 2010 covered about 30% of disaster losses overall (Munich Re, 2011). In terms of weather-related events, for the period 1980 to 2003, insurance overall covered about 20% of the losses, yet the distribution according to country income groups is uneven, with about 40% of the losses insured in high-income as compared to 4% in low-income countries (Mills, 2007). In developing countries, despite complexities and uncertainties involved in both supply and demand for risk transfer, risk financing mechanisms have been found to demonstrate substantial potential for absorbing the financial burden of disasters (Pollner, 2000; Andersen, 2001; Varangis et al., 2002; Auffret, 2003; Dercon, 2005; Hess and Syroka, 2005; Linnerooth-Bayer et al., 2005; Skees et al., 2005; World Bank, 2007; Cummins and Mahul, 2009; Hazell and Hess, 2010). There is, though, some uncertainty as to the extent to which the private sector would continue to play this role in the context of a changing environment due to uncertainty and imperfect information, missing and misaligned markets, and financial constraints (Smit et al., 2001; Aakre et al., 2010). Private insurers are concerned about changes in risks and associated risk ambiguity, that is, the uncertainty about the changes induced by climate change in terms of potentially modified extreme event intensity and frequency. Accordingly, as climate change, and other drivers such as changes in vulnerability and exposure (see Chapters 1, 2, and 3), are projected to lead to changes in frequency and intensity of some weather risks and extremes, insurers may be less prepared to underwrite insurance for extreme event risks. Innovative private-public sector partnerships may thus be required to better estimate and price risk as well as develop robust insurance-related products, which may be supported in developing countries by development partner funds as well (see Section 6.5.3 and Case Study 9.2.13).

Professional societies (such as builders and architects) and trade associations also play a key role in developing and implementing standards and practices for disaster risk reduction. These practices may include national and international standards and model building codes that are adopted in the regulations of local, state, and national governments. Although the potential for private sector players in disaster risk reduction in sectors such as engineering and construction, information communication technology, media and communication, as well as utilities and transportation seems large, *limited evidence* of successful private sector activity has been documented, owing to a number of reasons (Roeth, 2009). The business case for private sector involvement in disaster risk reduction remains unclear, hampering private sector engagement. Companies may also be averse to reporting activities that are fundamental to their business; and, in more community-focused projects, companies often work with local nongovernmental organizations (NGOs) and do not often report such efforts. Considering climate variability and change within the business model, companies may be an important entry point for disaster risk reduction, particularly in terms of guaranteeing global value chains in the presence of potentially large-scale disruptions triggered by climate-related disasters. For example, the economic viability of the Chinese coastal zone – the economic heartland of China and home to many multinational companies producing a large share of consumer goods globally – is highly exposed to typhoon risk and will increasingly depend on well-implemented disaster risk reduction mechanisms (Roeth, 2009).

6.2.3. Civil Society and Community-Based Organizations

At the national level, civil society organizations (CSOs) and community-based organizations (CBOs) play a significant role in developing initiatives to respond to disasters, reduce the risk of disasters, and, recently, adapt to climate-related hazards (see Section 5.1 for a discussion of 'local' and 'community' and Section 5.4.1 for the role of CBOs at the local level). CSOs and CBOs are referred to here as the wide range of associations around which society voluntarily organizes itself, with CBO referring to those associations primarily concerned with local interests and ties. CSO and CBO initiatives in the field of disaster risk management, which may usually begin as a humanitarian concern, often evolve to also embrace the broader challenge of disaster risk reduction following community-focused risk assessment, including specific activities targeting education and advocacy; environmental management; sustainable agriculture; infrastructure construction; and increased livelihood diversification (McGray et al., 2007; CARE International, 2008; Oxfam America, 2008; Practical Action Bangladesh, 2008; SEEDS India, 2008; Tearfund, 2008; World Vision, 2008).

Recently in some high-risk regions there has been rapid development of national platforms of CSOs and CBOs that have been working together in order to push for the transformation of policies and practices related to disaster risk reduction. This is true in the case of Central America, where at least four platforms are functioning in the same number of countries, involving more than 120 CSOs and CBOs (CRGR, 2007a). The efforts of these platforms have been aimed at advocacy, training, research, and capacity building in disaster risk reduction. In Central America, the experience is that advocacy on climate policy construction has become a new feature of such platforms since 2007 (CRGR, 2009). While beyond the scope of this chapter, on balance the majority of CSOs and CBOs focus efforts at the local level, trying to link disaster risk management with local development goals associated with water, sanitation, education, and health, for example (GNDR 2009; Lavell, 2009). Faith-based organizations are also influential in assisting local communities in disaster risk management, not only providing pastoral care in times of disasters but also playing an important role in raising awareness and training, with many international development partners often working with local church groups to build community resilience (see, for example, ADPC 2007; Gero et al., 2011; Tearfund, 2011).

In several countries in Latin America, CSOs and CBOs are considered, by law, as part of national systems for civil protection (Lavell and Franco, 1996; CRGR, 2007b) though participation, with the exception of National Red Cross/Red Crescent Societies, remains patchy (UNISDR, 2008c). In some countries where governments are not able or willing to fulfill certain disaster risk management functions, such as training, supporting food security, providing adequate housing, and preparedness, CSOs and CBOs have stepped in (Benson et al., 2001). While CSOs often face challenges in securing resources for replicating successful initiatives and scaling out geographically (CARE International, 2008; Oxfam America, 2008; Practical Action Bangladesh, 2008; SEEDS India, 2008; Tearfund, 2008; World Vision, 2008); sustaining commitment to work with local governments and stakeholders over the long term and maintaining partnerships with local authorities (Oxfam America, 2008); and coordinating and linking local-level efforts with sub-national government initiatives and national plans during the specific project implementation (SEEDS India, 2008), they are particularly well positioned to draw links between disaster risk reduction and climate change adaptation given that such organizations are currently among the few to combine such expertise (Mitchell et al., 2010b).

6.2.4. Bilateral and Multilateral Agencies

In developing countries, particularly where the government is weak and has limited resources, bilateral and multilateral agencies play a significant role in supplying financial, technical, and in some cases strategic support to government and nongovernment agencies to tackle the multifaceted challenges of disaster risk management and climate change adaptation in the context of national development goals (e.g., AusAid, 2009; DFID, 2011). Multilateral agencies are referred to here as international institutions with governmental membership that have a significant focus on development and aid recipient countries. Such agencies can include United Nations agencies, regional groupings (e.g., some European Union agencies), and multilateral development banks (e.g., World Bank, Asian Development Bank). Bilateral agencies (e.g., United Kingdom Department for International Development) are taken here as national institutions that focus on the relationship between one government and another. In the development sphere, this is often in the context of a richer government providing support to a poorer government. The role of international institutions, including bilateral and multilateral agencies, is discussed extensively in Section 7.3.

Bilateral and multilateral agencies have been key actors in advancing mainstreaming of disaster risk reduction and climate change adaptation into development planning (Eriksen and Næss, 2003; Klein et al., 2007; see Section 6.3). This has primarily been driven by a concern that development investments are increasingly exposed to climate- and disaster-related risks and that climate change poses security concerns (Harris, 2009; Persson and Klein, 2009). As a result, such agencies are influencing development policy and implementation at a national level as they require disaster and climate risk assessments and environmental screening to be conducted at different points in the project approval process and in some cases retrospectively when projects are already underway (Klein et al., 2007; OECD, 2009; Hammill and Tanner, 2010). A range of tools and methods have been developed, primarily by bilateral and multilateral agencies, to support such processes (Klein et al., 2007; Hammill and Tanner, 2010).

While significant progress has been made in developing appropriate tools and methods for assessing and screening risk, many bilateral and multilateral agencies continue to address disaster risk management and climate change adaptation separately, and link with respective regional and national agencies in the context of distinct international instruments (Mitchell and Van Aalst, 2008; Mitchell et al., 2010b; Gero et al., 2011). However, recent assessments suggest that the situation is improving, partially attributable to the process of authoring this Special Report and in the focus on risk management in the text of the Bali Action Plan (2007) and Cancun Agreement (2010) (Mitchell et al., 2010b; see Section 7.3.2.2 for more detail).

The diversity of national contexts requires bilateral and multilateral agencies to adopt different modalities to maximize the effectiveness of technical, financial, and strategic support. For example, in the Pacific and the Caribbean, regional bodies (e.g., the Caribbean Disaster Emergency Management Agency) commonly operate as an intermediary, channeling resources to island countries where it is not efficient for international agencies to establish a permanent adaptation or risk management-focused presence (Hay, 2009; Gero et al., 2011). In countries with weak national institutions, bilateral and multilateral agencies commonly choose to channel resources through civil society organizations with the intention of ensuring that resources reach the poorest and most vulnerable (Wickham et al., 2009). In such situations, coordination between agencies can be challenging and in certain circumstances can further reduce the risk management capacity of government organizations (Wickham et al., 2009). However, the broad trend is to maximize the support to national governments by seeking to improve national ownership of risk management and adaptation processes and in that respect support national governments to lead national systems (GFDRR, 2010; DFID, 2011).

6.2.5. Research and Communication

The effectiveness of national systems for managing climate extremes and disaster risks is highly dependent on the availability and communication of robust and timely scientific data and information (Sperling and Szekely, 2005; Thomalla et al., 2006; CACCA, 2010) and traditional knowledge (Mercer et al., 2007; Kelman et al., 2011; see Box 5-7) to inform not only community-based decisions and policymakers who manage national approaches to disaster risk and climate change adaptation, but also researchers who provide further analytical information to support such decisions.

Scientific and research organizations range from specialized research centers and universities, to regional organizations, to national research agencies, multilateral agencies, and CSOs playing differential roles, but generally continue to divide into disaster risk management or climate change adaptation communities. Scientific research bodies play important roles in managing climate extremes and disaster risks by: (a) supporting thematic programs to study the evolution and consequences of past hazard events, such as cyclones, droughts, sandstorms, and floods; (b) analyzing time-and-space dependency in patterns of weather-related risks; (c) building cooperative networks for early warning systems, modeling, and long-term prediction; (d) actively engaging in technical capacity building and training; (e) translating scientific evidence into adaptation practice; (f) collating traditional knowledge and lessons learned for wider dissemination; and (g) translating scientific information into user-friendly forms for community consumption (Sperling and Szekely, 2005; Thomalla et al., 2006; Aldunce and González, 2009).

Disaster practitioners largely focus on making use of short-term weather forecasting and effective dissemination and communication of hazard information and responses (Thomalla et al., 2006). Such climate change expertise can typically be found in meteorological agencies, environment or energy departments, and in academic institutions (Sperling and Szekely, 2005), while disaster risk assessments have been at the core of many multilateral and civil society organizations and national disaster management authorities (Sperling and Szekely, 2005; Thomalla et al., 2006). Although progress has been reported in the communication and availability of scientific information, there is still a lack of, for example, sufficient local or sub-national data on hazards and risk assessments to underpin area-specific disaster risk management (Chung, 2009; UNISDR, 2009c).

6.3. Planning and Policies for Integrated Risk Management, Adaptation, and Development Approaches

Given that learning will come from doing and in spite of differences, there are many ways that countries can learn from each other in prioritizing their climate and disaster risks; in mainstreaming climate change adaptation and disaster risk management into plans, policies, and processes for development; and in securing additional financial and human resources needed to meet increasing demands (UNDP, 2002; Thomalla et al., 2006; Schipper, 2009). This subsection will address frameworks for national disaster risk management and climate change adaptation planning and policies (Section 6.3.1), the mainstreaming of plans and policies nationally (Section 6.3.2), and the various sectoral disaster risk management and climate change adaptation options available for national systems (Section 6.3.3), recognizing the range of actors engaged in these processes as described in Section 6.2.

6.3.1. Developing and Supporting National Planning and Policy Processes

National and sub-national government and statutory agencies have a range of planning and policy options to help create the enabling environments for departments, public service agencies, the private sector, and individuals to act (UNDP, 2002; Heltberg et al., 2009; OECD, 2009; ONERC, 2009; Hammill and Tanner, 2010*).* When considering disaster risk management and adaptation to climate change actions, it is often the scale of the potential climate and disaster risks and impacts, the capacity of the governments or agencies to act, the level of certainty about future changes, the timeframes within which these future impacts and disasters will occur, and the costs and consequences of decisions that play an important role in their prioritization and adoption (Heltberg et al., 2008; World Bank, 2008; Wilby and Dessai, 2010).

The complexity and diversity of adaptation to climate change situations implies that there can be no single recommended approach for assessing, planning, and implementing adaptation options (Füssel, 2007; Hammill and Tanner, 2010; Lu, 2011). When the planning horizons are short and adaptation decisions only impact the next one or two decades, adaptation to recent climate variability and observed trends may be sufficient (Hallegatte, 2009; Wilby and Dessai, 2010; Lu, 2011). For long-lasting risks and decisions, the timing and sequencing of adaptation options and incorporation of climate change scenarios become increasingly important (Hallegatte, 2009; OECD, 2009; Wilby and Dessai, 2010). Studies suggest that the most pragmatic adaptation and disaster risk management options depend on the timeframes under consideration and the adaptive capacity and ability of the country or sectoral agencies to effectively integrate information on climate change and its uncertainties (McGray et al., 2007; Biesbroek et al., 2010; Krysanova et al., 2010; Wilby and Dessai, 2010; Juhola and Westerhoff, 2011). Given the various uncertainties at decisionmaking scales, studies suggest that adaptation actions based on information on the observed climate and its trends may be preferable in some cases while, in other cases with long-term irreversible decisions, climate change scenario-guided adaptation actions will be required (Auld, 2008b; Hallegatte, 2009; OECD, 2009; Krysanova et al., 2010; Wilby and Dessai, 2010). Climate change scenarios provide needed guidance for adaptation options when the direction of the climate change impacts are known and when the decisions involve long-term building infrastructure, development plans, and actions to avoid catastrophic impacts from more intense extreme events (Haasnoot et al., 2009; Hallegatte, 2009; Wilby and Dessai, 2010).

In dealing with climate change and disaster risk uncertainties, many national studies identify gradations or categories of adaptation and disaster risk management planning and policy options (Dessai and Hulme, 2007; Auld, 2008b; Hallegatte, 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010; Wilby and Dessai, 2010). These gradations in options range from climate vulnerability or resilience approaches, sometimes described as 'bottom-up'; vulnerability, tipping point, critical threshold, or policy-first approaches to climate modeling, impact-based approaches, sometimes described as 'top-down'; model or impacts-first; science-first; or classical approaches (as illustrated in Figure 6-2 and outlined in the sectoral option headings of Table 6-1 and described in Section 6.3.3). Although the bottom-up and top-down terms sometimes refer to scale, subject matter, or policy (e.g., national versus local, physical to socioeconomic systems), the terms are used here to describe the sequences or steps needed to develop adaptation and disaster risk management plans and policies at the national level. When dealing with long-term future climate change risks, the main differences between the scenarios-impacts-first and vulnerability-thresholds-first approaches lie in the timing or sequencing of the stages of the analyses, as shown in Figure 6-2 (Kwadijk et al., 2010; Ranger et al., 2010). Although this difference appears subtle, it has significant implications for the management of uncertainty, the timing of adaptation options, and the efficiency of the policymaking (Dessai and Hulme, 2007; Auld, 2008b; Kwadijk et al., 2010; Wilby and Dessai, 2010; Lu, 2011). For example,

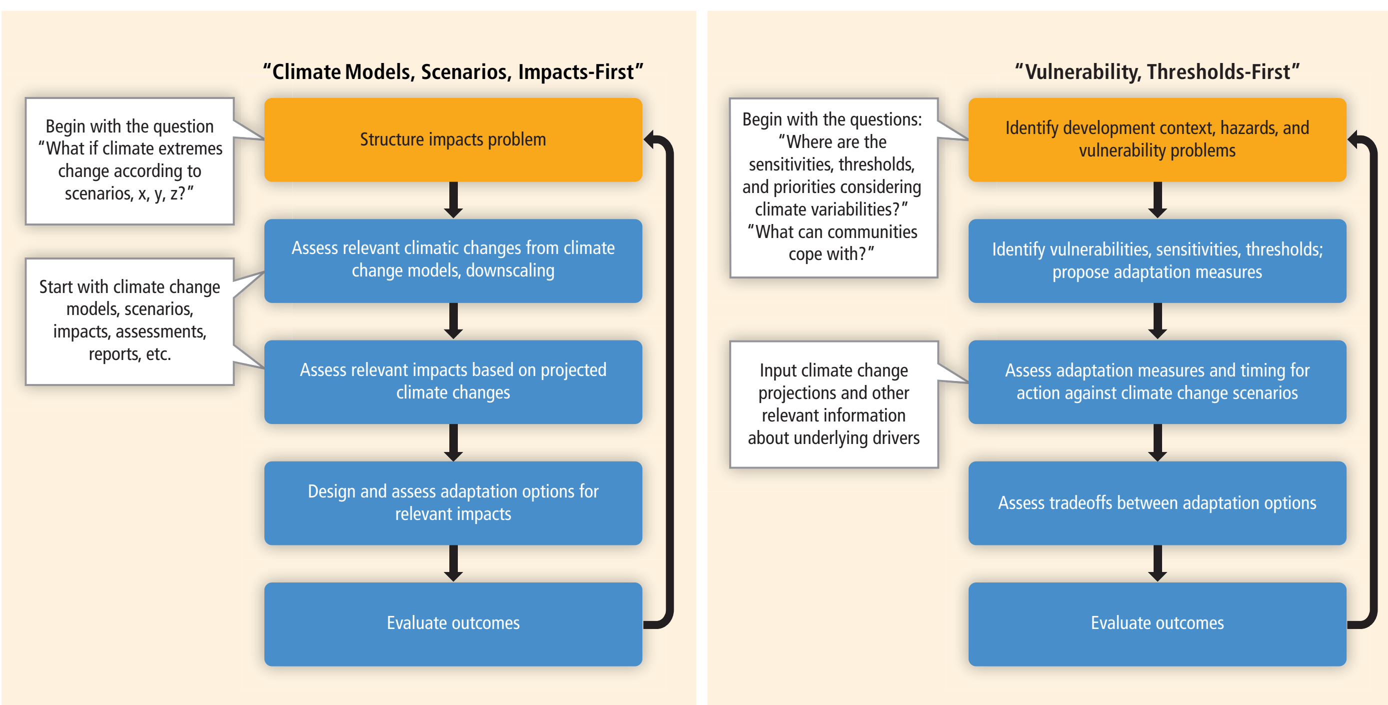

Figure 6-2 | Top-down scenario, impacts-first approach (left panel) and bottom-up vulnerability, thresholds-first approach (right panel) – comparison of stages involved in identifying and evaluating adaptation options under changing climate conditions. Adapted from Kwadijk et al. (2010) and Ranger et al. (2010).

when the lifespan of a decision, policy, or measure has implications for multiple decades or the decision is irreversible and sensitive to climate, the performance of adaptation and risk reduction options across a range of climate change scenarios becomes critical (Auld, 2008b; Kwadijk et al., 2010; Wilby and Dessai, 2010).

Vulnerability thresholds-based approaches start at the level of the decisionmaker, identify desired system objectives and constraints, consider how resilient or robust a system or sector is to changes in climate, assess adaptive capacity and critical 'tipping points' or threshold points, then identify the viable adaptation strategies that would be required to improve resilience and robustness under future climate scenarios (Auld, 2008b; Urwin and Jordan, 2008; Hallegatte, 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010; Wilby and Dessai, 2010). Vulnerability-thresholds approaches can be independent of any specific future climate condition.

Options that are known as 'no regrets' and 'low regrets' provide benefits under any range of climate change scenarios, although they may not be optimal for every future scenario, and are recommended when uncertainties over future climate change directions and impacts are high (Dessai and Hulme, 2007; Auld, 2008b; Hallegatte, 2009; Kwadijk et al., 2010). These 'low regrets' adaptation options typically include improvements to coping strategies or reductions in exposure to known threats (Auld, 2008b; Kwadijk et al., 2010; Wilby and Dessai, 2010), such as better forecasting and warning systems, use of climate information to better manage agriculture in drought-prone regions, flood-proofing of homesteads, or interventions to ensure up-to-date climatic design information for engineering projects. The vulnerability-thresholds-first approaches are particularly useful for identifying priority areas for action now, assessing the effectiveness of specific interventions when current climate-related risks are not satisfactorily controlled, when climatic stress factors are closely intertwined with non-climatic factors, planning horizons are short, resources are very limited (i.e., expertise, data, time, and money), or uncertainties about future climate impacts are very large (Agrawala and van Aalst, 2008; Hallegatte, 2009; Prabhakar et al., 2009; Wilby and Dessai, 2010).

Vulnerability-thresholds-first approaches have sometimes been critiqued for the time required to complete a vulnerability assessment, for their reliance on experts, and for their largely qualitative results and limited comparability across regions (Patt et al., 2005; Kwadijk et al., 2010). Vulnerability-thresholds approaches can sometimes prove less suited for guiding future adaptation decisions if coping thresholds change, or if climate change risks emerge that are outside the range of recent experiences (e.g., successive drought years could progressively reduce coping thresholds of the rural poor by increasing indebtedness) (McGray et al., 2007; Agrawala and van Aalst, 2008; Auld, 2008b; Hallegatte, 2009; Prabhakar et al., 2009; Wilby and Dessai, 2010).

The scenarios-impact-first approaches typically start with several climate change modeling scenarios and socioeconomic scenarios, evaluate the expected impacts of climate change, and subsequently identify adaptation and risk reduction options to reduce projected risks (Kwadijk et al., 2010; Mastrandrea et al., 2010; Wilby and Dessai, 2010). The scenarios-impacts-first approaches are most useful to raise awareness of the problem, to explore possible adaptation strategies, and to identify research priorities, especially when current climate and disaster risks can be effectively controlled, when sufficient data and resources are available to produce state-of-the-art climate scenarios at the spatial resolutions relevant for adaptation, and when future climate impacts can be projected reliably (Kwadijk et al., 2010; Wilby and Dessai, 2010). Scenarios-impacts approaches depend strongly on the chosen climate change scenarios and downscaling techniques, as well as the assumptions about scientific and socioeconomic uncertainties (OECD, 2009; Kwadijk et al., 2010). Pure scenarios-impacts approaches may not be available at the spatial scales relevant to the decisionmaker, may not be applicable for the purpose of the decisionmaker, and usually give less consideration to current risks from natural climate variability, to non-climatic stressors, and to key uncertainties along with their implications for robust adaptation policies (Füssel, 2007; Wilby and Dessai, 2010). In practice, there are very limited examples of actual adaptation policies being developed and planned adaptation decisions being implemented based on scenarios-impacts approaches only (Füssel, 2007; Biesbroek et al., 2010; Wilby and Dessai, 2010).

Increasingly, studies are recognizing that the scenarios-impacts and vulnerability-thresholds approaches are complementary and need to be integrated and that both can benefit from the addition of stakeholder and scientific input to determine critical thresholds for climate change vulnerabilities (Auld, 2008b; Haasnoot et al., 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010; Wilby and Dessai, 2010). Critical thresholds (or adaptation tipping points) help in answering the basic adaptation questions of decision- and policymakers – namely, what are the first priority issues that need to be addressed as a result of increasing disaster risks under climate change and when might these critical thresholds be reached (Auld, 2008b; Haasnoot et al., 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010). The integration of scenarios-impacts and vulnerability-thresholds approaches provides guidance on the sensitivity of sectors and durability of options under different climate change scenarios (Haasnoot et al., 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010). Integrated approaches that link changes in climate variables to decisions and policies and express uncertainties in terms of timeframes over which a policy or plan may be effective (i.e., roughly when will the critical threshold be reached) also provide valuable information for plans and policies and their implementation (Haasnoot et al., 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010).

Regardless of the approaches used, it is important that uncertainty over future climate change risks not become a barrier to climate change risk reduction actions (Auld, 2008b; Hallegatte, 2009; Krysanova et al., 2010; Wilby and Dessai, 2010). In cases where climate change uncertainties remain high, countries may choose to increase or build on their capacity to cope with uncertainty, rather than risk maladaptation from use of ambiguous impact studies or no action (McGray et al., 2007; Hallegatte, 2009; Wilby and Dessai, 2010). In order to reduce the risk of maladaptation

Table 6-1 | National policies, plans, and programs: a selection of disaster risk reduction and adaptation to climate change options by selected sectors.

Sector/ Response	'No regrets' and 'low regrets' actions for current and future risks	*('No/low regrets' options plus…)* Preparing for climate change risks by reducing uncertainties (building capacity)	*("Preparing for climate change" risks plus...)* Reduce risks from future climate change	Risk transfer	Accept and deal with increased and unavoidable (residual) risks	'Win-win' synergies for GHG reduction, adaptation, risk reduction, and development benefits
Natural Ecosystems and Forestry	• Use of Ecosystem-based Adaptation (EbA) or 'soft engineering'; integrate disaster risk reduction and climate into integrated coastal zone and water resources management, forest management, and land use management; conserve, enhance resilience of ecosystems; restore protective ecosystem services [1] • Adaptive forest management; forest fire management, controlled burns; agroforestry; biodiversity [2] • Reduce forest degradation, unsustainable harvests, and provide incentives for alternate livelihoods, eco-tourism [6]	• Synergies between UNFCCC and Rio Conventions; avoid actions that interfere with goals of other UN conventions [3] • Research on climate change–ecosystem–forest links, climate and ecosystem prediction systems, climate change projections; monitor ecosystem and climate trends [3] • Incorporate ecosystem management into National Adaptation Programmes of Action and disaster risk reduction plans [3]	• Adaptation to climate change interventions to maintain ecosystem resilience; corridors, assisted migrations; plan EbA for climate change [4] • Seed, genetic banks; new genetics; tree species improvements to maintain ecosystem services in future; adaptive agroforestry [4] • Changed timber harvest management, new technologies for adaptation to climate change, new uses to conserve forest ecosystem services [4]	• Micro-finance and insurance to compensate for lost livelihoods [5] • Investments in additional insurance, government reserve funds for increased risks due to loss of protective ecosystem services [5]	• Replace lost ecosystem services through additional hard engineering, health measures [6] • Restore loss of damaged ecosystems [6]	• Sustainable afforestation (for robust forests), reforestation, conservation of forests, wetlands and peatlands, sustainable and increased biomass; land use, land-use change, and forestry; reducing emissions from deforestation [7] • Incentives for sustainable sequestration of carbon; sustainable bio-energy; energy self-sufficiency [7]
Agriculture and Food Security	• Food security via sustainable land and water management, training; efficient water use, storage; agro-forestry; protection shelters, crop and livestock diversification; improved supply of climate stress tolerant seeds; integrated pest, disease management [8] • Climate monitoring; improved weather predictions; disaster management, crop yield and distribution models and predictions [9]	• Increased agriculture-climate research and development [10] • Research on climate tolerant crops, livestock; agrobiodiversity for genetics [10] • Integration of climate change scenarios into national agronomic assessments [11] • Diversification of rural economies for sensitive agricultural practices [10]	• Adaptive agricultural and agroforestry practices for new climates, extremes [12] • New and enhanced agricultural weather, climate prediction services [11] • Food emergency planning; distribution and infrastructure networks [12] • Diversify rural economies [12]	• Improved access to crop, livestock, and income loss insurance (e.g., weather derivatives) [13] • Micro-financing and micro-insurance [13] • Subsidies, tax credits [13]	• Changed livelihoods and relocations in regions with climate sensitive practices [12] • Secure emergency stock and improve distribution of food and water for emergencies [12]	• Energy efficient and sustainable carbon sequestering practices; training; reduced use of chemical fertilizers [14] • Use of bio-gas from agricultural waste and animal excreta [14] • Agroforestry [14]
Coastal Zone and Fisheries	• EbA; integrated coastal zone management (ICZM); combat salinity; alternate drinking water availability; soft and hard engineering [15] • Strengthen institutional, regulatory, and legal instruments; setbacks; tourism development planning [16] • Marine protected areas, monitoring fish stocks, alter catch quantities, effort, timing; salt-tolerant fish species [17] • Climate risk reduction planning; hazard delineation; improve weather forecasts, warnings, environmental prediction [16]	• Climate change projections for coastal management planning; develop modeling capacity for coastal zone-climate links; climate-linked ecological and resource predictions; improved monitoring, geographic and other databases for coastal management [18] • Monitor fisheries; selective breeding for aquaculture, fish genetic stocks; research on salt-tolerant crop varieties [19]	• Incorporate adaptation to climate change, sea level rise into ICZM, coastal defenses [18] • Hard and 'soft' engineering for adaptation to climate change; sustainable tourism development planning; resilient vessels and coastal facilities [16] • Manage for changed fisheries, invasives [20] • Inland lakes: alter transportation and industrial practices, soft and hard engineering [20]	• Enhance insurance for coastal regions and resources; fisheries insurance [21] • Government reserve funds [21]	• Enhance emergency preparedness measures for more frequent and intense extremes, including more evacuations [16] • Relocations of communities, infrastructure [16] • Exit fishing; provide alternate livelihoods [19]	• Use of sustainable renewable energy; conservation, energy self-sufficiency (especially for islands, coastal regions) [22] • Offshore renewable energy for alternate incomes and aquaculture habitat [22]

Continued next page →

Table 6-1 (continued)

Sector/ Response	'No regrets' and 'low regrets' actions for current and future risks	*('No/low regrets' options plus…)* Preparing for climate change risks by reducing uncertainties (building capacity)	*("Preparing for climate change" risks plus...)* Reduce risks from future climate change	Risk transfer	Accept and deal with increased and unavoidable (residual) risks	'Win-win' synergies for GHG reduction, adaptation, risk reduction, and development benefits
Water resources	• Implement Integrated Water Resource Management (IWRM), national water efficiency, storage plans [20] • Effective surveillance, prediction, warning and emergency response systems; better disease and vector control, detection and prediction systems; better sanitation; awareness and training on public health [24] • Adequate funding, capacity for resilient water infrastructure and water resource management; Improved institutional arrangements, negotiations for water allocations, joint river basin management [23]	• Develop prediction, climate projection, and early warning systems for flood events and low water flow conditions; research and downscaling for hydrological basins [24] • Multi-sectoral planning for water; selective decentralization of water resource management (e.g., catchments and river basins); joint river basin management (e.g., bi-national) [23]	• National water policy frameworks, robust integrated and adaptive water resource management for adaptation to climate change [25] • Investments in hard and soft infrastructure considering changed climate; river restoration [25] • Improved weather, climate, hydrology-hydraulics, water quality forecasts for new conditions [24]	• Public-private partnerships; Economics for water allocations beyond basic needs [26] • Mobilize financial resources and capacity for technology and EbA [26] • Insurance for infrastructure [26]	• Enhance national preparedness and evacuation plans for greater risks [24] • Enhance health infrastructure for more failures [24] • Alter transport, engineering; increases to temporary consumable water taking permits [24] • Enhance food , water distribution for emergencies, plan for alternate livelihoods [24]	• Integrated and sustainable water efficiency and renewable hydro power for adaptation to climate change [23]
Infra -structure, Housing, Cities, Transportation, Energy	• Building codes, standards with updated climatic values; climate- resilient infrastructure (and energy) designs; training, capacity, inspection, enforcement; monitoring for priority retrofits (e.g., permafrost); maintenance [27] • Legal alternatives to informal settlements, sanitation [27] • Strengthen early warning systems, hazard awareness; improved weather warning systems; disaster-resilient building components (rooms) in high-risk areas; tourism development planning; heat-health responses [28] • Integrate urban planning, engineering, maintenance [27] • Diversified energy systems; maintenance; self-sufficiency, clean energy technologies for national energy plans, international agreement goals (biogas, solar cooker); use of renewable energy in remote and vulnerable regions; use of appropriate energy mixes nationally [29] • Energy security; distributed energy generation and distribution [29]	• Improved downscaling of climate change information; maintain climate data networks, update climatic design information; increased safety/uncertainty factors in codes and standards; develop adaptation to climate change tools [28] • Research on climate, energy, coastal, and built environment interface, including flexible designs, redundancy; forensic studies of failures (adaptation learning); improved maintenance [27] • Investments for sustainable energy development; cooperation on trans-boundary energy supplies (e.g., wind energy at times of peak wind velocity) [29]	• Codes, standards for changed extremes [30] • Publicly funded infrastructure, coastal development and post-disaster reconstruction to include adaptation to climate change [30] • New materials, engineering approaches; flexible design and use structures; asset management for adaptation to climate change [30] • Hazard mapping; zoning and avoidance; prioritized retrofits, abandon the most vulnerable; soft engineering services [30] • Design energy generation, distribution systems for adaptation; switch to less risky energy systems, mixes; embed sustainable energy in disaster risk reduction and adaptation to climate change planning [29]	• Infrastructure insurance and financial risk management [29] • Insurance for energy facilities, interruption [29] • Innovative risk sharing instruments [29] • Government reserve funds [29]	• More relocations [28] • Enhance evacuation, transportation, and energy contingency planning for increases in extreme events [28] • Increase climate-resilient shelter construction [28]	• Implement energy- and water-efficient GHG reductions, disaster risk reduction and adaptation to climate change synergies [29] • Scale up, market penetration for sustainable renewable energy production; increased hydroelectric potential; sustainable biomass; 'greener' distributed community energy systems [29]

Continued next page →

Table 6-1 (continued)

Sector/ Response	'No regrets' and 'low regrets' actions for current and future risks	*('No/low regrets' options plus…)* Preparing for climate change risks by reducing uncertainties (building capacity)	*("Preparing for climate change" risks plus…)* Reduce risks from future climate change	Risk transfer	Accept and deal with increased and unavoidable (residual) risks	'Win-win' synergies for GHG reduction, adaptation, risk reduction, and development benefits
Health	• Community/urban and coastal zone planning, building standards and guidelines; cooling shelters; safe health facilities; retrofits for vulnerable structures; health facilities designed using updated climate information [31] • Strengthen surveillance, health preparedness; early warning weather-climate-health systems, heat alerts and responses; capacity for response to early warnings; prioritize disaster risks; disaster prevention and preparedness; public education campaigns; food security [31] • Strengthen disease surveillance and controls; improve health care services, personal health protection; improve water treatment/sanitation; water quality regulations; vaccinations, drugs, repellants; development of rapid diagnostic tests [31] • Monitor air and water quality; regulations; urban planning [31] • Better land and water use management to reduce health risks [31]	• Research on climate-health linkages and adaptation to climate change options; develop new health prediction systems for emerging risks; research on landscape changes, new diseases, and climate; urban weather-health modeling [31] • Education, disaster prevention and preparedness [31]	• New food and water security, distribution systems; air quality regulations, alternate fuels [32] • New warning and response systems; predict and manage health risks from landscape changes; target services for most at risk populations [32] • Climate proofing, refurbish/ maintain national health facilities and services [32] • Address needs for additional health facilities and services [32]	• Extend and expand health insurance coverage to include new and changed weather and climate risks [33] • Government reserve funds [33]	• National plan for heat and extremes emergencies [32] • New disease detection and management systems [32] • Enhanced prediction and warning systems for new risks [32]	• Use of clean and sustainable renewable energy and water sources; increase energy efficiency; air quality regulations; clean energy technologies to reduce harmful air emissions (e.g., cooking stoves) [34] • Design sustainable infrastructure for climate change and health [30]

References: 1. Adger et al., 2005; Barbier, 2009; Colls et al., 2009; FAO, 2008a; MEA, 2005; SCBD, 2009; Shepherd, 2004, 2008; UNEP, 2009; UNISDR, 2009d; World Bank, 2010. 2. FAO, 2007; Neufeldt et al., 2009; Shugart et al., 2003; Spittlehouse and Stewart, 2003, Weih, 2004. 3. Colls et al., 2009; FAO, 2008a; OECD, 2009; Rahel and Olden, 2008; Robledo et al., 2005; SCBD, 2009; UNEP, 2009; UNFCCC, 2006a. 4. Berry, 2007; FAO, 2007, 2008a,b; Leslie and McLeod, 2007; OECD, 2009; SCBD, 2009. 5. CCCD, 2009; Colls et al., 2009; FAO, 2008b; ProAct Network, 2008; UNFCCC, 2006a. 6. Chhatre and Agrawal, 2009; FAO, 2008b; Mansourian et al., 2009; Reid and Huq, 2005; SCBD, 2009. 7. FAO, 2008a; Reid and Huq, 2005; SCBD, 2009; UNEP, 2006; Venter et al., 2009. 8. Arnell, 2004; Branco et al., 2005; Campbell et al., 2008; Easterling et al., 2007; FAO, 2008a, 2009; Howden et al., 2007; McGray et al., 2007; Neufeldt et al., 2009; SCBD, 2009; UNISDR, 2009d; World Bank, 2009. 9. Easterling et al., 2007; FAO, 2007, 2010; Hammer et al., 2003; McCarl, 2007; UNFCCC, 2006a; World Bank, 2009. 10. Campbell et al., 2008; CCCD, 2009; Easterling et al., 2007; FAO, 2007, 2010; World Bank, 2009. 11. Easterling et al., 2007; FAO, 2007, 2010; World Bank, 2009. 12. Butler and Oluoch-Kosura, 2006; Butt et al., 2005; CCCD, 2009; Davis, 2004; FAO, 2006, 2008a; Howden et al., 2007; McCarl, 2007; World Bank, 2009. 13. CCCD, 2009; FAO, 2007; UNISDR, 2009d; World Bank, 2009. 14. FAO, 2007, 2008a; Rosenzweig and Tubiello, 2007. 15. Adger et al., 2005; FAO, 2008c; Kay and Adler, 2005; Kesavan and Swaminathan, 2006. 16. Adger et al., 2005; FAO, 2008c; Kesavan and Swaminathan, 2006; Klein et al., 2001; Nicholls, 2007; Nicholls et al., 2008; Romieu et al., 2010; UNFCCC, 2006a. 17. FAO, 2007, 2008c; Rahel and Olden, 2008; UNFCCC, 2006a. 18. Adger et al., 2005; Dolan and Walker, 2006; FAO, 2008b; Nicholls, 2007; Thorne et al., 2006; UNFCCC, 2006b; World Bank, 2010. 19. FAO, 2008c; Kesavan and Swaminathan, 2006; Rahel and Olden, 2008. 20. FAO, 2007, 2008c; IIED, 2009; Romieu et al., 2010. 21. FAO, 2007, 2008c; Nicholls, 2007. 22. FAO, 2008c; UNFCCC, 2006a. 23. Branco et al., 2005; CCCD, 2009; Hedger and Cacouris, 2008; ICHARM, 2009; Klijn et al., 2004; Krysanova et al., 2010; Mills, 2007; Olsen, 2006; Rahaman and Varis, 2005; World Bank, 2009; WSSD, 2002; WWAP, 2009. 24. Arnell and Delaney, 2006; Auld et al., 2004; CCCD, 2009; DaSilva et al., 2004; Hedger and Cacouris, 2008; Krysanova et al., 2010; Mills, 2007; Muller, 2007; Thomalla et al., 2006; UNFCCC, 2006b, 2009a; WHO, 2003; WWAP, 2009; WWC, 2009. 25. CCCD, 2009; Crabbé and Robin, 2006; Hedger and Cacourns, 2008; Krysanova et al., 2010; Rahaman and Varis, 2005; WWAP, 2009. 26. Few et al., 2006; Kirshen, 2007; Mills, 2007; Rahaman and Varis, 2005; Warner et al., 2009; WWAP, 2009. 27. Auld, 2008b; Haasnoot et al., 2009; Hodgson and Carter, 1999; Lowe, 2003; Mills, 2007; Nicholls et al., 2008; NRTEE, 2009; ProVention, 2009; Rossetto, 2007; Wamsler, 2004; Wilby and Dessai, 2010; World Bank, 2000, 2008; WWC, 2009. 28. Auld, 2008a,b; Haasnoot et al., 2009; Hallegatte, 2009; Lewis and Chisholm, 1996; Mills, 2007; Neumann, 2009; Nicholls et al., 2008; ProVention, 2009; Rosetto, 2007; UNFCCC, 2006a. 29. Auld, 2008b ; Islam and Ferdousi, 2007; Kagiannas et al., 2003; Maréchal, 2007; Mills, 2007; Neumann, 2009; Robledo et al., 2005; Van Buskirk, 2006; Warner et al., 2009; Younger et al., 2008. 30. Auld, 2008b; Freeman and Warner, 2001; Mills, 2007; Neumann, 2009; NRTEE, 2009; ProVention, 2009; Stevens, 2008; Younger et al., 2008. 31. Auld et al., 2004; Auld, 2008a; CCCD, 2009; Curriero et al., 2001; DaSilva et al., 2004; Ebi et al., 2006; Haines et al., 2006; Patz et al., 2000, 2005; UNFCCC, 2006a; WHO, 2003, 2005; World Bank, 2003. 32. CCCD, 2009; Ebi et al., 2006; Ebi, 2008; Haines et al., 2006; Patz et al., 2005; UNFCCC, 2006a; WHO, 2003, 2005; Younger et al., 2008. 33. Mills, 2005, 2006. 34. Haines et al., 2006; Younger et al., 2008.

into the future, some studies recommend the use of pro-adaptation and robust options to deal with climate change uncertainties (Auld, 2008b; Hallegatte, 2009; Wilby and Dessai, 2010). These robust options include actions that are reversible, flexible, less sensitive to future climate conditions (i.e., no and low regret), and can incorporate safety margins (e.g., infrastructure investments), employ 'soft' solutions (e.g., ecosystem services), and are mindful of actions being taken by others to either reduce greenhouse gases (GHGs) or adapt to climate change in other sectors (Hallegatte, 2009; Wilby and Dessai, 2010). Flexible options are those that provide benefits under a variety of climate conditions or reduce stress on affected systems to increase their flexibility (e.g., reducing pollution or demand on resources) (Auld, 2008b; Hallegatte, 2009; Wilby and Dessai, 2010).

Options that allow for incremental changes in, for example, infrastructure over time, or allow incorporation of future change, for example, support more flexible systems (Auld, 2008b; Hallegatte, 2009; OECD, 2009). Uncertainties over future risks can also be accounted for through 'safety margin' or over-design strategies to reduce vulnerability and increase resiliency at low and sometimes null costs (Auld, 2008b; Hallegatte, 2009). These safety margin strategies have been used to manage future risks for sea level rise and coastal defenses, for water drainage management, and for investments in other infrastructure (Hallegatte, 2009). Given uncertainties, national policies may need to become more adaptable and flexible, particularly where national plans and policies currently operate within a limited range of conditions and are based on certainty (McGray et al., 2007; Wilby and Dessai, 2010). Without flexibility, rigid national policies may become disconnected from evolving climate risks and bring unintended consequences or maladaptation (Sperling and Szekely, 2005; Hallegatte, 2009). Rigid plans and policies that are irreversible and based on a specific climate scenario that does not materialize can result in future maladaptation and imply wasted investments or harm to people and ecosystems that can prove unnecessary.

Several studies indicate that national plans and policies for adaptation to climate change and disaster risk management tend to favor options that deal with the current or near-term climate risks and 'win-win' options that satisfy multiple synergies for GHG reduction, disaster risk management, climate change adaptation, and development issues (World Bank, 2008; Heltberg et al., 2009; Ribeiro et al., 2009; Fankhauser, 2010; Mitchell and Maxwell, 2010). Many of these 'win-win' options include ecosystem-based adaptation actions, sustainable land and water use planning, carbon sequestration, energy efficiency, and energy and food self-sufficiency. For example, the ecosystem management practices of afforestation, reforestation, and conservation of forests offer co-benefits for disaster risk reduction from floods, landslides, avalanches, coastal storms, and drought while contributing to adaptation to future climates, economic opportunities, increased biomass and carbon sequestration, energy efficiency, energy savings, as well as energy and food self sufficiency (Thompson et al., 2009).

Disaster risk transfer options offer a viable adaptation response to current and future climate risks and include instruments such as insurance, micro-insurance, and micro-financing; government disaster reserve funds; government-private partnerships involving risk sharing; and new, innovative insurance mechanisms (Linnerooth-Bayer and Mechler, 2006; EC, 2009; World Bank, 2010). Risk transfer options can provide much needed, immediate liquidity after a disaster, allow for more effective government response, provide some relief from the fiscal burden placed on governments due to disaster impacts, and constitute critical steps in promoting more proactive risk management strategies and responses (Arnold, 2008). Case Study 9.2.13 and Section 6.5.3 provide more detail on risk transfer options.

Even with risk transfer instruments and adaptation to climate change options in place, residual losses can be realized when extreme events – well beyond those typically expected – result in high impacts. In spite of the evidence, decisions to ignore increasing future risks and even current risks remain common, particularly when uncertainties over the directions of future climate change impacts are high, when capacity is initially very limited, adaptation options are not available, or when the risks of future impacts are considered to be very low (Linnerooth-Bayer and Mechler, 2006; Heltberg et al., 2009; World Bank, 2010).The losses from deferring adaptation and disaster risk reduction actions are borne by all actors.

Table 6-1 outlines some of the adaptation to climate change and disaster risk management policy and planning options available nationally for selected sectors and described in the literature. Many of these options are incremental actions that complement and reinforce each other. The actions are organized using the gradations of planning and policy options described in this section.

6.3.2. Mainstreaming Disaster Risk Management and Climate Change Adaptation into Sectors and Organizations

National adaptation to climate change will involve stand-alone adaptation policies and plans as well as the integration or mainstreaming of adaptation measures into existing activities (OECD, 2009). Mainstreaming of adaptation and disaster risk management actions implies that national, sub-national, and local authorities adopt, expand, and enhance measures that factor disaster and climate risks into their normal plans, policies, strategies, programs, sectors, and organizations (Few et al., 2006; UNISDR, 2008a; OECD, 2009; Biesbroek et al., 2010; CACCA, 2010).

In reality, it can be challenging to provide clear pictures of what mainstreaming is, let alone how it can be made operational, supported, and strengthened at the various national and sub-national levels (Olhoff and Schaer, 2010). Some studies indicate that the real challenge to mainstreaming adaptation is not planning but implementation (Biesbroek et al., 2010; Krysanova et al., 2010; Tompkins et al., 2010). Some of the barriers to implementation include lack of funding, limited budget flexibility, lack of relevant information or expertise, lack of political will or support, and institutional silos (Krysanova et al., 2010;

Preston et al., 2011). Studies indicate that effective plans, policies, and programs for adaptation to climate change and disaster risk management need to go beyond identifying potential options to include better inventories of existing assets and liabilities for managing risk and specific actions for overcoming adaptation barriers (Haasnoot et al., 2009; Preston et al., 2011).

Recent studies investigating the success of existing adaptation plans and policies for Australia, the United States, countries in Europe, and major river basins in Africa and Asia, for example, indicate that there is a need for mainstreaming of adaptation into existing national policies and plans and a priority for capitalizing on 'win-win' or options that take advantage of synergies with other national objectives (Biesbroek et al., 2010; Tompkins et al., 2010; Preston et al., 2011). The studies found that many strategies and institutions were focused to a greater extent on lower-risk actions dealing with science and outreach (knowledge acquisition) and capacity building rather than moving forward on specific, more costly and difficult to implement adaptation and disaster risk management actions and managing at-risk public goods (Tompkins et al., 2010; Preston et al., 2011).

Preston et al. (2011) found in their studies from Australia, the United States, and the United Kingdom that most national adaptation strategies were based on vulnerability assessments informed by broad international and national climate change guidance, rather than any consistent or systematic use of scenarios, and favored bottom-up approaches for coordination across sectors and multiple government scales. Biesbroek et al. (2010) noted similar results for nine countries in Europe. Tompkins et al. (2010) and Krysanova et al. (2010) found that the sectors with the highest levels of adaptation implementation in the United Kingdom were those that tended to be most affected by current weather variability and extremes and that specific government initiatives had been successful in stimulating adaptation and disaster risk reduction (e.g., mandatory planning for flood-prone areas, ISO 14001). Tompkins et al. (2010) also found that successful implementation frequently resulted from multiple triggers, that few of these adaptation actions were solely initiated in response to climate change, and that the relative impact of weather on core business and organizational culture encouraged an ability and willingness to proactively act on climate change information.

Adaptation to climate change and disaster risk management needs to typically identify more adaptation options than most countries can reasonably implement in the short term due to resource constraints, requiring that actions be prioritized (OECD, 2009; Krysanova et al., 2010). Initially, actions that remove the existing barriers to managing disaster risks from today's climate variability can help to reduce the even greater barriers to managing future climate risks (UNDP, 2002, 2004a; CCCD, 2009; Prabhakar et al., 2009; Tompkins et al., 2010). As a result, a key challenge, and an opportunity for mainstreaming adaptation and disaster risk management, lies in building bridges between current disaster risk management actions for existing climate vulnerabilities and the additional revised efforts needed for future vulnerabilities (Few et al., 2006; Krysanova et al., 2010; Olhoff and Schaer, 2010; Wilby and Dessai, 2010).

An important prerequisite for informed decisions on adaptation to climate change and disaster risk management is that they should be based upon the best available information (OECD, 2009; Biesbroek et al., 2010; Lu, 2011). Preston et al. (2011) noted that many of the specific adaptation plans from Australia, the United States, and the United Kingdom indicated a need for improved gathering and sharing of climate and climate change science information prior to or in conjunction with the delivery of adaptation actions, perhaps reflecting a preference for delaying adaptation actions until greater certainty or better information on different adaptation actions was known. As noted in Chapter 3 (Section 3.2.3 and Box 3-2), many extreme events occur at small temporal and spatial scales, where climate change models, even when downscaled, cannot provide simulations at such spatial and temporal resolutions. A number of studies also contend that increased and better information on climate change scenarios and projections and potential impacts will accomplish little on their own to mainstream and alter on-the-ground decisions, policies, and plans unless the information provided can directly meet decisionmakers' needs (Stainforth et al., 2007; Auld, 2008b; Haasnoot et al., 2009; Krysanova et al., 2010; Mastrandrea et al., 2010; Wilby and Dessai, 2010). Users require relevant climate risk information that is accessible, can be explained in understandable language, provides straightforward estimates of uncertainties, and is relevant or tailored to their management functions (Stainforth et al., 2007; Mastrandrea et al., 2010; Lu, 2011). Increasingly, studies are showing that this is best accomplished through sustained interactions between scientists and stakeholders and policymakers, usually maintained through years of relationship- and trust-building (Mastrandrea et al., 2010; Wilby and Dessai, 2010; Lu, 2011).

Studies generally indicate that the most essential means for effectively mainstreaming both adaptation and disaster risk management nationally involve 'whole of government' coordination across different levels and sectors of governance, including the involvement of a broad range of stakeholders (Few et al., 2006; Thomalla et al., 2006; OECD, 2009; also Section 6.4.2). In spite of the strong interdependencies, governments have tended to manage these issues in their 'silos' with environment or energy authorities and scientific institutions typically responsible for climate change adaptation while disaster risk management authorities may reside in a variety of national government departments and national disaster management offices (Sperling and Szekely, 2005; Thomalla et al., 2006; Prabhakar et al., 2009). Progress in planning for adaptation and developing and implementing strategies within government agencies usually depends on political commitment, institutional capacity, and, in some cases, on enabling legislation, regulations, and financial support (Few et al., 2006; OECD, 2009; Krysanova et al., 2010; see Section 6.4). Nationally, studies indicate that it may be important to clearly identify a lead for disaster and climate risk reduction efforts where that lead has influence on budgeting and planning processes (Few et al., 2006; OECD, 2009). In some cases, countries and regions may be able to build on phases of raised awareness and increased attention to disaster risk in order to develop and strengthen their responsible institutions (Few et al., 2006; Krysanova et al., 2010).

While developed countries may be more financially equipped to meet many of the challenges of mainstreaming adaptation and disaster risk reduction into national plans and policies, the situation is often more challenging in developing countries (Krysanova et al., 2010). Nonetheless, there are examples from developing countries where adaptation to climate change and disaster risk management mainstreaming issues have been priorities for many years and significant progress in mainstreaming has been noted (e.g., the Caribbean Mainstreaming Adaptation to Climate Change project, which was implemented from 2004 to 2007; Case Studies 9.2.9 and 9.2.12). In other cases, international funding mechanisms such as the Least Developed Countries (LDC) Fund, the Special Climate Change Fund, the Multi-donor Trust Fund on Climate Change, and the Pilot Programme for Climate Resilience under the Climate Investment Fund are making funding and resources available to developing countries to pilot and mainstream changing climate risks and resilience into core development and as an incentive for scaled-up action and transformational change, although needs exceed availability of funds (O'Brien et al., 2008; Krysanova et al., 2010; see Sections 7.4.3.3 and 7.4.2 for additional discussion).

6.3.3. Sector-Based Risk Management and Adaptation

The challenge for countries is to manage short-term climate variability while also ensuring that different sectors and systems remain resilient and adaptable to changing extremes and risks over the long term (Füssel, 2007; Wilby and Dessai, 2010). The requirement is to balance the short-term and the longer-term actions needed to resolve the underlying causes of vulnerability and to understand the nature of changing climate hazards (UNFCCC, 2008a; OECD, 2009). Achieving adaptation and disaster risk management objectives while attaining human development goals requires a number of cross-cutting, interlinked sectoral and development processes, as well as effective strategies within sectors and coordination between sectors (Few et al., 2006; Thomalla et al., 2006; Biesbroek et al., 2010). Climate change is far too big a challenge for any single ministry of a national government to undertake (CCCD, 2009; Biesbroek et al., 2010).

Sector-based organizations and departments play a central role in national decisionmaking and are a logical focus for adaptation actions (McGray et al., 2007; Biesbroek et al., 2010). The impacts of changing climate risks in one sector, such as tourism, can affect other sectors and scales significantly, especially since sectoral linkages operate both vertically and horizontally. Sector plans, policies, and programs are linked vertically from national to local levels within the same sector as well as horizontally across different sectors at the same level (Urwin and Jordan, 2008; UNFCCC, 2008b; CCCD, 2009; Biesbroek et al., 2010). While the case and need for integration within sectors and levels may be clear, the issue of how to integrate or mainstream nationally across multiple sectors and multiple levels still remains challenging, requiring governance mechanisms and coordination that can cut across governments and sectoral organizations (UNISDR, 2005; UNFCCC, 2008b; CCCD, 2009; ONERC, 2009; Biesbroek et al., 2010). Typically, multi-sector integration tends to deal with the broader national scale (e.g., entire economy or system) and aims to be as comprehensive as possible in covering several affected sectors, regions, and issues (UNFCCC, 2008b). Studies from organizations and academia indicate that effective adaptation and risk reduction coordination between all sectors may only be realized if all areas of government are coordinated from the highest political and organizational level (Schipper and Pelling, 2006; UNFCCC, 2008b; CCCD, 2009; Prabhakar, 2009). Even when 'political champions' at the highest levels encourage mainstreaming across sectors and departments, competing national priorities will remain an impediment to progress.

Table 6-1 (Section 6.3.1) outlines adaptation to climate change and disaster risk management options for several selected sectors. As the table indicates, adaptation and disaster risk management approaches for many development sectors benefit jointly from ecosystem-based adaptation and integrated land, water, and coastal zone management actions. For example, conservation and sustainable management of ecosystems, forests, land use, and biodiversity have the potential to create win-win disaster risk protection services for agriculture, infrastructure, cities, water resource management, and food security. They can also create synergies between climate change adaptation and mitigation measures (SCBD, 2009; CCCD, 2009), as well as produce many co-benefits that address other development goals, including improvements in livelihoods and human well being, particularly for the poor and vulnerable, and biodiversity conservation, and are discussed further in Section 6.5.2.3 and in Case Studies 9.2.3, 9.2.4, 9.2.5, 9.2.7, 9.2.8, and 9.2.9. Likewise, water resource, land, and coastal zone management options deal with many sectors and issues and jointly provide disaster risk management and adaptation solutions, as mentioned in Case Studies 9.2.6 and 9.2.8 (WHO, 2003; Urwin and Jordan, 2008; UNFCCC, 2008b; CCCD, 2009; WWAP, 2009). Human health is a cross-cutting issue impacted by actions taken in many sectors, as indicated in Table 6-1 and discussed in Case Studies 9.2.2 and 9.2.7.

6.4. Strategies including Legislation, Institutions, and Finance

National systems for managing the risks of extreme events and disasters are shaped by legislative provision, compliance mechanisms, the nature of cross-stakeholder bodies, and financial and budgetary processes that allocate resources to actors working at different scales. These elements help to create the technical architecture of national systems and are often led by national government agencies. However non-technical dimensions of good governance, such as the distribution and decentralization of power and resources, processes for decisionmaking, transparency, and accountability are woven into the technical architecture and are significant factors in determining the effectiveness of risk management systems and actions (UNDP, 2004b, 2009). These technical and non-technical aspects of risk governance vary between countries as governance capacity varies (and, as detailed in Section 6.3, are critical in shaping investment in particular adaptation and disaster risk management options). Accordingly, risks can be addressed through both formal and informal governance modes and institutions in all countries (Jaspars and Maxwell, 2009), but a clear correlation between particular risk governance models and specific political-administrative contexts is difficult to identify (UNISDR, 2011a). The balance between formal or informal, or technical and non-technical, risk governance strategies depends on the economic, political, and environmental contexts of individual countries or scales within countries, and the culture of managing risks (Menkhaus, 2007; Kelman, 2008).

6.4.1. Legislation and Compliance Mechanisms

Disaster risk management legislation commonly establishes organizations and their mandates, clarifies budgets, provides (dis)incentives, and develops compliance and accountability mechanisms (UNDP, 2004b; Llosa and Zodrow, 2011). Creating and improving legislation for disaster risk reduction was included as a priority area in the HFA (UNISDR, 2005) and the majority of countries – in excess of 80% – now have some form of disaster risk management legislation (UNISDR, 2005; Bhavnani et al., 2008). Legislation continues to be considered as an important component of effective national disaster risk management systems (UNDP, 2004b; UNISDR, 2011a) as it creates the legal context of the enabling environment in which others, working at different scales, can act, and it helps to define people's rights to protection from disasters, assistance, and compensation (Pelling and Holloway, 2006). Multi-stakeholder, cross-sector bodies for coordinating disaster risk management actions and implementing the HFA, known commonly as National Platforms, are seen as key advocacy routes for achieving new and improved legislation (UNISDR, 2005, 2007b). Where National Platforms are less prevalent or less well organized, literature suggests that regional disaster management bodies are viewed as responsible for advancing legislation (Pelling and Holloway, 2006; UNISDR, 2007b). With new information on the impacts of climate change, legislation on managing disaster risk may need to be modified and strengthened to reflect changing rights and responsibilities and to support the uptake of adaptation options (UNDP, 2009; Llosa and Zodrow, 2011; see Case Study 9.2.12 on legislation).

There have been few detailed cross-comparative studies that assess the extent to which legislation in different countries is oriented toward managing uncertainty and reducing disaster risk compared with disaster response (Llosa and Zodrow, 2011). Limited evidence suggests that legislation in some countries (such as the United Kingdom, the United States, and Indonesia) has led to a focus on building institutional capacity to help create resilience to disasters at different scales, but even in such cases a strongly reactive culture is retained when observing the system as a whole (O'Brien and Read, 2005, O'Brien, 2006, 2008; UNDP, 2009; O'Brien and O'Keefe, 2010). This has been attributed to lack of political will and insufficient financial and human resources for disaster risk reduction (O'Brien 2006, 2008). Additionally, few studies have assessed whether disaster risk management legislation includes provision for the impact of climate change on disaster risk or whether aspects of managing disaster risk are included in other complementary pieces of legislation (Case Study 9.2.12; Llosa and Zodrow, 2011), though there are also a very limited number of normative studies on these aspects (Llosa and Zodrow, 2011). However, where reforms of disaster management legislation have occurred, they have tended to: (a) demonstrate a transition from emergency response to a broader treatment of managing disaster risk; (b) recognize that protecting people from disaster risk is at least partly the responsibility of governments; and (c) promote the view that reducing disaster risk is everyone's responsibility (Case Study 9.2.12; UNDP, 2004b; Llosa and Zodrow, 2011).

Vietnam has taken steps to integrate disaster risk management into legislation across key development sectors, including its Land Use Law and Law on Forest Protection. Vietnam's Poverty Reduction Strategy Paper also included a commitment to reduce by 50% those falling back into poverty as a result of disasters and other risks (Pelling and Holloway, 2006). Case Study 9.2.12, in examining legislation development processes in the Philippines and South Africa, highlights a number of components of effective disaster risk management legislation. An act needs to be: (a) comprehensive and overarching; (b) establish management structures and secure links with development processes at different scales; and (c) establish participation and accountability mechanisms that are based on information provision and effective public awareness and education. Box 6-1 supplements these cases with reflections on the process that led to the creation of disaster risk management legislation in Indonesia.

Where risk management dimensions are a feature of national legislation, positive changes are not always guaranteed (UNDP, 2004b). A lack of financial, human, or technical resources and capacity constraints present significant obstacles to full implementation, especially as experience suggests that legislation should be implemented continuously from the national to local level and is contingent on strong monitoring and enforcement frameworks and adequate decentralization of responsibilities and human and financial resources at every scale (UNDP, 2004b; Pelling and Holloway, 2006). In some countries, building codes, for instance, are often not implemented properly because of a lack of technical capacity and political will of officials concerned (UNDP, 2004b). Where enforcement is unfeasible, accountability for disaster risk management actions is extremely challenging; this supports the need for an inclusive, consultative process for discussing and drafting the legislation (UNDP, 2004b; UNISDR, 2007b). Effective legislation includes benchmarks for action, a procedure for evaluating actions, integrated planning to assist coordination across geographical or sectoral areas of responsibility, and a feedback system to monitor risk reduction activities and their outcomes (UNISDR, 2005; Pelling and Holloway, 2006).

6.4.2. Coordinating Mechanisms and Linking across Scales

As the task of managing the risks of changing climate conditions and climate extremes and disasters cuts across the majority of sectors and involves a wide range of actors, multi-stakeholder and cross-government mechanisms are commonly cited as preferred way to 'organize' disaster

Box 6-1 | Enabling Disaster Risk Management Legislation in Indonesia

Indonesia: Disaster Management Law (24/2007)

The legislative reform process in Indonesia that resulted in the passing of the 2007 Disaster Management Law (24/2007) created a stronger association between disaster risk management and development planning processes. The process was considered successful due to the following factors:

- **Strong, visible professional networks** – Professional networks born out of previous disasters meant a high level of trust and willingness to coordinate and became pillars of the legal reform process. The political and intellectual capital in these networks, along with leadership from the MPBI (The Indonesian Society for Disaster Management), was instrumental in convincing the lawmakers about the importance of disaster management reform.
- **Civil society leading the advocacy** – Civil society leading the advocacy for reform has resulted in CSOs being recognized by the Law as key actors in implementing disaster risk management in Indonesia.
- The impact of the 2004 South Asian tsunami helping to create a supportive **political environment** – The reform process was initiated in the aftermath of the tsunami that highlighted major deficiencies in disaster management. However, the direction of the reform (from emergency management toward disaster risk reduction) was influenced by the international focus, through the HFA, on disaster risk reduction.
- An **inclusive drafting process** – Consultations on the new Disaster Management Law were inclusive of practitioners and civil society, but were not so far-reaching as to delay or lose focus on the timetable for reform.
- Consensus that **passing an imperfect law is better than no law at all** – An imperfect law can be supplemented by additional regulations, which helps to maintain interest and focus.

Source: UNDP (2004b, 2009); Pelling and Holloway (2006).

risk management systems at the national level (UNISDR, 2005, 2007b; see Section 6.3.3), as well as for addressing the challenges associated with adaptation to climate change (ONERC, 2009). The HFA terms these 'National Platforms,' defined as a "generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are multi-sectoral and inter-disciplinary in nature, with public, private and civil society participation involving all concerned entities within a country" (UNISDR, 2005). In some countries such coordinating mechanisms are referred to by other names (Hay, 2009; Gero et al., 2011) but essentially perform the same function. Guidelines on establishing National Platforms suggest that they need to be built on existing relevant systems and should include participation from different levels of government, key line ministries, disaster management authorities, scientific and academic institutions, civil society, the Red Cross/Red Crescent, the private sector, opinion shapers, and other relevant sectors associated with disaster risk management (UNISDR, 2007b). Evaluations and reflections on the effectiveness of National Platforms for delivering results on the HFA and on disaster risk management more broadly indicate widely varying results (GTZ/DKKV, 2007; UNISDR, 2007c, 2008c; UNISDR/DKKV/Council of Europe, 2008; Sharma, 2009). An assessment in Asia found National Platforms struggling to obtain the legal mandate to secure full participation of stakeholders, particularly NGOs, difficulty in obtaining sustainable funding sources, and challenges associated with translating intent into implementation (Sharma, 2009). On the other hand, pockets of evidence exist where National Platforms have succeeded in generating senior political commitment for disaster risk reduction, in strengthening integration of disaster risk reduction into national policy and development plans, and in establishing institutions and programs on disaster risk management with engagement from academia, media, and the private sector (UNISDR, 2008b; Sharma, 2009). This assessment found only a limited number of genuinely independent studies on the effectiveness of National Platforms, with evidence particularly weak in Africa and elsewhere.

While the evidence again suggests significant differences between countries, on balance, national coordination mechanisms for adaptation to climate change and disaster risk management remain largely disconnected, although evidence suggests that the trajectory is one of improvement (National Platform for Kenya, 2009; Mitchell et al., 2010b; discussed in Chapter 1). Benefits of improved coordination between adaptation to climate change and disaster risk management bodies, and development and disaster management agencies, include the ability to (i) explore common tradeoffs between present and future action, including addressing human development issues and reducing sensitivity to disasters versus addressing post-disaster vulnerability; (ii) identify synergies to make best use of available funds for short- to longer-term adaptation to climate risks as well as to tap into additional funding sources; (iii) share human, information, technical, and practice resources; (iv) make best use of past and present experience to address emerging risks; (v) avoid duplication of project activities; and (vi) collaborate on reporting requirements (Mitchell and Van Aalst, 2008). Barriers to integrating disaster risk management and adaptation coordination mechanisms include the underdevelopment of the 'preventative' component of disaster risk management, the paucity of projects that

Box 6-2 | National and Sub-National Coordination for Managing Disaster Risk in a Changing Climate: Kenya

Kenya's National Platform is situated under the Office of the President and has made significant achievements in coordinating multiple stakeholders, but is constrained by limited resources and lack of budgets for disaster risk reduction in line ministries (National Platform for Kenya, 2009). Some key constraints of the national system are recognized as being difficulties in integrating disaster risk reduction in planning processes in urban and rural areas and lack of data on risks and vulnerabilities at different scales (Few et al., 2006). In this regard, Nairobi has experienced periods of drought and heavy rains in the last decade, prompting action to reduce exposure and vulnerability to what is perceived as changing hazard trends (ActionAid, 2006). Increasing exposure and vulnerability has resulted from a rapid expansion of poor people living in informal settlements around Nairobi, leading to houses of weak building materials being constructed immediately adjacent to rivers and blocking natural drainage areas. While data and coordination systems are still lacking, the Government of Kenya has established the Nairobi Rivers Rehabilitation and Restoration Programme (African Development Bank Group, 2010), designed to install riparian buffers, canals, and drainage channels, while also clearing existing channels. The Programme also targets the urban poor with improved water and sanitation, paying attention to climate variability and change in the location and design of wastewater infrastructure and environment monitoring for flood early warning (African Development Bank Group, 2010). This demonstrates the kind of options for investments that can be achieved in the absence of a fully fledged nationally coordinated disaster management system and in the absence of complete multi-hazard, exposure, and vulnerability data sets.

integrate climate change in the context of disaster risk management, disconnects between different levels of government, and the weakness of both disaster risk management and adaptation to climate change in national planning and budgetary processes (Few et al., 2006; Mitchell and Van Aalst 2008; Mitchell et al., 2010b) (see Box 6-2).

While national level coordination is important and the majority of risks associated with disasters and climate extremes are owned by national governments and are managed centrally (see Section 6.2.1), sources suggest that decentralization can be an effective risk management strategy, especially in support of community-based disaster risk management processes (Mitchell and Van Aalst, 2008; GNDR, 2009; Scott and Tarazona, 2011). However, there are few studies that critically examine the effectiveness of decentralization of disaster risk management in detail (Twigg, 2004; Tompkins et al., 2008; Scott and Tarazona, 2011). One such study of four countries – Colombia, Mozambique, Indonesia, and South Africa – found that effective decentralization of disaster risk reduction can be constrained by (a) low capacity at the local level; (b) funds dedicated to disaster risk reduction often being channeled elsewhere; (c) the fact that decentralization does not automatically lead to more inclusive decisionmaking processes; (d) an appreciation that decentralized systems face significant communications challenges; and (e) knowledge that robust measures for ensuring accountability and transparency are vital for effective disaster risk management but are often missing (Scott and Tarazona, 2011). It appears that motivation for management at a particular scale promises to influence how well the impacts of disasters and climate change are managed, and therefore affect disaster outcomes (Tsing et al., 1999). Decisions made at one scale may have unintended consequences for another (Brooks and Adger, 2005), meaning that governance decisions will have ramifications across scale and contexts. In all cases, the selection of a framework for governance of disasters and climate change-related risks may be issue- or context-specific (Sabatier, 1986).

6.4.3. Finance and Budget Allocation

Governments in the past have ignored catastrophic risks in decisionmaking, implicitly or explicitly exhibiting risk-neutrality (Mechler, 2004). This is consistent with the Arrow Lind theorem (Arrow and Lind, 1970), according to which a government may be well equipped to efficiently (i) pool risks as it possesses a large number of independent assets and infrastructure so that the aggregate risk converges to zero, and/or (ii) spread risk across the taxpaying population base, so that per capita risk accruing to risk-averse households converges to zero. In line with this theorem, due to their ability to spread and diversify risks, governments are sometimes termed 'the most effective insurance instrument of society' (Priest 1996). Accordingly, it has been deduced that, although individuals are risk-averse [to disasters risk], governments can take a risk-neutral approach. However, the experiences of highly exposed countries suggest otherwise and have led to a recent paradigm shift, with governments changing from being 'risk neutral' to being risk averse and managing disaster risks. Many highly exposed developing and developed countries (especially in the wake of the recent financial crisis) have very limited economic means, rely on small and exhausted tax bases, have high levels of indebtedness, and are unable to raise sufficient and timely capital to replace or repair damaged assets and restore livelihoods following major disasters. This can lead to increased impacts of disaster shocks on poverty and development (OAS, 1991; Linnerooth-Bayer et al., 2005; Hochrainer, 2006; Mahul and Ghesquiere, 2007; Cummins and Mahul, 2009). Exposed countries thus have had to rely on donors to 'bail' them out after events, although ex-post assistance usually only provides partial relief and reconstruction funding, and such assistance is also often associated with substantial time lags (Pollner, 2000; Mechler, 2004).

Furthermore, extreme events that are associated with large losses may lead to important downstream economic effects (see Section 4.5), causing depressed incomes and reduced ability to share the losses.

Table 6-2 | Government liabilities and disaster risk. Modified from Polackova Brixi and Mody (2002).

Liabilities	**Direct**: obligation in any event	**Contingent**: obligation if a particular event occurs
Explicit: Government liability recognized by law or contract	Foreign and domestic sovereign borrowing, expenditures by budget law and budget expenditures	State guarantees for non-sovereign borrowing and public and private sector entities, reconstruction of public infrastructure
Implicit: A 'moral' obligation of the government	Future recurrent costs of public investment projects, pensions, and health care expenditure	Default of sub-national government as public or private entities provide disaster relief

Consequently, a risk-neutral stance in dealing with catastrophic risk (implying that the consideration of risk broadly in terms of means – the statistical expectation – is sufficient) may not be suitable for exposed developing countries with limited diversification of their economies or small tax bases. Accordingly, assessing and managing risks over the whole spectrum of probabilities is gaining momentum (Cardenas et al., 2007; Cummins and Mahul, 2009). As the Organization of American States suggests: "Government decisions should be based on the opportunity costs to society of the resources invested in the project and on the loss of economic assets, functions and products. In view of the responsibility vested in the public sector for the administration of scarce resources, and considering issues such as fiscal debt, trade balances, income distribution, and a wide range of other economic and social, and political concerns, governments should not act risk-neutral" (OAS, 1991). Also, in more developed economies, less-pronounced but still considerable effects imposed by events linked to climate variability can be identified. This has been shown by the Austrian political and fiscal crisis in the aftermath of large-scale flooding that led to billions of Euros in losses in 2002 (Mechler et al., 2010).

Budget and resource planning for extremes is not an easy proposition. Governments commonly plan and budget for *direct* liabilities, that is, liabilities that manifest themselves through certain and annually recurrent events. Those liabilities are of explicit (as recognized by law or contract), or implicit nature (moral obligations) (see Table 6-2). Yet, governments are not good at planning for contingencies even for probable events, let alone improbable events. Explicit, contingent liabilities deal with the reconstruction of infrastructure destroyed by events, whereas implicit obligations are associated with providing relief – commonly considered as a moral liability for governments (Polackova Brixi and Mody, 2002). In many countries, governments do not explicitly plan for contingent liabilities, and rely on reallocating their resources following disasters and raising capital from domestic and international donations to meet infrastructure reconstruction needs and costs.

More recently, some developing and transition countries that face large contingent liabilities in the aftermath of extreme events and associated financial gaps have begun to plan for and consider contingent natural events (also see Section 6.5.3). Mexico, Colombia, and many Caribbean countries now include contingent liabilities in their budgetary process and eventually even transfer some of these risks (Cardenas et al., 2007; Linnerooth-Bayer and Mechler, 2007; Cummins and Mahul, 2009; see Box 6-3). Similarly, many countries have also started to focus on improving human development conditions as an adaptation strategy for climate change and extreme events, particularly with the help of international agencies such as the World Bank. These deliberations are

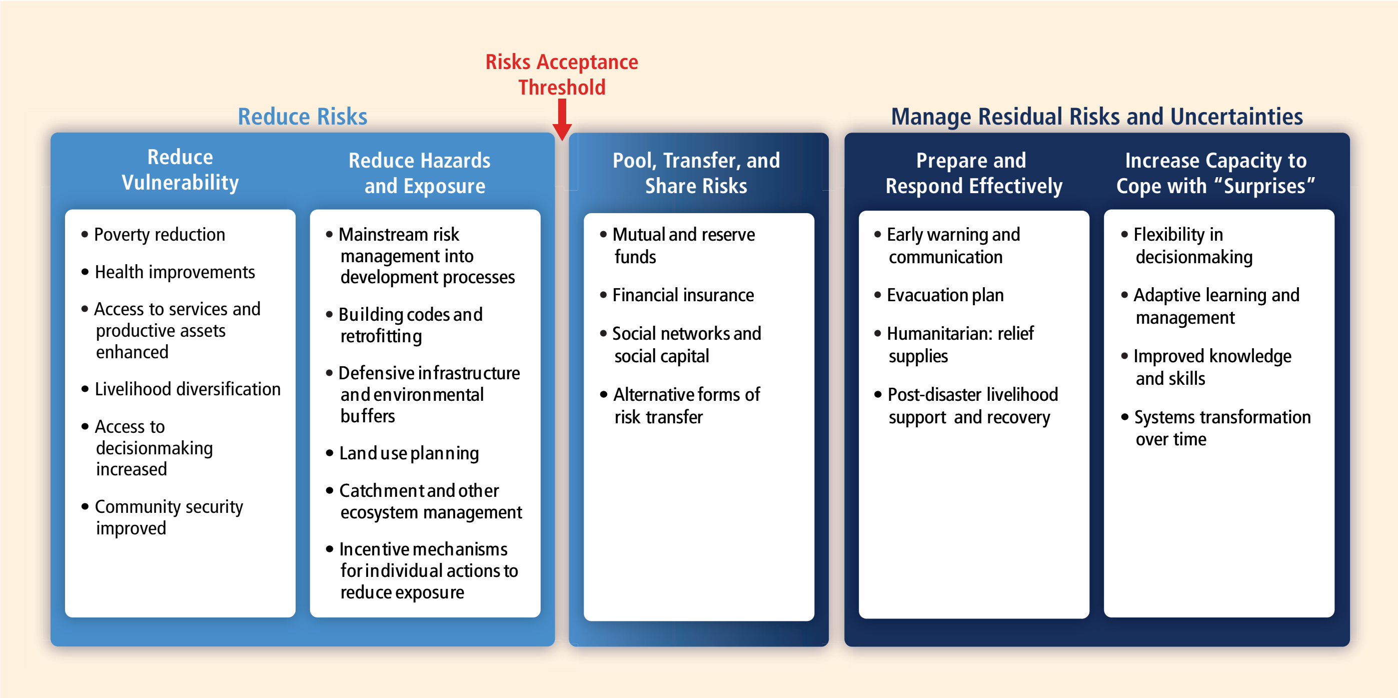

Figure 6-3 | Complementary response measures for observed and projected disaster risks supported by respective institutional and individual capacity for making informed decisions.

Box 6-3 | Mexico's Fund for Natural Disasters, FONDEN

Mexico is exposed to natural hazards due to its location within one of the world's most active seismic regions and in the path of hurricanes and tropical storms originating in the Caribbean Sea and Atlantic and Pacific Oceans. There have been many disaster events and in the past severe hurricane disasters (in addition to earthquakes) have created large fiscal liabilities and imbalances (Cardenas et al., 2007). Given high perceived financial vulnerability to disasters, in 1994, the Mexican Government passed a law that required federal, state, and municipal public assets to be insured. This was intended to relieve the central government of the obligation of having to pay for the reconstruction of public infrastructure, although the adequate level of insurance, particularly for very large events remained a concern. As a next step, in 1996, the national government established a system of allocating resources for disaster spending (FONDEN) in order to enhance the country's financial preparedness for disaster losses and prevent imbalances in the federal government finances derived from outlays caused by catastrophes. FONDEN serves as last-resort funding for uninsurable losses, such as emergency response and disaster relief expenditures. In addition to this budgetary program, in 1999, a reserve fund was created that accumulates the surplus of the previous year's FONDEN budget item (Cardenas et al., 2007).

After the initial phase that was characterized by spending in line with requirements caused by disaster events, one concern for the disaster management authorities became the regular demands on the funds in non-disaster years. As a consequence, budgeted FONDEN resources were declining while demands on FONDEN's resources were becoming more volatile, and outlays often exceeded budgeted funds causing the reserve fund to decline. In 2005, after the severe hurricane season affecting large parts of coastal Mexico, the fund was finally exhausted. This forced the Mexican Government to look at alternative risk financing strategies, which included hedging against disaster shocks, government agencies at all levels providing their insurance protection independent of FONDEN, and that FONDEN itself should only indemnify losses that exceed the financial capacity of the federal, local, or municipal government agencies. In 2006, Mexico became the first transition country to transfer part of its public sector catastrophe risk to the international reinsurance and capital markets, and, in 2009, the transaction was renewed for another three years, covering both hurricane and earthquake risk (Cardenas et al., 2007).

in line with the described 'no' and 'low regrets' strategies discussed in Section 6.3.1.

6.5. Practices including Methods and Tools

With some success and with many challenges, countries are increasingly adopting a diverse range of approaches, methods, and tools to manage disaster risk and adapt to a changing climate, with the intention of building a safe, secure society. This section discusses efforts made in building a culture of safety (Section 6.5.1), which includes methods associated with assessing and communicating risk; reducing climate-related disaster risks (Section 6.5.2); transferring and sharing residual risks (Section 6.5.3); and managing the impacts of disasters holistically (Section 6.5.4), as disaster risks can never be reduced to zero. Accordingly, it is important to recognize that the approaches, methods, and tools discussed here are complementary, often overlapping, and can be pursued simultaneously. Whereas the Summary for Policymakers includes a visual representation of the range of such approaches (see Figure SPM-2), Figure 6-3 on the previous page is tailored to incremental action at the national level.

Figure 6-3 characterizes the range of risk management and adaptation options open to stakeholders involved in national systems for managing disaster risk. Such options exist along a continuum of action, with choices between different options being dependent on the quality of information and how it is communicated, the findings of risk assessments, the culture of risk management/acceptability of risk, and on capacities and resources. In practice, different options will likely be pursued simultaneously and will have a high degree of co-dependence.

6.5.1. Building a Culture of Safety

Building a culture of safety involves several strategies and activities that start with the assessment of risk factors and development of information systems that provide relevant information for critical decisionmaking. It also involves understanding the large variety of beliefs and core value systems, which will help determine decisions made by different actors and stakeholders. A key ingredient is appropriate public education and awareness raising, and as such, early warning systems play an important role in managing residual risk as they can provide timely warnings to exposed communities and thus can promote action for a quick response. Time series empirical data used to generate risk assessments, including those contributing to early warnings, are also critical for long-term planning because of their relevance in generating appropriate information about adequate land use planning, for example, to reduce climatic risks. As examples, in the same sense, analyzed information about climate-adapted infrastructure, enhanced human development, ecosystems protection, risks transfer, and sharing and managing the impacts of climate-related disasters can play a fundamental role in building a culture and practice of human safety.

6.5.1.1. Assessing Risks and Maintaining Information Systems

As discussed widely in Chapter 1, the first key step in managing risk is to assess and characterize it. In terms of risk factors, disaster risk is commonly defined by three elements: the hazard, exposure of elements, and vulnerability (Swiss Re, 2000; Kuzak, 2004; Grossi and Kunreuther, 2005; CACCA, 2010). Thus, understanding risk involves observing and recording hazards and hazard analysis, studying exposure and drivers of vulnerability, and vulnerability assessment. Responding to risks is dependent on the way risk-based information is framed in the context of public perception and risk management needs.

Given the 'public good' nature of much of disaster-related information (Benson and Clay, 2004), governments have a fundamental role in providing good-quality and context-specific risk information about, for example, the geographical distribution of people, assets, hazards, risks, and disaster impacts and vulnerability to support disaster risk management (McBean, 2008). Good baseline information and robust time series information are key for long-term risk monitoring and assessments, not only for hazards, but also for evaluating the evolution of vulnerability and exposure (McEntire and Myers, 2004; Aldunce and León, 2007). Regular updating of information about hazards, exposure, and vulnerability are also necessary because of the dynamic nature of disaster risk, especially due to the effects of climate change and the associated uncertainty this creates (UNISDR, 2004; Prabhakar et al., 2009; CACCA, 2010).

A key component in the risk assessment process is to determine exposed elements at risk. This may relate to persons, buildings, infrastructure (e.g., water and sewer facilities, roads, and bridges), agricultural assets, livelihoods, ecosystems, natural infrastructure, and ecosystem services in harm's way that can be impacted in case of a disaster event. For national level assessments, their aggregate values are of interest. Ideally, this would be based on national asset inventories, national population census, and other national information. In practice, collecting an inventory on assets and their values often proves very difficult and expensive due to the heterogeneity and sheer number of the examined elements (see Cummins and Mahul, 2009). In addition, risk management processes require identifying those elements of the social process that also contribute to vulnerability – such as organizational and economic capacities, human development status of communities at risk, and capacity to respond to disasters (Lavell, 1996; Cardona et al., 2010) – as well as assessing the impacts following disaster events (ECLAC, 2003; Benson and Clay, 2004). Considerable progress has been made in the generation and use of such information including in some developing countries (Benson and Clay, 2004; UNISDR 2009c). Nevertheless, in many countries this is not a regular practice and efforts to document

Table 6-3 | Information requirements for selected disaster risk management and adaptation to climate change activities. Adapted from Wilby (2009).

	Activities	Examples of information needs
Cross-cutting	Climate change modeling	Time series information on climate variables – air and sea surface temperatures, rainfall and precipitation measures, wind, air circulation patterns, and greenhouse gas levels
	Hazard zoning and 'hot spot' mapping	Georeferenced inventories of landslide, flood, drought, and cyclone occurrence and impacts at local, sub-national and national levels
	Human development indicators	Geospatial distribution of poverty, livelihood sources, access to water and sanitation
	Disbursement of relief payments	Household surveys of resource access, social well-being, and income levels
	Seasonal outlooks for preparedness planning	Seasonal climate forecasts; sea surface temperatures; remotely sensed and *in situ* measurements of snow cover/depth, soil moisture, and vegetation growth; rainfall-runoff; crop yields; epidemiology
	A system of risk indicators reflecting macro and financial health of nation, social and environmental risks, human vulnerability conditions, and strength of governance (Cardona et al., 2010)	Macroeconomic and financial indicators (Disaster Deficit Index) Measures of social and environmental risks Measures of vulnerability conditions reflected by exposure in disaster-prone areas, socioeconomic fragility, and lack of social resilience in general Measures of organizational, development, and institutional strengths
Flood risk management	Early warning systems for fluvial, glacial, and tidal hazards	Real-time meteorology and water-level telemetry; rainfall, stream flow, and storm surge; remotely sensed snow, ice, and lake areas; rainfall-runoff model and time series; probabilistic information on extreme wind velocities and storm surges
	Flooding hot spots, and structural and non-structural flood controls	Rainfall data, rainfall-runoff, stream flow, floods, and flood inundation maps Inventories of pumps, stream gauges, drainage and defense works; land use maps for hazard zoning; post-disaster plan; climate change allowances for structures; floodplain elevations
	Artificial draining of proglacial lakes	Satellite surveys of lake areas and glacier velocities; inventories of lake properties and infrastructure at risk; local hydro-meteorology
Drought management	Traditional rain and groundwater harvesting, and storage systems	Inventories of system properties including condition, reliable yield, economics, ownership; soil and geological maps of areas suitable for enhanced groundwater recharge; water quality monitoring; evidence of deep-well impacts
	Long-range reservoir inflow forecasts	Seasonal climate forecast model; sea surface temperatures; remotely sensed snow cover; *in situ* snow depths; multi-decadal rainfall-runoff series
	Water demand management and efficiency measures	Integrated climate and river basin water monitoring; data on existing systems' water use efficiency; data on current and future demand metering and survey effectiveness of demand management

impacts are started only after major disasters (Prabhakar et al., 2009). Regular monitoring of vulnerability is also at a nascent stage (Dilley, 2006; Cardona et al., 2010). Table 6-3 on the previous page shows a sample of the kinds of information required for effective disaster risk management and adaptation to climate change activities.

Country- and context-specific information on disaster impacts and losses, including baseline data about observations (different types of losses, weather data) from past events, is often very limited and of mixed quality (see Embrechts et al., 1997; Carter et al., 2007). Data records at best may date back several decades, and thus often would provide only one reference data point for extreme events, such as a 100-year event (see Section 3.2.1). Data on losses from extremes can also be systematically biased due to high media attention (Guha-Sapir and Below, 2002). At times the data on losses are incomplete, as in the Pacific small island developing states, because of limited capacity to systematically collect information at the time of disaster, or because of inconsistent methodologies and the costs of measures used (Chung, 2009; Lal, 2010).

International disaster impact databases are available, such as the EM-DAT database of the Centre for the Epidemiology of Disasters (CRED) in Brussels, Desinventar maintained by a network of scientists involved in studying disasters in Latin America (Red de Estudios Sociales en Prevención de Desastres en América Latina – LA RED), as well as databases of reinsurers such as Munich Re. Comparisons of international and national disaster loss databases have shown significant variations in documented losses due to inconsistencies in the definition of key parameters and estimation methods used. This emphasizes the need to standardize parameter definitions and estimation methods (Guha-Sapir and Below, 2002; ECLAC, 2003; Tschoegl et al., 2006). For some countries, a reasonable quality and quantity of information may exist on the direct impacts, particularly where the reinsurance industry, consulting firms, and multi-lateral financial institutions have worked together with the research communities. Limited information is generally available on socially relevant effects of disasters, such as the incidence of health effects after a disaster as well as the impacts on ecosystems, which have not been well studied (Benson and Twigg 2004). Furthermore, the assessment of indirect disaster impacts on social or economic systems, such as on income-generating sectors and national savings, needs greater attention (ECLAC, 2003; Benson and Clay, 2004). Such information can often also be very useful in order to assess risks by using statistical estimation techniques (Embrechts et al., 1997) or catastrophe modeling approaches (Grossi and Kunreuther, 2005).

6.5.1.2. Preparedness: Risk Awareness, Education, and Early Warning Systems

National governments create the environment and communication channels to develop and disseminate different kinds of information on, for example, the hazards that affect different populations and preparedness for disaster response. Numerous studies indicate that up-to-date and robust early warning systems play a critical role in reducing the impacts of potential disasters and enable populations to protect lives and some property and infrastructure (White et al., 2004; Aldunce and León, 2007; McBean, 2008; Rogers and Tsirkunov, 2010), and as illustrated in Case Study 9.2.11.

Traditionally, early warning systems have been interpreted narrowly as technological instruments for detecting and forecasting impending hazard events and for issuing alerts (Rogers and Tsirkunov, 2010). However, this interpretation does not clarify whether warning information is received by or helpful to the population it serves or is actually used to reduce risks (Basher, 2006; Rogers and Tsirkunov, 2010). As noted in Case Study 9.2.11, the HFA 2005-2015 stated a need for more than just accurate predictions, stressing that early warning systems should be "people centered" and that warnings need to be "timely and understandable to those at risk" and include "guidance on how to act upon warnings" (UNISDR, 2005).

Governments also maintain early warning systems to warn their citizens and themselves about impending creeping climate- and weather-related hazards. For example, 'early warnings' of potentially poor seasons have been successful at informing key actions for agricultural planning on longer time scales and for producing proactive responses (Meinke et al., 2006; Vogel and O'Brien, 2006). Case Study 9.2.11 provides examples of early warning systems for short-response hazards as well as for creeping hazards operating on time scales from weeks to seasonal. This case study also highlights the possibility of using weather and climate predictions for timeframes longer than a few days to provide advanced warning of extreme conditions, which has been only a very recent development. Studies indicate that successful early warning systems are reliant on close inter-institutional collaboration between national meteorological and hydrological services and the agencies that directly intervene in rural areas, such as extension services, development projects, and civil society organizations (Meinke et al., 2006; Vogel and O'Brien, 2006; Rogers and Tsirkunov, 2010).

An effective early warning system delivers accurate, timely, and meaningful information, with its success dependent on whether the warnings trigger effective responses (UNISDR, 2005; Basher, 2006; Gwimbi, 2007; Auld, 2008a; van Aalst, 2009; Rogers and Tsirkunov, 2010). Warnings fail in both developing and developed countries for a number of reasons, including inaccurate weather and climate forecasting, public ignorance of prevailing conditions of vulnerability, failure to communicate the threat clearly or in time, lack of local organization, and failure of the recipients to understand or believe in the warning or to take suitable action (UNISDR, 2006; Auld, 2008a; Rogers and Tsirkunov, 2010). To be effective and complete, an early warning system typically is composed of four interacting elements (Basher, 2006; UNISDR, 2006): (1) generation of risk knowledge including monitoring and forecasting; (2) surveillance and warning services; (3) dissemination and communication; and (4) response capability. Warnings are received and understood by the target audience and are most relevant when the communications have meaning that is shared between those who issue the forecasts, local knowledge, and the decisionmakers they are intended to inform (Basher, 2006; UNISDR, 2006; Auld, 2008a; Case Study 9.2.2). Because emergency responders, the media, and the public often are unable to translate the scientific information on forecast hazards in warnings into risk levels and responses, early warning systems are most effective when their users can identify and interpret the general warning messages into simple and relevant local impacts and actions (e.g., flash flood warning and the need to evacuate areas at risk), prioritize the most dangerous hazards, assess potential contributions from cumulative and sequential events to risks, and identify thresholds linked to escalating risks for infrastructure, communities, and disaster response (UNISDR, 2006; Auld, 2008a).

Different hazards and different sectors often require unique preparedness, warnings, and response strategies (Basher, 2006; UNISDR, 2006). For example, the needs and responses behind a warning of a drought, a tornado, a cyclone, or a fire are very different. Some hazards may represent singular extreme events, sequences, or compound combinations of hazards while other hazards can be described as 'creeping' or accumulations of events (or non-events). For example, the World Meteorological Organization (WMO), national meteorological and hydrological services, the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and others recognize that combinations of weather and climate hazards can result in complex emergency response situations and are working to establish multi-hazard early warning systems for complex risks such as heat waves and vector-borne diseases (UNISDR, 2006; WMO, 2007) and early warnings of pests and food safety threats and disease outbreaks (e.g., prediction of a potential desert locust crisis) (WMO, 2004, 2007; FAO, 2010). Other 'creeping' hazards can evolve over a period of days to months; floods and droughts, for example, can result from cumulative or sequential multi-hazard events, especially when accompanied by an already existing vulnerability, while other hazards such as accumulated precipitation can lead to critical infrastructure failure (Basher, 2006; Auld, 2008a; Rogers and Tsirkunov, 2010). Section 3.1.3 provides more detail on compound, multiple, and creeping hazards.

Studies indicate that an understanding by the public and community organizations of their risks and vulnerabilities are critical but insufficient for risk management and that early warning systems need to be complemented by preparedness programs as well as public education and awareness programs (Basher, 2006; UNISDR, 2006; Gwimbi, 2007; Rogers and Tsirkunov, 2010). This requires systematic linkages and integration between early warning systems and contingency planning processes (Pelham et al., 2011). For example, a significant long-term social protection program known as the Productive Safety Net Programme (PSNP) was implemented in Ethiopia in 2007 in response to experiences from a series of drought-related disaster responses during the late 1990s and early 2000s (Pierro and Desai, 2008; Conway and Schipper, 2011). The aim of the PSNP was to shift institutional approaches away from just emergency responses and into more sustainable livelihood approaches involving asset protection and food security. Under this program, millions of people in 'chronically' food-insecure households in rural Ethiopia received resources from the PSNP through cash transfers or food payments for their participation in labor-intensive public works projects with a particular focus on environmental rehabilitation (Conway and Schipper, 2011). The case study on drought (Case Study 9.2.3) also emphasizes the importance of proactive steps in the form of drought preparedness and mitigation, and improved monitoring and early warning systems.

Some studies indicate that public awareness and support for disaster prevention and preparedness are often high immediately after a major disaster event and that such moments can be capitalized on to strengthen and secure the sustainability of, for example, early warning systems (Basher, 2006; Rossetto, 2007). It should be noted that such windows require the pre-existence of a social basis for cooperation that, in turn, supports a collaborative framework between research and management (Rossetto, 2007; Tompkins et al., 2008; Pelham et al., 2011).

The timing and form of climatic information (including forecasts and projections), and access to trusted guidance to help interpret and implement the information and projections in decisionmaking processes, may be more important to individual users than improved reliability and forecast skill (Pulwarty and Redmond, 1997; Rayner et al., 2005; Gwimbi, 2007; Rogers and Tsirkunov, 2010). Decisionmakers typically manage risks holistically, while scientific information is generally derived using reductionist approaches (Meinke et al., 2006). The net outcome can be a 'disconnect' between scientists and decisionmakers with the result that climate and hydro-meteorological information can be developed that, although scientifically sound, may lack relevance to the decisionmaker (Cash and Buizer, 2005; Meinke et al., 2006; Vogel and O'Brien, 2006; Averyt, 2010). Perceptions of irrelevance, inconsistency, confusion, or doubt can delay action (NRC, 2009). Some studies (Lowe, 2003; Glantz, 2005; Meinke et al., 2006; Feldman and Ingram, 2009) advise scientists and practitioners to work together to produce trustworthy knowledge that combines scientific excellence with social relevance, a point also emphasized in Case Study 9.2.2 on fire. These studies suggest that decision support activities should be driven by users' needs, not by scientific research priorities, and that these user needs are not always known in advance, but should be identified collaboratively and iteratively in ongoing two-way communication between knowledge producers and decisionmakers (Cash and Buizer, 2005; NRC, 2009). It has been suggested that this ongoing interaction, two-way communication, and collaboration allows scientists and decisionmakers to get to know each other, to develop an understanding of what decisionmakers need to know and what science can provide, to build trust, and, over time, develop highly productive relationships as the basis for effective decision support (Feldman and Ingram, 2009; NRC, 2009; Averyt, 2010).

Since early warning information systems are multi-jurisdictional and multidisciplinary, they usually require anticipatory coordination across a spectrum of technical and non-technical actors. National governments can play an important role in setting the high-level policies and supporting frameworks involving multiple organizations, in adopting multi-hazard and multi-stakeholder approaches, and in promoting community-based early warning systems (Pulwarty et al., 2004; Basher, 2006, UNISDR, 2010). National governments can also interact with regional and international governments and agencies to strengthen early warning capacities and to ensure that warnings and related responses are directed toward the most vulnerable populations (Basher, 2006; UNISDR, 2010). At the same time, national governments can also play an important role in supporting regions and sub-national governments in developing operational and local response capabilities (Basher, 2006; UNISDR, 2010; see Section 6.5.4). In Japan and the Mekong region, for example, in addition to using an early warning system based on extensive flood modeling exercise, the emergency basin-level management relies on the flood mitigation capacity of paddy fields (Masumoto et al., 2006, 2008).

6.5.2. Reducing Climate-Related Disaster Risk

National climate-related disaster risk reduction activities include a broad range of options that vary from safe infrastructure and building codes to those aimed to enhance and protect natural ecosystems, support human development and even 'build back better' following a disaster. Each of these strategies can prove minimally effective in isolation but highly effective in combination. These and other different options, along with their limitations (e.g. lack of information and understanding, human resource capacity, scientific requirements, financing) are addressed in the following subsections, noting how risk reduction measures are increasingly being considered as good practices to promote adaptation to climate change.

6.5.2.1. Applying Technological and Infrastructure-Based Approaches

Climate change has the potential to directly and indirectly impact the safety of existing infrastructure and to alter engineering and maintenance practices, and will require changes in building codes and standards where they exist (Bourrelier et al., 2000; Füssel, 2007; Wilby, 2007; Auld, 2008b; Stevens, 2008; Hallegatte, 2009). The changing climate also has the potential regionally to increase premature deterioration and weathering impacts on the built environment, exacerbating vulnerabilities to climate extremes and disasters and negatively impacting the expected and useful life spans of structures (Auld, 2008b; Larsen et al., 2008; Stewart et al., 2011). As noted in Case Study 9.2.8, people living with un-adapted and inadequate infrastructure and housing will be more at risk from climate change.

With projected increases in the magnitude and/or frequency of some extreme events in many regions (see Chapter 3), small increases in climate extremes above thresholds or regional infrastructure 'tipping points' have the potential to result in large increases in damages to all forms of existing infrastructure nationally and to increase disaster risks (Coleman, 2002; Munich Re, 2005; Auld, 2008b; Larsen et al., 2008; Kwadijk et al., 2010; Mastrandrea et al., 2010). Since infrastructure systems, such as buildings, water supply, flood control, and transportation networks often function as a whole or not at all, an extreme event that exceeds an infrastructure design or 'tipping point' can sometimes result in widespread failure and a potential disaster (Ruth and Coelho, 2007; Haasnoot et al., 2009). For example, a break in a water main, dike, or bridge can impact other systems and sectors and render the regional system incapable of providing needed services (Ruth and Coelho, 2007). These infrastructure thresholds or adaptation 'tipping points' become important when considering sensitivities to climate change and adaptation and disaster risk reduction options for the future (see Section 6.6.1 for further discussion on thresholds and management of climate change uncertainties). Infrastructure thresholds refer here to the critical climate conditions where acceptable technical, economic, spatial, or societal limits are exceeded and the current built environment system is no longer "future climate proof" (i.e., it fails, requiring proactive adaptation actions and changes in infrastructure codes, standards, and management processes) (Auld, 2008b; Haasnoot et al., 2009; Kwadijk et al., 2010; Mastrandrea et al., 2010).

The need to address the risk of climate extremes and disasters in the built environment and urban areas, particularly for low- and middle-income countries, is one that is not always fully appreciated by many national governments and development and disaster specialists (Rossetto, 2007; Moser and Satterthwaite, 2008). Low- and middle-income countries, which account for close to three-quarters of the world's urban populations, are at greatest risk from extreme events and also have far less capacity than do high-income countries, largely due to backlogs in protective infrastructure and services and limitations in urban government (Satterthwaite et al., 2007; Moser and Satterthwaite, 2008). Rapid growth and expansion in urban areas, particularly in developing countries, can outpace infrastructure development and lead to a lack of infrastructure services for housing, sewer systems, effective transportation, and emergency response and increased vulnerability to weather and climate extremes (Satterthwaite et al., 2007; Birkmann et al., 2011). These impacts from the changing climate will be particularly severe for populations living in poor-quality housing on illegally occupied land, where there is little incentive for investments in more resilient buildings or infrastructure and service provision (Freeman and Warner, 2001; Satterthwaite et al., 2007; Birkmann et al., 2011). Case Study 9.2.8 provides further discussion on the best adaptation and risk management practices for cities and their built environment.

An inevitable result of potentially increased damages to infrastructure will be a dramatic increase in the national resources needed to restore infrastructure and assist the poor affected by damaged infrastructure (Freeman and Warner, 2001). A study by the Australian Academy of Technological Sciences and Engineering concluded that national retrofit measures will be needed to safeguard existing infrastructure in Australia and new adaptation approaches and national codes and standards will be required for construction of new infrastructure (Stevens, 2008). Recommendations reported from this study call for research to fill gaps on the future climate risks, comprehensive risk assessments for existing critical climate-sensitive infrastructure, development of information and supporting tools (e.g., non-stationary extreme value analysis methods) about future climate change events, investigation of the links between soft and hard engineering solutions, and strengthened research efforts to improve the modeling of small-scale climate events (Wilby, 2007; Auld, 2008b; Stevens, 2008).

The recommended national adaptation options to deal with projected impacts to the built environment range from deferral of actions pending development of new climate change information to modification of infrastructure components according to national guidance, acceptance of residual losses, reliance on insurance and other risk transfer instruments, formalized asset management and maintenance, mainstreaming into environmental assessments, new structural materials and practices, improved emergency services, and retrofitting and replacement of infrastructure elements (Bourrelier et al., 2000; Auld, 2008b; Stevens, 2008; Haasnoot et al., 2009; Hallegatte, 2009; Neumann, 2009; Kwadijk et al., 2010; Wilby and Dessai, 2010).

Strategic environmental assessment approaches, such as those recommended by the Organisation for Economic Cooperation and Development (OECD) and many national environmental assessment agencies, offer an effective means for ensuring that adaptation to climate change and disaster risk management, as well as GHG reduction practices, are mainstreamed into policies and planning for new programs on infrastructure and systems (OECD, 2006; Benson, 2007). Environmental impact assessment approaches can reduce the risks of environmental degradation from a project and reduce future disaster risks from current and changing climate conditions (Benson, 2007). For long-lived infrastructure or networks, studies recommend consideration of likely climate change impacts that will potentially affect the planned useful life of the infrastructure system (e.g., seasonal variability in water flows, temperatures, incidence of extreme weather events) (OECD, 2006; Bosher et al., 2007; Auld, 2008b; Larsen et al., 2008; Neumann, 2009; NRTEE, 2009).

The implementation of adequate national building codes that incorporate up-to-date regionally specific climate data and analyses can improve resilience of infrastructure for many types of weather-related risks (Auld, 2008b; WWC, 2009; Wilby et al., 2009). Typically, infrastructure codes and standards in most countries use historical climate analyses to climate-proof new structures, assuming that the past climate can be extrapolated to represent the future. For example, water-related engineering structures, including both disaster-proofed infrastructure and services infrastructure (e.g., water supply, irrigation and drainage, sewerage, and transportation), are typically designed using analysis of historical rainfall records (Ruth and Coelho, 2007; Auld, 2008b; Haasnoot et al., 2009; Hallegatte, 2009; Wilby and Dessai, 2010). Since infrastructure is built for long life spans and the assumption of climate stationarity will not hold for future climates, it is important that national climate change guidance, tools, and consistent adaptation options be developed to ensure that climate change can be incorporated into infrastructure design (Auld, 2008b; Stevens, 2008; Hallegatte, 2009; Wilby et al., 2009). While some government departments responsible for building regulations and the insurance industry are taking the reality of climate change very seriously, challenges remain about how to incorporate the uncertainty of future climate projections into engineering risk management and into codes and standards, especially for climate elements such as extreme winds and extreme precipitation and their various phases (e.g., short- and long-duration rainfalls, freezing rain, snowpacks) (Sanders and Phillipson, 2003; Auld, 2008b; Haasnoot et al., 2009; Hallegatte, 2009; Kwadijk et al., 2010; Wilby and Dessai, 2010; Lu, 2011). Recent advances in characterizing the uncertainties of climate change projections, in regionalization of climate model outputs, and in the application and mainstreaming of integrated top-down, bottom-up approaches for assessing impacts and adaptation options (Sections 6.3.1 and 6.3.2) will help to ensure that infrastructure and technology can be better adapted to a changing climate. Sections 3.2.3, 3.3, and 3.4 provide further details on scientific advances for the construction, assessment, and communication of climate change projections, including a discussion on recent advances in the development of regionalization or downscaling techniques and approaches used to quantify uncertainties in climate change model outputs.

Some implementation successes are emerging. In one example, discussed in Case Study 9.2.10, the Canadian Standards Association (CSA) and its National Permafrost Working Group developed a Technical Guide, CSA Plus 4011-10, on *Infrastructure in Permafrost: A Guideline for Climate Change Adaptation*, that directly incorporated climate change temperature projections from an ensemble of climate change models. This CSA Guide considered climate change projections of temperature and precipitation and incorporated risks from warming and thawing permafrost to foundations over the planned life spans of the structure (Hayley and Horne, 2008; NRTEE, 2009; CSA, 2010a; Smith et al., 2010; Grosse et al., 2011). The guide suggested possible adaptation options, taking into account the varying levels of risks and the consequences of failure for foundations of structures, whether buildings, water treatment plants, towers, tank farms, tailings ponds, or other infrastructure (NRTEE, 2009; CSA, 2010a; see Case Study 9.2.10). Similarly, working with the Canadian meteorological service, engineering associations, and national water stakeholder associations, the CSA has also developed an initial rainfall Intensity-Duration-Frequency Guideline for water practitioners with adaptation guidance (CSA, 2010b).

In developing countries, structures are often built using prevalent local practices, which may not reflect best practices from disaster risk reduction or adaptation perspectives. These prevalent local practices usually do not include the use of national building standards or adequately account for local climate conditions (Rossetto, 2007). While the perception in some developing countries is that national building codes and standards are too expensive, experience in the implementation of incremental hazard-proof measures in building structures has proven in some countries to be relatively inexpensive and highly beneficial in reducing losses (Rossetto, 2007; ProVention, 2009). In reality, the most expensive components of codes and standards are usually the cost to implement national policies for inspections, knowledge transfer to trades, and national efforts for their uptake and implementation (Rossetto, 2007). Bangladesh, for example, has implemented simple modifications to improve the cyclone resistance of (non-masonry) kutcha or temporary houses, with costs that amounted to only 5% of the construction costs (Lewis and Chisholm, 1996; Rossetto, 2007). Bangladesh is also developing national policies requiring that houses built following disasters include a small section of the replacement house that meets 'climate proofing' standards and acts as a household shelter in the next disaster. In many countries, climate-proofing guidelines and standards are applied to structures that are used as emergency shelters and for structures that form the economic and social lifeline of a society, such as its communications links, hospitals, and transportation networks (Rossetto, 2007).

Many studies advocate that technical and infrastructure solutions are not the only way of adapting to changing climates and that 'soft solutions' such as financial tools, land use planning, and ecosystem conservation or soft engineering approaches are also needed (Adger et al., 2007; Auld, 2008b; Nicholls et al., 2008; Hallegatte, 2009; McEvoy et al., 2010). Land and water use planning, use of bioshields as natural buffers, soft defenses, and green or 'soft engineering' are complementary adaptation options, described further in Section 6.5.2.3 and in Case Studies 9.2.1 and 9.2.8.

6.5.2.2. Human Development and Vulnerability Reduction

Vulnerabilities to climate-related hazards and the options to reduce them vary between and within countries due to factors such as poverty, social positioning, geographic location, gender, age, class, ethnicity, ecosystem condition, community structure, community decisionmaking processes, and political issues (Yodmani, 2001; Yamin et al., 2005; Halsnaes and Traerup, 2009). Overall, studies indicate that the extent of the vulnerability to climate variability and climate change is shaped by both the dependence of the national economy and livelihoods on climate-sensitive natural resources and the resilience or robustness of the country's social institutions to equitable distribution of resources under climate change (Ikeme, 2003; Brooks et al., 2009; Virtanin et al., 2011). The poorest regions are often characterized by vulnerable housing, weak emergency services and infrastructure, and a dependence on agriculture and other natural resources (Ikeme, 2003; Manuel-Navarrete et al., 2007; Reid et al., 2010).

Many vulnerable communities already suffer greater water stress, food insecurity, disease risks, and loss of livelihoods, which have the potential to increase under climate change (Manuel-Navarrete et al., 2007; Brooks et al., 2009; Halsnaes and Traerup, 2009; Virtanin et al., 2011). For example, climate change may increase the risk of waterborne diseases, requiring targeted assistance for health and water sanitation issues (Curriero et al., 2001; Brooks et al., 2009). Small island states and low-lying countries may require support to relocate vulnerable groups to safer locations or other countries, all requiring a complex set of actions at the national and international levels (Manuel-Navarrete et al., 2007; McGranahan et al., 2007). Other studies indicate that resilient housing and safe shelters will remain a key adaptation action to protect vulnerable people from disasters and climate extremes, requiring national guidelines to ensure that new or replacement structures are built with flexibility to accommodate future changes (Ikeme, 2003; Manuel-Navarrete et al., 2007; Rossetto, 2007; Auld, 2008b). Under climate change, it is expected that food security issues among vulnerable populations will become more impacted by climate variability, erratic rainfall, and more frequent extreme events (Ikeme, 2003; IRI, 2006; Brooks et al., 2009; Halsnaes and Traerup, 2009; and regional studies through global partnerships, such as the Consultative Group on International Agricultural Research). When faced with food scarcity, vulnerable populations sometimes adopt maladaptive coping strategies such as overgrazing, deforestation, and unsustainable extraction of water resources that aggravate long-term disaster risks (Brooks et al., 2009; Bunce et al., 2010).

Studies indicate that the greatest losses in suitable agricultural cropland due to climate change are likely to be in Africa, particularly sub-Saharan Africa (Ikeme, 2003; FAO, 2010). Assessing food security issues in this vulnerable area requires consideration of multiple socioeconomic and environmental variables, including climate (Verdin et al., 2005; Virtanin et al., 2011). In sub-Saharan Africa, where large and widely dispersed populations depend on rain-fed agriculture and pastoralism, climate monitoring and forecasting are important inputs to food security analysis and assessments. Since conventional climate and hydro-meteorological networks in these areas are sparse and often report with significant delays, there is a growing need for increased capacity in rainfall observations, forecasting, data management, and modeling applications (Verdin et al., 2005; Heltberg et al., 2009; FAO, 2010). Studies indicate a need for rainfall observation networks to be expanded and to incorporate satellite information; for data management systems to be improved; for tailored forecast information to be disseminated and used by decisionmakers; and for more effective early warning systems that can integrate seasonal forecasts with drought projections as inputs for hazards, food security, and vulnerability analysis (Verdin et al., 2005; Heltberg et al., 2009; FAO, 2010). Other short-term but limited strategies to minimize food security risks include diversifying livelihoods to spread risk, farming in different ecological niches, building social networks, productive safety net and social protection schemes, and risk pooling at the regional or national level to reduce financial exposure (Brooks et al., 2009; Halsnaes and Traerup, 2009; Heltberg et al., 2009; FAO, 2010). Specific longer-term strategies to address the increasing risks, particularly given uncertainties, include land rehabilitation, terracing and reforestation, measures to enhance water catchment and irrigation techniques, improvements to infrastructure quality for better access to markets, and the introduction of drought-resistant crop varieties (Halsnaes and Traerup, 2009; Heltberg et al., 2009).

In the longer term, studies indicate that increasing food security risks under climate change will require higher agricultural productivity, reduced production variability, and agricultural systems that are more resilient to disruptive events (Cline, 2007; Stern, 2007; Halsnaes and Traerup, 2009; FAO, 2010). This implies transformations in the management of natural resources; new climate-smart agriculture policies, practices, and tools; better use of climate science information in assessing risks and vulnerability; and financing for food security (Brooks et al., 2009; Ericksen et al., 2009; FAO, 2010). Other coping strategies may include increased non-farm incomes, migration, government and other financial assistance, microfinance, social protection, other safety nets, and various insurance products (Barrett et al., 2007; Heltberg et al., 2009; FAO, 2010). The Sustainable Livelihoods Approach or Framework has been used internationally for rural and coastal development to holistically describe the variables that impact livelihoods locally and to define the capacity, assets (both natural and social), and policies required for sustainable living, poverty reduction, and recovery from disasters (Brocklesby and Fisher, 2003; Yamin et al., 2005). Sections 2.3, 2.4.3, 2.6.1, 5.2.3, and 5.4, and Case Studies 19.2.1 and 19.2.2, also discuss sustainable livelihood approaches that can be considered in building adaptive capacity and resilience to climate hazards and climate change.

Early identification of populations at risk can enable timely and appropriate actions needed to avert widespread impacts. Reliable and detailed information on the current and future climates and their impacts can play an important role in the recognition of the need to adapt and the successful evolution of effective adaptation strategies (Ikeme, 2003; Verdin et al., 2005; Heltberg et al., 2009; Wilby et al., 2009; and as discussed in Section 6.5.1). Some studies claim that one of the potential barriers for identifying the most vulnerable regions and people in developing countries under future climate change is the limited human resource capacity regionally to downscale global and regional climate projections to a scale suitable to support national-level planning and programming processes (Ikeme, 2003; Verdin et al., 2005; CCCD, 2009; Wilby et al., 2009). Not all of the climate variables of importance for development can be projected and downscaled with confidence, particularly given that many development activities are especially sensitive to changes in climate extremes (Agrawala and van Aalst, 2008). Even when downscaled results are available, their use can be limited by a lack of understanding and interpretation of how these downscaled projections can be translated to highlight vulnerabilities with certainty (Agrawala and van Aalst, 2008; Heltberg et al., 2009). Agrawala and van Aalst (2008) argue that development practitioners and climate scientists should join forces to make climate information more accessible, relevant, and usable.

Because the risks posed by climate change can affect the long-term efficiency with which development resources can be invested and development objectives achieved, studies indicate that it remains important to integrate or mainstream disaster risk management and climate change adaptation into a range of development activities (Agrawala and van Aalst, 2008; Halsnaes and Traerup, 2009; Heltberg et al., 2009; Mitchell et al., 2010a). Lack of awareness within the development community of the many implications of climate change and limitations on resources for implementation are frequently cited reasons for difficulties in mainstreaming adaptation and disaster risk management (Agrawala and van Aalst, 2008; Heltberg et al., 2009; also see Section 6.3.2). Adaptation to climate change and disaster risk management actions can be considered to be successfully mainstreamed when they reduce the vulnerability of susceptible populations to existing climate variability and are also able to strengthen the capacity of the population to prepare for and respond to further changes (Yamin et al., 2005; Manuel-Navarrete et al., 2007; Mertz et al., 2009). Studies indicate that national policies can increase this capacity (Ikeme, 2003; Heltberg et al., 2009). Policies and measures such as the establishment of an LDC fund, Special Climate Fund, Adaptation Fund, climate change Multi-Donor Trust Fund, etc., have all been developed to address the special adaptation and risk reduction issues of vulnerable countries (see Sections 7.4.2 and 7.4.3.3 for more details).

In spite of recommendations to target assistance to the most vulnerable in the developing world, practical 'on the ground' examples have been limited (Yamin et al., 2005; Ayers and Huq, 2009; Heltberg et al., 2009). Nonetheless, some developing countries have implemented successful policies and plans. Nationally, good progress is being made in strengthening some disaster reduction capacities for disaster preparedness and early warning and response systems and in addressing some of the underlying risk drivers in many developing country regions and sectors (Manuel-Navarrete et al., 2007; UNISDR, 2009c). For example, social safety nets and other similar national-level programs, particularly for poverty reduction and attainment of the Millennium Development Goals, have helped the poorest to reduce their exposure to current and future climate hazards (Yamin et al., 2005; Tanner and Mitchell 2008; Heltberg et al., 2009). Some examples of social safety nets are cash transfers to the most vulnerable, versions of weather-indexed crop insurance, employment guarantee schemes, and asset transfers (Yamin et al., 2005; CCCD, 2009; also see Section 6.6.3). A national policy to help the vulnerable build assets should incorporate climate screening in order to remain resilient under a changing climate (UNISDR, 2004; Tanner and Mitchell, 2008; Heltberg et al., 2009). Other measures, such as social pensions that transfer cash from the national level to vulnerable people, provide some buffers against climate hazards (Davies et al., 2008; Heltberg et al., 2009). However, lack of capacity and good governance has remained a major barrier to efficient and effective delivery of assistance to the most vulnerable (Yamin et al., 2005; CCCD, 2009; Heltberg et al., 2009; Warner et al., 2009).

National Adaptation Programme of Actions (NAPA) under the UNFCCC process have helped least-developed countries assess the climate-sensitive sectors and prioritize projects to address the most urgent adaptation issues of the most vulnerable regions, communities, and populations. The NAPA process has proven instrumental in increasing awareness of climate change and its potential impacts in the poorest countries. The proposed adaptation projects under the NAPA usually cover small areas and address a few components within a given sector with a view to addressing urgent and immediate needs. The choice of projects is based on the urgency of the actions as well as cost-effectiveness in cases where delays would increase the costs of later addressing the issue. Assessment of completed NAPAs show different national and regional priority sectors such as health, food security, infrastructure, coastal zone and marine ecosystem, insurance, early warning and disaster management, terrestrial ecosystem, education and capacity building, tourism, energy, water resources, and cross-sectoral areas. The NAPA process forms a good basis for developing medium- and long-term adaptation plans and policies. The capacity within NAPA teams and the subsequent networks that are created are proving very useful in the design of broader national adaptation plans (UNFCCC, 2011a,b).

6.5.2.3. Investing in Natural Capital and Ecosystem-Based Adaptation

Ecosystem-based adaptation, which integrates the use of biodiversity and ecosystem services into an overall adaptation strategy, can be a cost-effective strategy for responding to the effects of weather and climate extremes (SCBD, 2009). It is generally agreed that investment in sustainable ecosystems and environmental management has the potential to also provide improved livelihoods and increased biodiversity conservation (Bouwer, 2006; UNEP, 2006, 2010; McGray et al., 2007; Colls et al., 2009; SCBD, 2009; Sudmeier-Rieux and Ash, 2009; World Bank, 2009).

Healthy, natural or modified, ecosystems (see Section 6.3.1 and Box 6-4) have a critical role to play in reducing risks of climate extremes and disasters (Sidle et al., 1985; Dorren et al., 2004; Phillips and Marden, 2005; Reid and Huq, 2005; UNISDR, 2005, 2007a,b, 2009a,b; Bebi et al., 2009; Colls et al., 2009; SCBD, 2009; Sudmeier-Rieux and Ash, 2009; UNEP, 2009; Lal, 2010). Although the scientific evidence base relating to the role of ecosystem services in reducing the sensitivity of natural systems to weather and climate extremes and reducing vulnerabilities to many disasters is nascent, investment in natural ecosystem management has long been used to reduce risks of disasters (see Box 6-4). Forests, for example, have been used in the Alps and elsewhere as effective risk-reducing measures against avalanches, rockfalls, and landslides since the 1900s (Sidle et al., 1985; Dorren et al., 2004; Phillips and Marden, 2005; Bebi et al., 2009). The damage caused by wildfires, wind erosion, drought, and desertification are reported to have been buffered by forest management, shelterbelts, greenbelts, hedges, and other 'living fences' (ProAct Network, 2008; Dudley et al., 2010). Mangrove replanting has been used as a buffer against cyclones and storm surges, with reports of a 70 to 90% reduction in energy from wind-generated waves in coastal areas (UNEP, 2006) and reduction in the number of deaths from cyclones (Das and Vincent, 2009), depending on the health and extent of the mangroves. Many sectoral examples are provided in Table 6-1 that also provide evidence of the value of ecosystem services in disaster risk reduction and adaption to climate change (see also Section 6.5.2.1).

The extent to which ecosystems support such benefits, though, depends on a complex set of dynamic interactions among ecosystem-related factors, as well as the intensity of the hazard (UNEP, 2006; Sudmeier-Rieux and Ash, 2009) and institutional and governance arrangements (see case studies in Angelsen et al., 2009). Scientific understanding of the relationship between ecosystem structure and function and the reduction of risks associated with weather and climate extremes is limited, though growing.

Box 6-4 | Value of Ecosystem Services in Disaster Risk Management: Some Examples

- In the Maldives, degradation of protective coral reefs necessitated the construction of artificial breakwaters at a cost of US$ 10 million per kilometer (SCBD, 2009).
- In Vietnam, the Red Cross began planting mangroves in 1994 with the result that, by 2002, some 12,000 hectares of mangroves had cost US$1.1 million for planting but saved annual levee maintenance costs of US$ 7.3 million, shielded inland areas from a significant typhoon in 2000, and restored livelihoods in planting and harvesting shellfish (Reid and Huq, 2005; SCBD, 2009).
- In the United States, wetlands are estimated to reduce flooding associated with hurricanes at a value of US$ 8,250 per hectare per year, and US$ 23.2 billion a year in storm protection services (Costanza et al., 2008).
- In Orissa, India, a comparison of the impact of the 1999 super cyclone on 409 villages in two tahsils with and without mangroves showed that villages that had healthy stands of mangroves suffered significantly less loss of lives than those without (or limited areas) healthy mangroves, even though all villages had the benefit of early warnings and accounting for other social and economic variables (Das and Vincent, 2009).

Investment in natural ecosystems also contributes significantly to reduction in GHG emissions, through practices such as those associated with Land Use, Land-Use Change, and Forestry (LULUCF) and through Reduced Carbon Emissions from Deforestation and Forest Degradation (REDD) or REDD+, which additionally includes the value of conservation from sustainable management of forests and enhancement of forest carbon stocks (UNEP, 2006; SCBD, 2009). Mangrove ecosystems, for example, are important for carbon sequestration and storage, containing among the highest carbon pools: 1,060-2,020 t CO_2 ha^{-1} or an annual carbon sequestration of 6.32 t CO_2 ha^{-1} (Murray et al., 2010), as well as providing the buffers against weather and climate extremes, biodiversity values, and livelihood benefits discussed above. Investment in natural ecosystems, through REDD and REDD+ related strategies, can generate alternative sources of income for local communities and provide much needed financial incentives to prevent deforestation (Reid and Huq, 2005; Angelsen et al., 2009; SCBD, 2009; Sudmeier-Rieux and Ash, 2009; Murray et al., 2010), as well as provide additional livelihood benefits from the conservation and restoration of forest ecosystems and the services they support (Longley and Maxwell, 2003; MEA, 2005; SEEDS India, 2008; Sudmeier-Rieux and Ash, 2009; Murray et al., 2010).

Some countries have begun to explicitly consider ecosystem-based solutions for climate change mitigation and/or adaptation to risks

Box 6-5 | Some Examples of Ecosystem Based Adaptation Strategies and Disaster Risk Management Interventions Taking into Account the Role of Ecosystem Services

- Vietnam has applied strategic environmental assessments to land use-planning projects and hydropower development for the Vu Gia-Thu Bon River basin, including climatic disaster risks (OECD, 2009; SCBD, 2009).
- European countries affected by severe flooding, notably the United Kingdom, The Netherlands, and Germany, have made policy shifts to 'make space for water' by applying more holistic river basin management plans and integrated coastal zone management (DEFRA, 2005; Wood and Van Halsema, 2008; EC, 2009; ONERC 2009).
- At the regional level, the Caribbean Development Bank has integrated weather and climatic disaster risks into its environmental impact assessments for new development projects (CDB and CARICOM, 2004; UNISDR, 2009c).
- Under the Amazon Protected Areas Program, Brazil has created a more than 30 million hectare mosaic of biodiversity-rich forests reserve of state, provincial, private, and indigenous land, resulting in a potential reduction in emissions estimated at 1.8 billion tonnes of carbon through avoided deforestation (World Bank, 2009).
- Swiss Development Cooperation's four-year project in Muminabad, Tajikistan adopted an integrated approach to risk through reforestation and integrated watershed management (SDC, 2008).

associated with weather and climatic extremes as an integral element of national and sectoral development decisions (see Box 6-5).

Ecosystem-based adaptation strategies, often considered as part of 'soft' options, are a widely applicable approach to climate change adaptation because they can be applied at regional, national, and local levels, at both project and programmatic levels, and benefits can be realized over short and long time scales. They can be a more cost-effective adaptation strategy than hard infrastructure and engineering solutions, as also discussed in Section 6.5.2.1, and produce multiple benefits, and are also considerably more accessible to the rural poor than measures based on hard infrastructure and engineering solutions (Sudmeier-Rieux and Ash, 2009). Communities are also able to integrate and maintain traditional and local knowledge and cultural values in their risk reduction efforts (SCBD, 2009).

In the choice of ecosystem-based adaptation options, decisionmakers may at times require making judgements about the tradeoffs between particular climatic risk reduction services and other ecosystem services also valued by humans. Such decisions benefit from information resulting from risk assessments, scenario planning, and adaptive management approaches that recognize and incorporate these potential tradeoffs. This might be the case, for example when deciding to use wetlands for coastal protection that requires emphasis on silt accumulation and stabilization possibly at the expense of wildlife values and recreation (SCBD, 2009), particularly when achieving a full complement of biodiversity values is highly complex and long-term in nature (UNEP, 2006).

However, countries would need to overcome many challenges if they are to be successful in increasing investment in ecosystem-based solutions, including for example:

- Insufficient recognition of the economic and social benefits of ecosystem services under current risk situations, let alone under potential changes in climate extremes and disaster risks (Vignola et al., 2009).
- Lack of interdisciplinary science and implementation capacity for making informed decisions associated with complex and dynamic systems (Leslie and McLeod, 2007; OECD, 2009).
- Ability to estimate economic values of different ecosystem services supported by nature (TEEB, 2009).
- Lack of capacity to undertake careful cost and benefit assessments of alternative strategies to inform choices at the local level. Such assessments could provide the total economic value of the full range of disaster-related ecosystem services, compared with alternative uses of the forested land such as for agriculture (see, e.g., Balmford et al., 2002).
- Where they exist, data on and monitoring of ecosystem status and risk are often dispersed across agencies at various scales and are not always accessible at the sub-national or municipal level where land use-planning decisions are made (UNISDR, 2009a).
- The mismatch in geographic scales and mandates between the administration and responsibilities for disaster reduction, and that of ecosystem extent and functioning, such as in water basins (Leslie and McLeod, 2007; OECD, 2009).

6.5.3. Transferring and Sharing 'Residual' Risks

Not all risk can be reduced, and a residual, often sizeable risk will remain. Mechanisms for sharing and transferring residual risks for households and businesses have been introduced in Section 5.5.2.2 in the context of managing local-level impacts and risks. Chapter 5 also discusses the incentive and disincentive aspects provided by insurance for risk management and adaptation to climate change at the local level. This section sets out the role of national-level institutions, especially governments, in enabling and regulating practices at national scales. It also discusses the need on the part of some governments to transfer their own risks.

Markets offer risk-sharing and transfer solutions, most prominently property and asset insurance for households and businesses, and crop insurance for farmers. Insurance markets are generally segregated and regulated nationally. Existing national insurance systems commonly offer a wide variety of choice in providing protection for property and assets against natural hazards. National insurance systems differentially include hazards, such as storms, hail, floods, earthquake, and also landslides or subsidence. Risks may be covered separately or bundled with a fire policy or covered under an 'all hazards' policy. The contracts differ in the extent of cover offered, as well as indemnity limits, and whether the policies are compulsory, bundled, or voluntary. Importantly, they differ institutionally with regard to the involvement of the public authorities and private insurers and how they allocate liability and responsibility for disaster losses across individual households, businesses, and taxpayers (Schwarze and Wagner, 2004; Aakre et al., 2010).

Yet, insurance coverage is limited and globally only about 20% of the losses from weather-related events have been insured over the period 1980 to 2003 (also see Section 6.2.2). In many instances, insurance providers even in industrialized countries have been reluctant to offer region- or nationwide policies covering flood and other hazards because of the systemic nature of these risks, as well as problems of moral hazard and adverse selection (Froot, 2001; Aakre et al., 2010). In some highly exposed countries, such as The Netherlands for flood risk, insurance is even non-existent and government relief is dispensed in lieu (Botzen et al., 2009). In many developing countries, there is little in terms of insurance for disaster risks, yet novel index-based micro-insurance solutions have been developed and are starting to show results (Hazell and Hess, 2010; see also Sections 5.6.3 and Case Study 9.2.13 on risk financing). Market mechanisms may work less well in developing countries, particularly because there is often limited risk assessment information, limited scope for risk pooling, and little or no supply of insurance instruments. In such circumstances, governments may need to create enabling environments by helping to estimate risk, helping to develop training programs for insurer's staff, and generally promoting awareness among the population at risk (Linnerooth-Bayer et al., 2005; Hoeppe and Gurenko, 2006; Cummins and Mahul, 2009; Hazell and Hess, 2010).

Employing insurance and other risk-financing instruments for helping to manage the vagaries of nature may often involve the building of PPPs in developing and in developed countries in order to tackle market failure, adverse selection, and the sheer non-availability of such instruments (see Aakre et al., 2010). Because of such reasons, there is a role for governments to not only create an enabling environment for private sector engagement, but also to regulate its activities. In the development context, Hazell and Hess (2010) distinguish between protection and promotion models, while acknowledging that in many instances hybrid combinations may contain elements of both. Protection relates to governments helping to protect themselves, individuals, and businesses from destitution and poverty by providing ex-post financial assistance, which, however, is taken out as an ex-ante instrument as insurance before disasters. The promotion model relates to the public sector promoting more stable livelihoods and higher income opportunities by better helping businesses and households access risk financing, including micro-financing.

Private insurers are often not willing to fully underwrite the risks and many countries, including Japan, France, the United States, Norway, and New Zealand, have therefore instituted public-private national insurance systems, where participation of the insured is mandatory or voluntary and single hazards may be insured or comprehensive insurance offered (Linnerooth-Bayer and Mechler, 2007). Further, specific strategies may be employed to increase market penetration of risks that are not easily covered by regular avenues. As one example, in India, pro-poor regulation stipulates that insurers within their regular business segment reserve a certain quota of insurance policies for the poor and thus cross-subsidize fledgling low-income micro-insurance policies (Mechler et al., 2006a).

As well, governments may insure their liabilities through sovereign insurance. Liabilities arise as governments own a large portfolio of public infrastructure and other assets that are exposed to disaster risks. Moreover, most governments accept their role as provider of post-disaster emergency relief and assistance to vulnerable and affected households and businesses. In wealthy countries, government (sovereign) insurance hardly exists at the national level and, in Sweden, insurance for public assets is illegal (Linnerooth-Bayer and Amendola, 2000). On the other hand, states in the United States, Canada, and Australia, although regulated not to incur budget deficits, often carry cover for their public assets (Burby, 1991). As discussed earlier (see Section 6.4.3), this is consistent with the Arrow and Lind Theorem, which suggests that governments can efficiently spread and share risk over their citizens without buying sovereign insurance policies.

Yet, realizing the shortcomings of after-the-event approaches for coping with disaster losses for small, low-income or highly exposed countries with over-stretched tax bases and highly correlated infrastructure risks (OAS, 1991; Pollner, 2000; Mechler, 2004; Cardona, 2006; Linnerooth-Bayer and Mechler, 2007; Mahul and Ghesquiere, 2007), sovereign insurance for public sector assets and relief expenditure has become a recent cornerstone for tackling the substantial and increasing effects of disasters (Mahul and Ghesquiere, 2007). As a general statement, the strategy involves transferring a layer of risks ranging from infrequent risk (such as events with a return period of more than 10 years) up to risks associated with 150-year return periods, beyond which it will become very costly to insure (Cummins and Mahul, 2009). One key element is to define the financial vulnerability indicating the inability to bear losses with a certain return period (Mechler et al., 2010).

Key applications have been implemented in Mexico in 2006, which insured its government emergency relief expenditure, and in the Caribbean with the Caribbean Catastrophe Risk Insurance Facility in 2007 (Ghesquiere, et al., 2006; Cardenas et al., 2007). Like national governments, donor organizations, exposed indirectly through their relief and assistance programs, also have been considering similar transactions; the World Food Programme in 2006, for example, purchased 'humanitarian insurance' for its drought exposure in Ethiopia through index-based reinsurance (see Section 9.2.13). These transactions set innovative and promising precedents in terms of protecting highly exposed developing and transition government portfolios against the risks imposed by disasters.

6.5.4. Managing the Impacts

Even in the rare circumstances where efforts outlined previously are all in place, there still needs to be investment in capacities to manage potential disaster impacts as risk cannot be reduced to zero (Pelling, 2003; Wisner et al., 2004; Coppola, 2007). The scale of the disaster impact should ideally dictate the level and extent of response. Individual household capacities to respond to disasters may be quickly overwhelmed, requiring local resources to be mobilized (del Ninno, 2001). When community-level responses are overwhelmed, regional or central governments are called upon (Coppola, 2007). Some events may overwhelm national government capacities too, and may require mobilization of the international community of humanitarian responders (Fagen, 2008; Harvey, 2009). International responses pose the most complex management challenges for national governments, because of the diversity of actors that are involved and the multiple resources flows that are established (Borton, 1993; Bennett et al., 2006; Ramalingam et al., 2008; ALNAP, 2010a). However, although humanitarian principles call for a proportionate and equitable response, in practice there are a few high-profile disasters that are over-resourced, with many more that are 'forgotten or neglected emergencies' (Slim, 2006). Despite the definition of international or national disasters as those where immediate capacities are overwhelmed, evaluations routinely find that most of the vital life-saving activities happen at the local level, led by households, communities, and civil society (see Sections 5.1 and 5.2; Smillie, 2001; Hilhorst, 2003; ALNAP, 2005; Telford and Cosgrave, 2006).

In terms of how responses are managed nationally, there are different models to consider (ALNAP, 2010b). Many countries now have some standing capacity to manage disaster events (Interworks, 1998) and this should be considered distinct from national systems for managing disaster risk, commonly associated with 'national platforms' detailed in Section 6.4.2. Examples of standing disaster management capacity include the Federal Emergency Management Agency in the United States, Public Safety in Canada, the National Commission for Disaster Reduction in China, the National Disaster Management Authorities in India and Indonesia, National Disaster Management Offices (NDMO) in many Pacific island countries, and the Civil Contingencies Secretariat in the United Kingdom. Comparative analysis of these structures shows that there are a number of common elements (Interworks, 1998; Coppola, 2007). Countries with formal disaster management structures typically operate a system comprised of a National Disaster Committee, which works to provide high-level authority and ministerial coordination, alongside an NDMO to lead the practical implementation of disaster preparedness and response (Interworks, 1998). National Committees are typically composed of representatives from different ministries and departments as well as the Red Cross/Red Crescent. They might also include donor agencies, NGOs, and the private sector. The committee works to coordinate the inputs of different institutions to provide a comprehensive approach to disaster management. NDMOs usually act as the executive arm of the national committee. Focal points for disaster management are usually professional disaster managers. NDMOs may be operational, or in large countries they may provide policy and strategic oversight to decentralized operational entities at federal or local levels. Where formal structures do not exist, national ministerial oversight is provided to the efforts of the NDMO in times of national disasters.

Government ownership of the national disaster management function can vary, with three models evident: it may reside with the presidential or prime ministerial offices; it may sit within a specific ministry; or it may be distributed across ministries (Interworks, 1998). The way in which the international community is engaged in major emergencies is shaped by existing national capabilities and social contracts, with four possible response approaches (Chandran and Jones 2008; ALNAP, 2010b; see Table 6-4). Analysis based on these broad categories helps clarify the ways in which international agencies are mobilized to manage disaster impacts, following from national structure and capabilities.

There may be states where there is an existing or emerging social contract with its citizens, by which the state undertakes to assist and protect them in the face of disasters, and there is a limited role for international agencies, focusing on advocacy and fundraising. By comparison, there are states that have a growing capacity to respond and request international agencies to supplement their effort in specific locally owned ways, through filling gaps in national capacities or resources. Next, there are states that have limited capacity and resources to meet their responsibilities to assist and protect their citizens in the face of disasters, and which request international assistance to cope with the magnitude of a disaster, resulting in a fully fledged international response. Finally, there are states that lack the will to negotiate a resilient social contract, including assisting and protecting their citizens

Table 6-4 | Activities associated with managing the impacts of disasters. Adapted from Coppola (2007) and ALNAP (2010a).

Pre-disaster	Immediate post-disaster	Recovery
• Public education • Awareness raising • Warning and evacuation plans • Pre-positioning of resources and supplies • Last minute alleviation and preparedness measures	• Search and rescue • Emergency medical treatment • Damage and Needs Assessment • Provision of services – water, food, health, shelter, sanitation, social services, security • Resumption of critical infrastructure • Coordination of response • Coordination / Management of development partner support	• Transitional shelter in form of temporary housing or long-term shelter • Demolition of critically damaged structures • Repair of less seriously damaged structures • Clearance, removal, and disposal of debris • Rehabilitation of infrastructure • New construction • Social rehabilitation • 'Building back better' to reduce future risk • Employment schemes • Reimbursement for losses • Reassessment of risks

Box 6-6 | National Disaster Preparedness, Prevention, and Management Systems: China and Kenya

China

The Government's disaster management process, developed as National Integrated Disaster Reduction, is a comprehensive system bringing together a number of central and local government sectors and covering the different phases of disasters preparedness, response, and recovery/rehabilitation. China has put in place over 30 laws and regulations regarding disaster management. The Emergency Response Law was adopted on 30 August 2007, as the central legal document governing all disaster-related efforts in China.

Under the related law and regulations, the Government has established an emergency response system consisting of three levels:

- The National Master Plan for Responding to Public Emergencies – a framework to be used throughout government to ensure public security and cope with public emergency events, including all disaster response activities.
- Five national thematic disaster response plans that outline the detailed assignment of duties and arrangements for major disaster response categories – disaster relief, flood and drought, earthquakes, geological disasters, and very severe forest fires.
- Emergency response plans for 15 central government departments and their detailed implementation plans and operation norms (UNESCAP, 2009).

Kenya

The government is working toward a national disaster management policy with the intention of preventing disasters and minimizing the disruption they cause through taking steps to reduce risks. The policy will help enhance existing capacities by building resilience to hazard events, building institutional capacity, developing a well-managed disaster response system, reducing vulnerability, and ensuring that disaster policy is integrated with development policy and poverty reduction and takes a multi-sectoral, multi-level approach. The Ministry of State for Special Programmes will be responsible for the coordination of the disaster management policy, will promote integration and coordination of disaster management, and will establish a national institute for disaster research to improve systematic monitoring and promotion of research.

The draft policy published in 2009 stressed the central role of climate change in any future sustainable planned and integrated National Strategy for Disaster Management. It sets out principles for effective disaster management, codes of conduct of different stakeholders, and provides for the establishment of an institutional framework that is legally recognized and embedded within the government structures. It stresses the importance of mobilizing resources to enable the implementation of the policy, with provision of 2% of the annual public budget to a National Disaster Management Fund.

At the time of writing, this policy has not reached Parliament for discussion and approval (MOSSP, 2010).

in times of disaster. These pose significant challenges and involve a combination of direct delivery and advocacy. Across all four categories of response, there are challenges around resources availability, proportionality of distribution, coordination, and leadership (ALNAP, 2010a).

Box 6-6 outlines details of the disaster management systems of two countries, which were chosen to illustrate the different stages of disaster management development that are evident across states.

Although level of response and actors involved can vary considerably between disasters and countries (ALNAP, 2010a), the basic actions taken to manage disaster impacts remain broadly the same across countries, and correspond closely to the different stages of the disaster timeline (see Table 6-4; Coppola, 2007). In general, disaster management employs immediate humanitarian activities, needs assessments, and the delivery of goods and services to meet requirements. The demand for water, food, shelter, sanitation, healthcare, security, and – later on – education, employment, reconstruction, and so on is balanced against available resources (Wisner and Adams, 2002).

Despite the existence of evidence that climate change is not responsible for the vast majority of the increasing trend in disaster losses (see SPM and Section 4.5.3.3), climate change-related disasters are still widely, if incorrectly, seen by particularly the humanitarian community as playing a major role in increasing the overall human impact of disasters. Numerous trends in disaster events are commonly attributed to climate change (IASC, 2009a; IFRC, 2009), and, as such, climate change is often cited as a reason for enhancing both national and international disaster management capacities (HFP, 2007; Oxfam, 2007; IASC, 2009a,b). Consequently, climate change-related considerations are increasingly featuring in literature on disaster management (Barrett et al., 2007;

McGray et al., 2007; Mitchell and Van Aalst, 2008; Venton and La Trobe, 2008; IASC, 2009a). As presented in this report, evidence is available for the influence of climate change on some extreme weather events but not for others (see Chapter 3), and, perhaps because of this, challenges remain in how climate change-related information can be used as a direct guide to decisionmaking in the humanitarian sector (IASC, 2009a).

The challenges of climate change call for institutional changes in approaches to managing disasters that are far from trivial (Salter 1998), with such challenges including more appropriate policies and legislation; decentralization of capacities and resources; greater budgetary allocation; improved capacity building at the local level; and the political will to bridge the divide between disaster risk reduction activities and the humanitarian action associated with managing disasters (Sanderson, 2000; UNISDR, 2005). Recent analyses of the need for greater innovation in international humanitarian responses (Ramalingam et al., 2009) present these shifts as among the most significant and important reforms the international system must undergo.

6.6. Aligning National Disaster Risk Management Systems with the Challenges of Climate Change

As mentioned, climate change presents multidimensional challenges for national systems for managing the risks of climate extremes and disaster risks, including potential changes in the way society views, treats, and responds to risks and projected impacts on hazards, exposure, and vulnerability. As climate change is altering the frequency and magnitude of some extreme events (see Chapter 3) and contributing to trends in exposure and vulnerability (see Chapter 4), the efficacy of national systems of disaster risk management requires review and realignment with the new challenges (UNISDR, 2009c; Mitchell et al., 2010a; Polack, 2010; see FAQ 6.1). Literature suggests that the effectiveness of national systems for managing disaster risk in a changing climate will be improved if they integrate assessments of changing climate extremes and disasters into current investments, strategies, and activities; seek to strengthen the adaptive capacity of all actors; and address the causes of vulnerability and poverty recognizing climate change as one such cause (Schipper, 2009; UNISDR 2009c; Mitchell et al., 2010a). In practice, this might require: (i) new alliances and hybrid organizations across government and potentially across countries; (ii) different actors to join the national system; (iii) new cross-sector relationships; (iv) reallocation of functions, responsibilities, and resources across scales; and (v) new practices (Hedger et al., 2010; Mitchell et al., 2010a; Polack, 2010). As a complement to the available data, information, and knowledge about the impact of climate change and disaster risk presented in Chapters 2, 3, and 4, this section seeks to elaborate the key areas where realignment of national systems could occur – in assessing the effectiveness of disaster risk management in a changing climate (Section 6.6.1), managing uncertainty and adaptive management (Section 6.6.2), in tackling poverty, vulnerability, and their structural causes (Section 6.6.3); and commenting on the practicalities of approaching such changes holistically (Section 6.6.4).

6.6.1. Assessing the Effectiveness of Disaster Risk Management in a Changing Climate

In order to align disaster risk management with the challenges presented by climate change, it is necessary to assess the effectiveness and efficiency of management options in a changing climate based on the best available information, recognizing that that information remains patchy at best. Adopting an economic assessment framework, different approaches have been used to comment on the effectiveness or efficiency of adaptation options. Many climate adaptation studies have focused on the national-level costs of adaptation rather than comparing costs and benefits (i.e., examining the benefits of adaptation or reduced disaster impacts and damage costs) (see Nordhaus, 2006; EEA, 2007; UNFCCC, 2007a; Agrawala and Fankhauser, 2008; World Bank, 2008; ECA, 2009; Parry et al., 2009). National-level adaptation assessments have been conducted, among others, in the European Union, the United Kingdom, Finland, The Netherlands, and Canada, as well as in a number of developing countries using the NAPA approach (UNDP, 2004c; MMM, 2005; DEFRA, 2006; UNFCCC, 2007b; Lemmen et al., 2008; De Bruinet al., 2009a).

Other approaches include assessments of disaster risk management with risk assessment at the core, and focusing on economic efficiency of management responses (see World Bank, 1996; Benson and Twigg, 2004; Mechler, 2004). Using such a rationale, the World Bank, for example, goes as far as suggesting that governments should in many instances prioritize allocating their resources on early warning (such as for floods), critical infrastructure, such as water and electricity lifelines, and supporting environmental buffers such as mangroves, forests, and wetlands, of which the latter should be treated with caution (World Bank and UN, 2010). Another report suggests taking an adaptation cost curve approach to selecting adaptation options (ECA, 2009); this approach organizes adaptation options around their cost-benefit ratios, similar to mitigation cost curves. Interestingly, many of the options considered efficient in this analysis are 'soft' options, such as reviving reefs, using mangroves as barriers, and nourishing beaches.

It is, however, difficult to make conclusive assessments about the effectiveness of disaster risk management in a changing climate, as overall the evidence base used to determine economic efficiency – that is, benefits net of costs of adaptation – remains limited and fragmented (Adger et al., 2007; UNFCCC, 2007a; Agrawala and Fankhauser, 2008). In addition to the rather small number of studies available, there are important limitations of these assessments as well. These relate to the types of hazards examined as well as treatment of extreme events and risk, affecting the robustness of the results. Another key limitation, relevant for this report, is that only very few national level studies assessing economic efficiency of options have focused explicitly on disaster risk, and in most instances the hazards examined have been gradual, such as sea level rise and slower onset impacts, such as drought, on agriculture (see UNFCCC, 2007a; Agrawala and Fankhauser, 2008). Where extreme events and disaster risks have been considered, studies have often adopted deterministic impact metrics, when disaster risk associated with frequency and variability of extreme events can change. Where

FAQ 6.1 | What can a government do to better prepare its people for changing climate-related disaster risks?

In almost all countries, governments create the enabling environment of policies, regulations, institutional arrangements, and coordination mechanisms to guide and support the efforts of all agencies and stakeholders involved in managing disaster risks at different scales. Such risks are increasing and changing because of population growth, migration, climate change, and a range of other factors. National systems for managing disaster risk need to act on these changes in order to build resilience in the short and long term. Accordingly, the following measures can be considered:

- **Generate and communicate robust information about the dynamic nature of disaster risk**: Given the dynamic and changing nature of disaster risks in the context of climate change, regular updates on changes in the level of risk will further strengthen such systems if the information is acted upon. Not possessing information about changing disaster risks or not integrating the information into decisions about longer-term investments can lead to increases in the exposure and vulnerability of people and assets and may increase risk over time. An example could be non-drought-tolerant monoculture agriculture in an area likely to experience increased frequency and/or longer durations of drought conditions, or water harvesting tanks installed in houses or communities that lack the capacity to supply water during longer periods of drought, or roads not raised sufficiently above future projected flood levels. Knowledge about dynamic risks can be generated from scientific observations and models, combined with analysis of patterns of vulnerability and exposure and from the experiences of local communities (see Section 6.5.1).
- **Even without robust information, consider 'no or low regrets' strategies, including ecosystem-based adaptation**: Countries have started to adopt 'no or low regrets' strategies that generate short-term benefits as well as help to prepare for projected changes in disaster risks, even when robust information is not available (see Section 6.3.1). Included in these 'no or low regrets' strategies are ecosystem-based strategies that not only help reduce current vulnerabilities and exposure to hazards under a range of climatic conditions, but also produce other co-benefits such as improved livelihoods and poverty reduction that help reduce vulnerability to projected changes in climate. Table 6-5, a considerably reduced version of Table 6-1, shows a summary of these options. Such 'no or low regrets' practices also tend to include measures to tackle the underlying drivers of disaster risk and are effective irrespective of projected changes in extremes of weather or climate (see Section 6.5.2). Where better information is available, this can be mainstreamed across line ministries and other agencies to shape practices that help to build resilience to projected changes in disaster risk over the longer term. These are highlighted in the right-hand column of Table 6-5.

Table 6-5 | Range of practices to demonstrate comparison between 'no or low regrets' measures and those integrating projected changes in disaster risk.

'No or low regrets' practices with demonstrated evidence of having integrated observed trends in disaster risks to reduce the effects of disasters	Practices that enhance resilience to projected changes in disaster risk
• Effective early warning systems and emergency preparedness (*very high confidence*) • Integrated water resource management (*high confidence*) • Rehabilitation of degraded coastal and terrestrial ecosystems (*high confidence)* • Robust building codes and standards reflecting knowledge of current disaster risks (*high confidence)* • Ecosystem-based/nature-based investments, including ecosystem conservation measures (*high confidence*) • Micro-insurance, including weather-indexed insurance (*medium confidence)* • Vulnerability-reducing measures such as pro-poor economic and human development, through for example improved social services and protection, employment, wealth creation *(very high confidence)*	• Crop improvement for drought tolerance and adaptive agricultural practices, including responses to enhanced weather and climate prediction services (*high confidence*) • Integrated coastal zone management integrating projections of sea level risk and weather/climate extremes (*medium confidence*) • National water policy frameworks and water supply infrastructures, incorporating future climate extremes and demand projections (*medium-high confidence*) • Strengthened and enforced building codes, standards for changed climate extremes (*medium confidence*) • Advances in human development and poverty reduction, through, for example, social protection, employment, and wealth creation measures, taking future exposure to weather and climate extremes into account *(very high confidence)*

Continued next page →

disaster risks have been accounted for, the robustness of future projections of risk is also uncertain (Bouwer, 2010).

Furthermore, many of the economic cost assessments faced key methodological challenges, including the difficulty in estimating economic values of intangible effects of disasters, such as impact on human life, suffering, and ecological services, different rates of time preferences or discounting the future, as well as the difficulties associated with properly accounting for the distribution of costs and benefits across different sectors of society (Parry et al., 2009). Such challenges suggest that the value of tools, such as cost-benefit analysis, for the assessment of economic efficiency, even with risk considerations, may lie in the usefulness of the analytical process rather than the numeric outcomes per se. They suggest that in the context of climate adaptation, such tools may be most usefully employed as a heuristic tool in the context of iterative stakeholder decisionmaking processes (Moench et al., 2007).

- **Use risk-sharing and transfer mechanisms to protect financial security**: To effectively support communities and protect the financial security of the country, governments are increasingly using a range of financial instruments for transferring costs of disaster losses through risk-sharing mechanisms. Key risk transfer instruments include financial insurance, micro-insurance, and micro-financing, investment in social capital, government disaster reserve funds, and intergovernmental risk sharing. The latter two help to provide much needed relief and immediate liquidity after a disaster in regions where individual countries, because of their size and lack of diversity, cannot have viable risk insurance schemes. Such mechanisms can allow for more effective government response, provide some relief of the fiscal burden placed on governments due to disaster impacts, and constitute critical steps in promoting more proactive risk management strategies and responses (see Section 6.5.3).
- **Not all disaster risk can be eliminated, so act to manage residual risk too**: Even with effective disaster risk reduction policies and practices in place, it is impossible to reduce all disaster risks to zero and some residual risks will remain. With disaster risks increasing in many countries, steps could be taken to strengthen governments' ability to effectively manage residual risks effectively, and in doing so will need to strengthen partnerships with other actors and stakeholders to enable quick and effective humanitarian response that includes measures to 'build back better' and build resilience over time (for example, using rapid climate risk assessments to position critical infrastructure or relief camps in safer locations during relief and reconstruction phases). Many governments are also already working to enhance their disaster preparedness and early warning systems, focusing on the accuracy and timeliness of warnings, increasing public awareness, working with communities to ensure messages are communicated and transmitted effectively, and enhancing preparedness measures, such as first aid training, providing swimming lessons, encouraging households to have a disaster plan and an emergency kit, securing and indicating evacuation routes and shelters, and enhancing the skills of relief workers in child protection, for example (see Section 6.5.4).
- **Review resilience-building efforts**: Given competing priorities and development goals, governments are forced to balance resource allocation across development goals. The decision to bear residual losses is always a risk management option due to financial and other constraints. Many governments decide to accept the full risk of very low probability and surprise events, but new information on the impacts of climate change on such events may lead to such decisions being reviewed. Even in such cases where risk reduction and risk transfer is not a viable management option, investments in reducing vulnerability and enhancing early warning, preparedness, and standing capacity for emergency response can lead to positive returns. Furthermore, given uncertainties associated with disasters, efforts to promote flexible institutions, cross-scale learning, improved knowledge and awareness, and redundancies in response systems (in case one part of the system is badly impacted) can all help to promote resilience to very low probability and surprise events. Many governments are also encouraging maintenance and strengthening of social cohesiveness and social networks as a form of insurance enabling families and friends to support each other in times of disasters (see Sections 6.6.2 and 6.6.3).

A limited number of studies have used other tools such as multi-criteria analysis and other variants, which do not rely on just quantitative values, to help in the stakeholder-based adaptation decisionmaking (De Bruin et al., 2009a; Debels et al., 2009; Cardona et al., 2010). Debels et al. (2009) developed a multi-purpose index for a quick evaluation of adaptation practices in terms of proper design, implementation, and post-implementation evaluation and applied it to cases in Latin America. Mechler et al. (2006b) developed a metric for measuring fiscal vulnerability to natural hazards, capturing the relationship between the economic and fiscal losses that a country could experience when a catastrophic event occurs and the availability of funds to address the situation. Cardona et al. (2010), building on this, constructed the Disaster Deficit Index and applied it across a range of Latin American countries to support governmental decisionmaking in disaster risk management over time. De Bruin et al. (2009b) describe a hybrid approach based on qualitative and quantitative assessments of adaptation options for flood risk in The Netherlands. For the qualitative part, stakeholders selected options in terms of their perceived importance, urgency, and other elements. In the quantitative assessment, costs and benefits of key adaptation options are determined. Finally, using priority ranking based on a weighted sum of the qualitative and quantitative criteria suggests that in The Netherlands, for example, an integrated portfolio of nature and water management with risk-based policies has particularly high potential and acceptance for stakeholders. Overall, the assessment of adaptation explicitly considering the risk-based nature of extreme events remains fragmented and incipient, and more work will be necessary to improve the robustness of results and confidence in assessments.

6.6.2. Managing Uncertainties and Adaptive Management in National Systems

Disasters associated with climate extremes are inherently complex, involving socioeconomic as well as environmental and meteorological uncertainty (Hallegatte et al., 2007; see Chapter 3). Population, social, economic, and environmental change all influence the way in which hazards are experienced, through their impact on levels of exposure and on people's sensitivity to hazards (Pielke Jr. et al., 2003; Aldunce et al., 2008). Uncertainty about the magnitude, frequency, and severity of climate extremes is managed, to an extent, through the development of

Box 6-7 | Building Resilience to Disasters in the Cayman Islands

Key aspects that are relevant to building disaster resilience are flexibility, learning, and adaptive governance (Adger et al., 2005; Berkes, 2007), and the Cayman Islands (Tompkins et al., 2008) illustrate how such factors help to successfully manage their disaster risks. For example, in 2004, Hurricane Ivan (which was similar in magnitude to Hurricane Katrina that hit New Orleans in 2005) only caused two fatalities in the island, largely due to the activities of the National Hurricane Committee (NHC), which manages hurricane disaster risk reduction in the Cayman Islands and is responsible for preparedness, response, and recovery. The NHC is a learning-based organization. It learns from its successes, but more importantly from mistakes made. Each year the disaster managers actively assess the previous year's risk management successes and failures. Every year the National Hurricane Plan is revised to incorporate this learning and to ensure that good practices are institutionalized. Evidence of adaptive governance can be observed, for example, in the changing composition of the NHC, its structure, network arrangements, funding allocation, and responsibilities. Policymakers are encouraged to design and to implement new initiatives, to make adjustments, and take motivated actions. Creating such space for experimentation, innovation, learning, and institutional adjustment is crucial for disaster resilience.

predictive models and early warning systems (see Section 3.2.3 and Box 3-2; Section 9.2.11). Early warning systems are also based on models and consequently there is always a probability of their success (or failure) in predicting events accurately, although the failure to heed early warning systems is also a function of social factors, such as perception of risk, trust in the information-providing institution, previous experience of the hazard, degree of social exclusion, and gender (see, e.g., Drabek, 1986, 1999). Enhanced scientific modeling and interdisciplinary approaches to early warning systems can address some of these uncertainties provided good baseline and time series information are available (see Section 3.2.3 and Box 3-2). Even where such information is available, there remain other unresolved questions that influence the outcome of hazards. These relate to the capacity of ecosystems to provide buffering services, and the ability of systems to recover. Management approaches that take these issues into account include adaptive management and resilience, yet these approaches are not without their challenges (also see Section 8.6.3.1).

Adaptive management, as defined in Chapter 8 (Section 8.6.3.1), is "a structured process for improving management policies and practices by systemic learning from the outcomes of implemented strategies, and by taking into account changes in external factors in a proactive manner" (Pahl-Wostl et al., 2009; Pahl-Wostl, 2009). It has come to also mean bringing together interdisciplinary science, experience, and traditional knowledge into decisionmaking through 'learning by doing' by individuals and organizations (Walters, 1997). Decisionmakers, under adaptive management, are expected to be flexible in their approach, and accept new information as it become available, or when new challenges emerge, and not be rigid in their responses. Proponents argue that effective adaptive management contributes to more rapid knowledge acquisition and better information flows between policymakers, and ensures that there is shared understanding of complex problems (Lee, 1993).

In most cases, adaptive management has been implemented at the local or regional scale and there are few examples of its implementation at the national level. Examples of adaptive management abound in ecosystem management (Johnson, 1999; Ladson and Argent, 2000) and in disaster risk management (Thompson and Gaviria, 2004; Tompkins, 2005; see Box 6-7). Nearly 40 years of research, after the seminal paper was published by Holling in 1973, have produced evidence of the impacts of aspects of resilience policy (notably adaptive management) on forests, coral reefs, disasters, and adaptation to climate change; however, most of this has been at the local or ecosystem scale.

One of the main unresolved issues in adaptive management is how to ensure that scientists and engineers tasked with investigating adaptation and disaster risk management processes are able to learn from each other and from practitioners and how this learning can be integrated to inform policy and management practices. In the case of the restoration of the Florida Everglades, a limiting factor to effective management observed was the unwillingness of some parts of society to accept short-term losses for longer-term sustainability of ecosystem services (Kiker et al., 2001). Investment in hurricane preparedness in New Orleans prior to Hurricane Katrina provides a contemporary example of science not being included in disaster risk decisionmaking and planning (Laska, 2004; Congleton, 2006). The Cayman Islands hurricane management, on the other hand, demonstrates a success story in a flexible disaster management committee being prepared to change its strategies and measures from experience, and essentially learning by doing (Box 6-7).

Spare capacity within institutions has been argued to increase the ability of socio-ecological systems to address surprises or external shocks (Folke et al., 2005). McDaniels et al. (2008), in their analysis of hospital resilience to earthquake impacts, agreed with this finding, concluding that key features of resilience include the ability to learn from previous experience, careful management of staff during hazard, daily communication, and willingness of staff to address specific system failures. The latter can be achieved through creating overlapping institutions with shared delivery of services/functions, and providing redundant capacity within these institutions thereby allowing a sharing of the risks (Low et al., 2003). Such redundancy increases the chances of social memory being retained within the institution (Ostrom, 2005). However, if not carefully managed, costs of this approach can include fragmented policy, high transactions costs, duplication, inconsistencies, and inefficiencies (Imperial, 1999).

'Learning by doing' in disaster risk management can only be undertaken effectively if the management institutions are scaled appropriately, where necessary at the local level, or at multiple scales with effective interaction (Gunderson and Holling, 2002; Eriksen et al., 2011). For the management of climate extremes, the appropriate scale is influenced by the magnitude of the hazard and the affected area, including biological diversity. Research suggests that increasing biological diversity of ecosystems allows a greater range of ecosystem responses to hazards, and this increases the resilience of the entire system (Elmqvist et al., 2003). Other research has shown that reducing non-climate stresses on ecosystems can enhance their resilience to climate change. This is the case for coral reefs (Hughes et al., 2003; Hoegh-Guldberg et al., 2008) and rainforests (Malhi et al., 2008). Managing the resources at the appropriate scale, for example, water catchment or coastal zone instead of managing smaller individual tributaries or coastal sub-systems (such as mangroves), is becoming more urgent (Sorensen, 1997; Parkes and Horwitz, 2009).

Climate resilience as a development objective is, however, difficult to implement, particularly as it is unclear as to what resilience means (Folke, 2006). Unless resilience is clearly defined and broadly understood, with measurable indicators designed to fit different local contexts and to show the success, the potential losers from this policy may go unnoticed, causing problems with policy implementation and legitimacy (Eakin et al., 2009). See the Glossary for this report's definition of resilience, and more details regarding uncertainty and resilience related to extreme events in the light of climate change are given in Section 3.2.3, Box 3-2, and Section 8.5.1.

6.6.3. Tackling the Underlying Drivers of Vulnerability

This assessment has found that future trends in exposure, vulnerability, and climate extremes may further alter disaster risk and associated impacts. Future trends in climate extremes will be affected by anthropogenic climate change in addition to natural climate variability, and exposure and vulnerability will be influenced by both climatic and non-climatic factors (SPM; Sections 2.2, 2.3, and 2.5). Accordingly, reducing vulnerability and its underlying drivers is a considered a critical aspect of addressing both observed and projected changes in disaster risk (UNISDR 2009c, 2011b; Figure 6-3). Section 6.5.2.2 discussed the centrality of human development and vulnerability reduction to the goal of disaster risk reduction. As an extension, literature focused on aligning national disaster risk management systems to the challenges posed by climate change and other dynamic drivers of disaster risk places considerable importance on addressing the underlying drivers of vulnerability as one of the most effective 'low or no regrets' measures (see Figure 6-3 and Table 6-5 in FAQ 6.1; Tanner and Mitchell, 2008; Davies et al., 2008; CCCD, 2009; UNISDR, 2009c; Mitchell et al., 2010a). Such underlying drivers of vulnerability include inequitable development; poverty; declining ecosystems; lack of access to power, basic services, and land; and weak governance (Wisner et al., 2004; Schipper 2009; UNISDR 2009c, 2011b). An approach to managing disaster risk in the context of a changing climate highlights that disaster risk management efforts should seek to develop partnerships to tackle vulnerability drivers by focusing on approaches that promote more socially just and economic systems; forge partnerships to ensure the rights and entitlements of people to access basic services, productive assets, and common property resources; empower communities and local authorities to influence the decisions of national governments, NGOs, and international and private sector organizations and to promote accountability and transparency; and promote environmentally sensitive development (Hedger et al., 2010; Mitchell et al., 2010a; Polack, 2010).

To date, strategies for tackling the risks of climate extremes and disasters, in practice, have tended to focus on treating the symptoms of vulnerability, and with it risk, rather than the underlying causes, partly due to disaster risk management still not being a core component of sustainable development (Schipper, 2009). The mid-term review of the HFA indicates that insufficient effort is being made to tackle the conditions that create risk (UNISDR, 2011b), and other studies have found a continued disconnect between disaster risk management and development processes that tackle the structural causes of poverty and vulnerability and between knowledge and implementation at all scales (CCCD, 2009; UNISDR, 2009c). The impacts of climate change, both on disaster risk and on vulnerability and poverty, are viewed by some as a potential force that will help to forge a stronger connection between disaster risk reduction measures and poverty and vulnerability reduction measures, also partly as a result of increased availability of financial resources and renewed political will (Soussan and Burton, 2002; Schipper, 2009; Mitchell et al., 2010a). A recent and growing body of literature has focused on the potential for strengthening the links among particular forms of social protection, disaster risk reduction, and climate change adaptation measures as a way to simultaneously tackle the drivers of vulnerability, poverty, and hence disaster risk (see Section 8.3.1; Davies et al., 2008; Heltberg et al., 2009). With increasing levels of exposure to disaster risk in middle-income countries (see Section 6.1; UNISDR, 2009c, 2011a), reducing vulnerability of poor people and their assets in such locations is becoming a focus for those governments and for CSOs and CBOs (Tanner and Mitchell, 2008).

6.6.4. Approaching Disaster Risk, Adaptation, and Development Holistically

As this chapter has demonstrated, climate change poses diverse and complex challenges for actors in national disaster risk management systems and for disaster risk management policies and practices more broadly. These challenges include changes in the magnitude and frequency of some hazards in some regions, impacts on vulnerability and exposure, new agreements and resource flows, and the potential of climate change to alter value systems and people's perceptions. As Table SPM.1 highlights, it is the complexity resulting from the combination of these factors, in addition to the uncertainty generated, that means national disaster risk management systems and broader national strategies may need to be realigned to maintain and improve their effectiveness. There is *high agreement* but *limited evidence* to suggest that a business-as-usual approach to disaster risk management that fails to take the impacts of climate change into account will become increasingly ineffective. Section 6.6 and other parts of this chapter have assessed evidence on the different elements involved in such a realignment. A selection of these elements is briefly summarized here.

As discussed in Section 6.6.2, there is *high agreement* but *limited evidence* to suggest that flexible and adaptive national systems for disaster risk management, based on the principle of learning by doing, are better suited to managing the challenges posed by changes in exposure, vulnerability, and weather and climate extremes than static and rigid systems (see Section 8.6). This ability to be flexible will be tested by a systems' capacity to act on new knowledge generated by the frequent assessment of dynamic risk needed to capture trends in exposure vulnerability and weather and climate extremes and by information on how the costs and benefits of different response measures change as a result (Section 6.6.1). The accuracy of these assessments will be based on the quality of available data (Section 6.5.2.1). Where such assessments generate uncertainty for decisionmakers, tools such as multi-criteria analysis, scenario planning, and flexible decision paths offer ways of supporting informed action (Section 6.6.1).

There is *high agreement* and *robust evidence* to demonstrate that the mainstreaming of disaster risk management processes into development planning and practice leads to more resilient development pathways. By extension, with climate change and other development processes having an impact on disaster risk, these changes then need to be factored into development and economic planning decisions at different scales. This suggests an ideal national system for managing the risks from climate extremes and disasters would be designed to be fully integrated with economic and social development, environmental, poverty reduction, and humanitarian dimensions to create a holistic approach. The nature of transformational changes in thinking, analysis, planning, approaches, strategies, and actions is the subject of Chapter 8 (particularly Section 8.2.2).

While there is *limited evidence* that some countries have begun to factor climate change into the way disaster risks are assessed and managed (see Sections 6.3 and 6.6.1), few countries appear to have adopted a comprehensive approach – for example, by addressing projected changes in exposure, vulnerability, and extremes as well as adopting a learning-by-doing approach to decisionmaking embedded in the context of national development planning processes. Incremental efforts toward implementing suitable strategies for mainstreaming climate change responses into national development planning and budgetary processes, and climate proofing at the sector and project levels (Sections 6.2 and 6.3) in the context of disaster risk management appear to be the most likely approach adopted by many countries. None of these measures will be easy to implement, as actors and stakeholders at all levels of society are being asked to embrace a dynamic notion of risk as an inherent part of their decisions, and continuously learn and modify policies, decisions, and actions taking into account new traditional and scientific knowledge as it emerges.

The knowledge base for understanding changing climate-related disaster risks and for the way national systems are acting on this understanding through modifying practices, altering the nature of relationships between different actors, and adopting new strategies and policies is fragmented and incomplete. As this chapter has illustrated, incomplete information and knowledge gaps do not need to present blockages to action. As FAQ 6.1 and Section 6.3.1 highlight, there is considerable experience of governments and other actors investing in measures to respond to existing climate variability and disaster risk that can be considered as 'no or low regrets' options when taking into account the uncertainty associated with future climate. However, in conducting this assessment, some knowledge gaps have emerged that, if filled, would aid the creation of enduring national risk management systems for tackling observed and projected disaster risk. These gaps include the need for more research on:

- The extent to which efforts to build disaster risk management capacities at different scales prepare people and organizations for the challenges posed by climate change.
- Whether the current trend of decentralizing disaster risk management functions to sub-national and local governments and communities is effective, given the level of information and capacity requirements, changing risks, and associated uncertainties presented by climate change.
- How the function, roles, and responsibilities of different actors working within national disaster risk management systems are changing, given the impacts of climate change at the national and sub-national level.
- The characteristics of flexibility, learning-by-doing, and adaptive management in the context of national disaster risk management systems in different governance contexts.
- How decisions on disaster risk management interventions are made at different scales if there is limited context-specific information.
- The costs and benefits of different risk management interventions if the impacts of climate change and other dynamic drivers of risk are factored in.
- The benefits and tradeoffs of creating integrated programs and policies that seek to manage disaster risk, mitigate GHGs, adapt to climate change, and reduce poverty simultaneously.

References

A digital library of non-journal-based literature cited in this chapter that may not be readily available to the public has been compiled as part of the IPCC review and drafting process, and can be accessed via either the IPCC Secretariat or IPCC Working Group II web sites.

Aakre, S., I. Banaszak, R. Mechler, D. Rübbelke, A. Wreford, and H. Kalirai, 2010: Financial adaptation to disaster risk in the European Union. *Mitigation and Adaptation Strategies for Global Change*, **15(7)**, 721-736.

ActionAid, 2006: *Climate Change, Urban Flooding and the Rights of the Urban Poor in Africa: Key findings from six African cities*. ActionAid International, London, UK and Johannesburg, South Africa.

Adger, W.N., T.P. Hughes, C. Folke, S.R. Carpenter, and J. Rockstrom, 2005: Social-ecological resilience to coastal disasters. *Science*, **5737(309)**, 1036-1039.

Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit, and K. Takahashi, 2007: Assessment of adaptation practices, options, constraints and capacity. In: *Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. Van Der Linde, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 717- 743.

ADPC, 2007: *Community Self-Resilience and Flood Risk Reduction*. ADB TA 4574-CAM Report, Asian Disaster Preparedness Centre, Asian Development Bank, Manila, Philippines.

African Development Bank Group, 2010: *Nairobi Rivers Rehabilitation and Restoration Program: Sewerage Improvement Project*. Project Appraisal Report, African Development Bank, www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Kenya%20-%20Nairobi%20rivers%20rehabilitation%20and%20restoration%20program%20-%20sewerage%20improvement%20project.pdf. Last accessed on: 26th Sept 2011.

Agrawala, S. and S. Fankhauser, 2008: *Economic Aspects of Adaptation to Climate Change. Costs, benefits and policy instrument*s. Organisation for Economic Cooperation and Development, Paris, France.

Agrawala, S. and M. van Aalst, 2008: Adapting development cooperation to adapt to climate change. *Climate Policy*, **8(3)**, 183-193.

Albala-Bertrand, J.M., 1993: *Political Economy of Large Natural Disasters with Special Reference to Developing Countries*. Clarendon Press, Oxford, UK.

Aldunce, P. and M. González, 2009: *Desastres Asociados al Clima en la Agricultura y Medio Rural de Chile*. Universidad de Chile, Santiago, Chile.

Aldunce, P. and A. Leon, 2007: Opportunities for improving disaster management in Chile: A case study. *Disaster Prevention and Management*, **16**(1), 33-41.

Aldunce, P, C. Neri, and C. Szlafsztein (eds.), 2008: Hacia la Evaluación de Prácticas de Adaptación ante la Variabilidad y el Cambio Climático. Nucleo de Meio Ambiente/Universidad Federal do Para, Belém, Brazil.

ALNAP, 2005: *Capacity Building amid Humanitarian Response*. Active Learning Network for Accountability and Performance in Humanitarian Action, London, UK.

ALNAP, 2010a: *The State of the Humanitarian System: assessing performance and progress.* Active Learning Network for Accountability and Performance in Humanitarian Action, London, UK.

ALNAP, 2010b: *The Role of National Governments in International Humanitarian Response to Disasters*. Meeting Background Paper, 26th ALNAP Meeting, Active Learning Network for Accountability and Performance in Humanitarian Action, London, UK, www.alnap.org/pool/files/26-meeting-background-paper.pdf.

Amendola, A., J. Linnerooth-Bayer, N. Okada, and P. Shi, 2008: Towards integrated disaster risk management: case studies and trends from Asia. *Natural Hazards*, **44**, 163-168.

Andersen, T.J., 2001: *Managing Economic Exposures of Natural Disasters. Exploring Alternative Financial Risk Management Opportunities and Instruments*. Inter-American Development Bank, Washington, DC.

Angelsen, A., M. Brockhaus, M. Kanninen, E. Sills, W.D. Sunderlin, and S. Wertz-Kanounnikoff, 2009: *Realising REDD: National strategy and policy options*. Center for International Forestry Research, Indonesia.

Arnell, N., 2004: Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change*, **14(1)**, 31-52.

Arnell, N.W. and E.K. Delaney, 2006: Adapting to climate change: Public water supply in England and Wales. *Climatic Change*, **78**(2-4), 227- 255.

Arnold, M., 2008: *The Role of Risk Transfer and Insurance in Disaster Risk Reduction and Climate Change Adaptation*. Policy brief, Commission on Climate Change and Development, Stockholm, Sweden.

Arrow, K. and R. Lind, 1970: Uncertainty and the evaluation of public investment decisions. *The American Economic Review*, **60**, 364-378.

Auffret, P., 2003: *Catastrophe Insurance Market in the Caribbean Region: Market Failures and Recommendations for Public Sector Interventions*. World Bank Policy Research Working Paper 2963, World Bank, Washington DC.

Auld, H., 2008a: Disaster risk reduction under current and changing climate conditions. *World Meteorological Organization Bulletin*, **57(2)**, 118-125.

Auld, H.E., 2008b: Adaptation by design: The impact of changing climate on infrastructure. *Journal of Public Works and Infrastructure*, **3**, 276-288.

Auld, H., D. MacIver, and J. Klaassen, 2004: Heavy rainfall and waterborne disease outbreaks: The Walkerton example. *Journal of Toxicology and Environmental Health, Part A*, **67(20-22)**, 1879-1887.

AusAid, 2009: Investing in a Safer Future: A Disaster Risk Reduction policy for the Australian aid program. AusAid, Canberra, Australia, www.ausaid.gov.au/publications/pdf/disasterriskreduction.pdf.

Averyt, K., 2010: Are we successfully adapting science to climate change? *Bulletin of the American Meteorological Society*, **91(6)**, 723-726.

Ayers, J.M. and S. Huq, 2009: The value of linking mitigation and adaptation: A case study of Bangladesh. *Environmental Management*, **43**(5), 753-764.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R.E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, and J. Madden, 2002: Economic reasons for conserving wild nature. *Science*, **297(5583)**, 950-953.

Barbier, E.B., 2009: *Rethinking the Economic Recovery: A Global Green New Deal.* Report prepared for the Economics and Trade Branch, Division of Technology, Industry and Economics, United Nations Environment Programme (UNEP), Geneva, Switzerland.

Barrett, E., S. Murfitt, and P. Venton, 2007: *Mainstreaming the Environment into Humanitarian Response: An Exploration of Opportunities and Issues*. Environmental Resource Management Limited, London, UK.

Basher, R., 2006: Global early warning systems for natural hazards: Systematic and people-centered. *Philosophical Transactions of the Royal Society A*, **364(1845)**, 2167-2182.

Bebi, P., D. Kulakowski, and C. Rixen, 2009: Snow avalanche disturbances in forest ecosystems – State of research and implications for management. *Forest Ecology and Management*, **257(9)**, 1883-1892.

Bennett, J., W. Bertrand, C. Harkin, S. Samarasinghe, and H. Wickramatillake, 2006: *Coordination of International Humanitarian Assistance in Tsunami Affected Countries.* Tsunami Evaluation Coalition, London, UK.

Benson, C., 2007: *Tools for Mainstreaming Disaster Risk Reduction: Environmental Assessments*. Guidance Note 7, ProVention Consortium, Geneva, Switzerland.

Benson, C. and E. Clay, 2002a: *Understanding the Economic and Financial Impacts of Natural Disasters*. World Bank, Washington, DC.

Benson, C. and E. Clay, 2002b: Disasters, vulnerability, and the global economy. In: *Building Safer Cities: The Future of Disaster Risk* [Kreimer, A., M. Arnold, and A. Carlin (eds.)]. Disaster Risk Management Series No. 3, World Bank, Washington, DC, pp. 3-32.

Benson, C. and E. Clay, 2004: Understanding the *Economic and Financial Impacts of Natural Disasters*. Disaster Risk Management Series 4, World Bank, Washington, DC.

Benson, C. and J. Twigg, 2004: *Measuring Mitigation: Methodologies for Assessing Natural Hazard Risks and the Net Benefits of Mitigation – A Scoping Study*. The International Federation of Red Cross and Red Crescent Societies/The ProVention Consortium, Geneva, Switzerland.

Benson, C., J. Twigg, and M. Myers, 2001: NGO initiatives in risk reduction: An overview. *Disasters*, **25(3)**, 199-215.

Berkes, F., 2007: Understanding uncertainty and reducing vulnerability: Lessons from resilience thinking. *Natural Hazards*, **41(2)**, 283-295.

Berry, P., 2007: *Adaptation Options on Natural Ecosystems*. Report to the Financial and Technical Support Division, United Nations Framework Convention on Climate Change, Bonn, Germany.

Bhavnani, R., M. Owor, S. Vordzorgbe, and F. Bousquet, 2008: *Status of Disaster Risk Reduction in the Sub-Saharan Africa Region*. World Bank, Washington, DC.

Biesbroek, G.R., R.J. Swart, T.R. Carter, C. Cowan, T. Henrichs, H. Mela, M.D. Morcecroft, and D. Rey, 2010: Europe adapts to climate change: Comparing National Adaptation strategies. *Global Environmental Change*, **20(3)**, 440-450.

Birkmann, J., M. Garschagen, F. Kraas, and N. Quang, 2011: Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science*, **5**, 185-206.

Borton, J., 1993: Recent trends in the international relief system. *Disasters*, **17(3)**, 187-201.

Bosher, L., P. Carillo, A. Dainty, J. Glass, and A. Price, 2007: Realising a resilient and sustainable built environment: Towards a strategic agenda for the United Kingdom. *Disasters*, **31**, 236-255.

Botzen, W.J.W., J.C.J.H. Aerts, and J.C.J.M. van den Bergh, 2009: Willingness of homeowners to mitigate climate risk through insurance. *Ecological Economics*, **68(8-9)**, 2265-2277.

Bourrelier, P.H., B.G. Deneufbourg, and B. de Vanssay, 2000: IDNDR objectives: French technical sociological contributions. *Natural Hazards Review*, **1(1)**, 18-26.

Bouwer, L.M., 2006: The benefits of disaster risk reduction and their effects on loss trends. In: *Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections* [Hoppe, P. and R. Pielke (eds.)]. Centre for Science and Technology Policy Research, Tyndall Centre, Munich Re and National Science Foundation, Hamburg, Germany, pp 26-28.

Bouwer, L.M., 2010: *Disasters and Climate Change: Analysis and Methods for Projecting Future Losses from Extreme Weather.* PhD thesis, Vrije Universiteit, Amsterdam, The Netherlands, 141 pp., dare.ubvu.vu.nl/bitstream/1871/16355/1/dissertation.pdf.

Branco, A., J. Suassuna, and S.A. Vainsencher, 2005: Improving access to water resources through rainwater harvesting as a mitigation measure: The case of the Brazilian semi-arid region. *Mitigation and Adaptation Strategies for Global Change*, **10(3)**, 393-409.

Brocklesby, M. and E. Fisher, 2003: Community development in sustainable livelihoods approaches – an introduction. *Community Development Journal*, **38**, 185-198.

Brooks, N. and W.N. Adger, 2005: Adaptation policy frameworks for climate change: developing strategies, policies and measures. In: *Assessing and Enhancing Adaptive Capacity* [Lim, B., E. Spanger-Siegfried, I. Burton, E.L. Malone, and S. Huq (eds.)]. Cambridge University Press, Cambridge, UK, pp. 165-181.

Brooks, N., N. Grist, and K. Brown, 2009: Development futures in the context of climate change: Challenging the present and learning from the past. *Development Policy Review*, **27**, 741-765.

Bunce, M., K. Brown, and S. Rosendo, 2010: Policy misfits, climate change and cross-scale vulnerability in coastal Africa: how development projects undermine resilience. *Environmental Science and Policy*, **13**, 485-497.

Burby, R, 1991. *Sharing Environmental Risks: How to Control Governments' Losses in Natural Disasters*. Westview Press, Boulder, CO.

Butler, C.D. and W. Oluoch-Kosura, 2006: Linking future ecosystem services and future human well-being. *Ecology and Society*, **11(1)**, 30.

Butt, T.A., B.A. Mccarl, J. Angerer, P.T. Dyke, and J.W. Stuth, 2005: The economic and food security implications of climate change in Mali. *Climatic Change*, **68(3)**, 355-378.

CACCA, 2010: *Approaches to Climate Change Adaptation*. Committee on Approaches to Climate Change Adaptation, Global Environment Bureau, Ministry of Environment, Tokyo, Japan, www.env.go.jp/en/earth/cc/adapt_guide.

Campbell, A., V. Kapos, A. Chenery, S.I. Kahn, M. Rashid, J.P.W. Scharlemann, and B. Dickson, 2008: *The Linkages between Biodiversity and Climate Change Mitigation.* UNEP World Conservation Monitoring Center, Cambridge, UK.

Cardenas, V., S. Hochrainer, R. Mechler, G. Pflug, and J. Linnerooth-Bayer, 2007: Sovereign financial disaster risk management: The case of Mexico. *Environmental Hazards*, **7(1)**, 40-53.

Cardona, O., 2006: Measuring vulnerability to natural hazards: Towards disaster resilient societies. In: *A system of indicators for disaster risk management in the Americas* [Birkmann, J. (ed.)]. United Nations University Press, Tokyo, Japan.

Cardona, O.D., M.G. Ordaz, M.C. Marulanda, M.L. Carreno, and A.H. Barbat, 2010: Disaster risk from a macroeconomics perspective: a metric for fiscal vulnerability evaluation. *Disasters*, **34(4)**, 1064-1083.

CARE International, 2008: Community preparedness for emergencies helps poverty. In: *Linking Disaster Risk Reduction and Poverty: Good Practices and Lessons Learnt* [United Nations International Strategy for Disaster Reduction (ed.)]. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland, pp. 6-10.

Carter, T.R., R.N. Jones, X. Lu, S. Bhadwal, C. Conde, L.O. Mearns, B.C. O'Neill, M. Rounsevell, and M.B. Zurek, 2007: New assessment methods and the characterisation of future conditions. In: *Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. Van Der Linde, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp.133-171.

Carter, W.N., 1992: *Disaster Management: A Disaster Manager's Handbook*. Asian Development Bank, Manila, Philippines.

Caselli, F. and P. Malthotra, 2004: *Natural Disasters and Growth: From Thought Experiment to Natural Experiment*. International Monetary Fund, Washington, DC.

Cash, D.W. and J. Buizer, 2005: *Knowledge-Action Systems for Seasonal to Interannual Climate Forecasting: Summary of a Workshop*. Roundtable on Science and Technology for Sustainability Policy and Global Affairs Division, National Research Council of the National Academies, The National Academies Press, Washington DC.

CCCD, 2009: *Closing the Gaps: Disaster Risk Reduction and Adaptation to Climate Change in Developing Countries: Final Report*. Commission on Climate Change and Development, Ministry for Foreign Affairs, Stockholm, Sweden.

CDB and CARICOM, 2004: *Sourcebook on the Integration of Natural Hazards into Environmental Impact Assessment (NHIA-EIA Sourcebook).* Caribbean Development Bank, Bridgetown, Barbados.

Chandran, R. and B. Jones, 2008: *Concepts and Dilemmas of State Building in Fragile Situations: from fragility to resilience*. OECD/DAC Discussion Paper, Organisation for Economic Cooperation and Development, Paris, France.

Charveriat, C., 2000: *Natural disasters in Latin America and the Caribbean: an overview of risk*. Inter-American Development Bank, Washington, DC.

Chhatre, A. and A. Agrawal, 2009: Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences*, **106(42)**, 17667-17670.

Christensen, J.H., B. Hewitson, A. Busuioc, A Chen, A. Gao, I. Held, R. Jones, R.K. Koli, W.T. Kwon, R. Laprise, V.M. Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, 2007: Regional climate predictions. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, pp. 847-940.

Chung, J., 2009: *Situation analysis for strengthening disaster information management systems in Fiji: baseline data preparedness and assessment methodologies*. A report prepared for the Fiji Government and Pacific Disaster Risk Management Partnership, United Nations International Strategy for Disaster Reduction and South Pacific Applied Geoscience Commission, Suva, Fiji.

Cline, W.R., 2007: *Global Warming and Agriculture: Impact Estimates by Country*. Center for Global Development and Peterson Institute for International Economics, Washington, DC.

Coleman, T., 2002: *The Impact of Climate Change on Insurance against Catastrophes*. Insurance Australia Group, Melbourne, Australia.

Colls, A., N. Ash, and N. Ikkala, 2009: *Ecosystem-based Adaptation: A Natural Response to Climate Change*. International Union for Conservation of Nature, Gland, Switzerland.

Congleton, R.D., 2006: The story of Katrina: New Orleans and the political economy of catastrophe. *Public Choice*, **127(1)**, 5-30.

Conway, D. and L. Schipper, 2011: Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change*, **21(1)**, 227-237.

Coppola, D.P, 2007: *Introduction to International Disaster Management*. Butterworth-Heinemann, Oxford, UK.

Costanza, R., O. Pérez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson, and K. Mulder, 2008: The value of coastal wetlands for hurricane protection. *Ambio*, **37(4)**, 241-248.

Crabbé, P. and M. Robin, 2006: Institutional adaptation of water resource infrastructures to climate change in eastern Ontario. *Climatic Change*, **78(1)**, 103 -133.

CRGR, 2007a: Lineamientos generales de organización y funcionamiento de la Concertación Regional de Gestión de Riesgos. *Políticas, Prácticas y Gestión del Riesgo*, **1(7)**, 4-7.

CRGR, 2007b: Reforma del Estado y gestión del riesgo de desastres. *Políticas, Prácticas y Gestión del Riesgo*, **2(8)**, 3-11.

CRGR, 2009: Centroamérica frente a los retos del cambio climático. Posicionamiento político de la sociedad civil y pueblos indígenas organizados. *Políticas, Prácticas y Gestión del Riesgo*, **3(12)**, 12-15.

Crowards, T., 2000: *Comparative Vulnerability to Natural Disasters in the Caribbean.* Caribbean Development Bank, Bridgetown, Barbados.

CSA, 2010a: *Infrastructure in Permafrost: A Guideline for Climate Change Adaptation. A Technical Guide.* Canadian Standards Association, Mississauga, Canada.

CSA, 2010b: *Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners*. Technical Guide, Canadian Standards Association, Mississauga, Canada.

Cummins, J., and O. Mahul, 2009: *Catastrophe Risk Financing In Developing Countries: Principles For Public Intervention.* World Bank, Washington, DC.

Curriero, F.C., J.A. Patz, J.B. Rose, and S. Lele, 2001: The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994. *American Journal of Public Health*, **91(8)**, 1194-1199.

Das, S. and J.R. Vincent, 2009: Mangroves protected villages and reduced death tolls during Indian super cyclone. *Proceedings of the National Academy of Sciences*, **106(18)**, 7357-7360.

DaSilva, J., B. Garanganga, V. Teveredzi, S.M. Marx, S.J. Mason, and S.J. Connor, 2004: Improving epidemic malaria planning, preparedness and response in Southern Africa. *Malaria Journal*, **3(1)**, 37.

Davies, M., B. Guenther, J. Leavy, T. Mitchell, and T. Tanner, 2008: Adaptive social protection synergies for poverty reduction. *Institute of Development Studies (IDS) Bulletin*, **39(4)**, 105-112.

Davis, K. (ed.), 2004: *Technology Dissemination among Small-Scale Farmers in Meru Central District of Kenya: Impact of Group Participation.* USA: University of Florida.

De Bruin, K., R. Dellink, and S. Agrawala, 2009a: *Economic Aspects of Adaptation to Climate Change: Integrated Assessment Modeling of Adaptation Costs and Benefits.* Environment Working Paper No. 6, Organisation for Economic Cooperation and Development, Paris, France.

De Bruin, K., R.B. Dellink, A. Ruijs, L. Bolwidt, A. van Buuren, J. Graveland, R.S. de Groot, P.J. Kuikman, S. Reinhard, R.P. Roetter, V.C. Tassone, A. Verhagen, and E.C. van Ierland, 2009b: Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. *Climatic Change*, **95**, 23-45.

Debels, P., C. Szlafsztein, P. Aldunce, C. Neri, Y. Carvajal, M. Quintero-Angel, A. Celis, A. Bezanilla, and D. Martinez, 2009: IUPA: A tool for the evaluation of the general usefulness of practices for adaptation to climate change and variability. *Natural Hazards*, **50(2)**, 211-233.

DEFRA, 2005: *Making Space for Water. Taking Forward a New Government Strategy for Flood and Coastal Erosion Risk Management in England.* Department for Environment, Food and Rural Affairs, London, UK.

DEFRA, 2006: *The UK's Fourth National Communication under the United Nations Framework Convention on Climate Change*. Department for Environment, Food and Rural Affairs, London, UK.

del Ninno, C., 2001: The 1998 Floods in Bangladesh: Disaster Impacts, Household Coping Strategies, and Response. Research Report 122, International Food Policy Research Institute, Washington, DC.

del Ninno, C., P.A. Dorosh, and L.C. Smith, 2003: Public policy, markets and household coping strategies in Bangladesh; Avoiding a food security crisis following the 1998 floods. *World Development,* **31(7)**, 1221-1238.

Dercon, S., 2005: Risk, insurance, and poverty: A review. In: *Insurance Against Poverty. A study prepared by the World Institute for Development Economics Research of the United Nations University (UNU-WIDER)*[Dercon, S. (ed.)]. Oxford University Press, Oxford, UK, pp. 9-37.

Dessai, S., and M. Hulme, 2007: Assessing the robustness of adaptation decisions to climate change uncertainties: A case study on water resources management in the East of England. *Global Environmental Change*, **17**, 59-72.

DFID, 2005: *Natural Disaster and Disaster Risk Reduction Measures: A Desk Review of Costs and Benefits*. UK Department for International Development, The Stationery Office, London, IK.

DFID, 2011: *Multilateral Aid Review: Ensuring Maximum Value for Money for UK Aid through Multilateral Organisations*. UK Department for International Development, London, UK.

Dilley, M., 2006: Risk identification: A critical component of disaster risk management. *World Meteorological Organisation Bulletin*, **55(1)**, 13-20.

Dolan, A.H. and I.J. Walker, 2006: Understanding vulnerability of coastal communities to climate change related risks. In: *Proceedings of the 8th Int'l Coastal Symposium.* Itajaí, Brazil, 14-18 March 2004. *Journal of Coastal Research*, **SI 39**, 1316-1323.

Dorren, L.K.A., F. Berger, A.C. Imeson, B. Maier, and F. Rey, 2004: Integrity, stability and management of protection forests in the European Alps. *Forest Ecology and Management*, **195(1-2)**, 165-176.

Drabek, T.E., 1986: *Human System Responses To Disaster: An Inventory Of Sociological Finding*. Springer-Verlag New York, NY.

Drabek, T.E., 1999: Understanding disaster warning responses. *The Social Science Journal*, **36**, 515-523.

Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. Mackinnon, T. Sandwith, and N. Sekhran, 2010: *Natural Solutions: Protected Areas Helping People Cope with Climate Change*. IUCN, WCPA, TNC, UNDP, WCS, World Bank and WWF, Gland, Switzerland, Washington, DC and New York, NY.

Eakin, H., E.L. Tompkins, D.R. Nelson, and J.M. Anderies, 2009: Adapting to climate change: Thresholds, values, governance. In: *Hidden Costs and Disparate Uncertainties: Trade-Offs Involved in Approaches to Climate Policy* [Adger, W.N., I. Lorenzoni, and L.O.B. Karen (eds.)]. Cambridge University Press, Cambridge, UK, pp. 212-226.

Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber, and F.N. Tubiello, 2007: Food, fibre and forest products. In: *Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. Van Der Linde, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 273-313.

Ebi, K.L., 2008: Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. *Globalization and Health*, **6**, 9, doi:10.1186/1744-8603.

Ebi, K.L., R.S. Kovats, and B. Menne, 2006. An approach for assessing human health vulnerability and public health interventions to adapt to climate change. *Environmental Health Perspectives*, **114**, 12, doi:10.1289/Ehp.8430.

EC, 2009: Technical Report – 2009 – 040, Guidance Document No. 24, River Basin Management. In: *A Changing Climate, Common Implementation Strategy for the Water Framework*. Directive 2000/60/EC. European Commission, Brussels, Belgium.

ECA, 2009: *Shaping Climate-Resilient Development: A Framework For Decision-Making Study.* Economics of Climate Adaptation Working Group, World Bank, Washington, DC.

ECLAC, 2002: *Handbook for Establishing the Socio-Economic and Environmental Effects of Natural Disasters*. United Nations, ECLAC and World Bank, Mexico City, Mexico.

ECLAC, 2003: *Handbook for Establishing the Socio-Economic and Environmental Effects of Natural Disasters*. United Nations, Economic Commission for Latin America and the Caribbean, and World Bank, Santiago, Chile.

EEA, 2007: *Climate change: The Cost of Inaction and the Cost of Adaptation*. Technical Report, European Environment Agency, Copenhagen, Denmark.

Elmqvist, T., C. Folke, M. Nyström, G. Peterson, J. Bengtsson, B. Walker, and J. Norberg, 2003: Response diversity, ecosystem change, and resilience. *Frontiers in Ecology and the Environment*, **1(9)**, 488-494.

Embrechts, P., C. Klüppelberg, and T. Mikosch, 1997: *Modelling Extremal Events for Insurance And Finance*. Springer, Berlin, Germany.

Ericksen, P., J. Ingram, and D. Liverman, 2009: Food security and global environmental change: emerging challenges. *Environmental Science and Policy*, **12**, 373-377.

Eriksen, S. and L.O. Næss, 2003: Pro-Poor Climate Adaptation: Norwegian Development Cooperation and Climate Change Adaptation – An Assessment of Issues, Strategies and Potential Entry Points. Report 2003:02. Center for International Climate and Energy Research – Oslo (CICERO), Oslo, Norway, 75pp.

Eriksen, S., P. Aldunce, C. Bahinipati, R. D'Almeida, J. Molefe, C. Nhemachena, K. O'Brien, F. Olorunfemi, J. Park, L. Sygna, and K. Ulsrud, 2011: When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate Change and Development*, **3(1)**, 7-20.

Fagen, P., 2008: *Natural Disasters in Latin America and the Caribbean: National, Regional and International Interactions*. HPG Working Paper, Overseas Development Institute, London, UK.

Fankhauser, S., 2010: The costs of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, **1(1)**, 23-30.

FAO, 2006: *Third session of the sub-committee on aquaculture: Committee on Fisheries* (CoFI). India, New Delhi, 4-8 September. Food and Agriculture Organization, Rome, Italy.

FAO, 2007: *Building Adaptive Capacity to Climate Change: Policies to Sustain Livelihoods and Fisheries*. New Directions in Fisheries – A Series of Policy Briefs on Development Issues, 0816. Food and Agriculture Organization, Rome, Italy.

FAO, 2008a: Climate change adaptation and mitigation in the food and agriculture sector: In: *Technical background document from the expert consultation held on 5 to 7 March 2008* (Paper presented at Climate change, energy and food). Food and Agriculture Organization, Rome, Italy.

FAO, 2008b: *Challenges for Sustainable Land Management for Food Security in Africa*. 25th Regional Conference for Africa, Nairobi, Kenya. Food and Agriculture Organization, Rome, Italy.

FAO, 2008c: *Climate Change for Fisheries and Aquaculture*. (Technical background document from the expert consultation). Food and Agriculture Organization, Rome, Italy.

FAO, 2009: *Seed Security for Food Security in the Light of Climate Change and Soaring Food Prices: Challenges and Opportunities* (Report of the twenty first session of the Committee on Agriculture*).* Food and Agriculture Organization, Rome, Italy.

FAO, 2010: *"Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*. Food and Agriculture Organization, Rome, Italy.

Feldman, D.L. and H.M. Ingram, 2009: Making science useful to decision makers: Climate forecasts, water management, and knowledge networks. *Weather, Climate and Society*, **1**, 9-20.

Few, R., H. Osbahr, L.M. Bouwer, D. Viner, and F. Sperling, 2006: *Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction* (Synthesis report). Vulnerability and Adaptation Resource Group, Washington, DC.

Folke, C., 2006: Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, **16(3)**, 253-267.

Folke, C., T. Hahn, P. Olsson, and J. Norberg, 2005: Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, **30**, 441-473.

Freeman, P.K. and Warner, K., 2001: *Vulnerability of Infrastructure to Climate Variability: How Does this Affect Infrastructure Lending Policies*? World Bank and ProVention Consortium, Washington, DC.

Freeman, P.K, L.A. Martin, J. Linnerooth-Bayer, R. Mechler, G. Pflug, and K. Warner, 2003: *Disaster Risk Management: National Systems for the Comprehensive Management of Disaster Risk and Financial Strategies for Natural Disaster Reconstruction*. Sustainable Development Department, Inter-American Development Bank, Washington, DC.

Froot, K.A., 2001: The market for catastrophe risk: A clinical examination. *Journal of Financial Economics*, **60**, 529-571.

Füssel, H., 2007: Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. *Sustainability Science*, **2(2)**, 265-275.

Gero, A., K. Méheux, and D. Dominey-Howes, 2011: Integrating community based disaster risk reduction and climate change adaptation: examples from the Pacific. *Natural Hazards and Earth System Sciences*, **11**, 101-113.

GFDRR, 2010: *Partnership Charter*. Global Facility for Disaster Risk Reduction, Washington, DC, gfdrr.org/gfdrr/sites/gfdrr.org/files/publication/GFDRR_Partnership_Charter_2010.pdf.

Ghesquiere, F., O. Mahul, M. Forni, and R. Gartley, 2006: *Caribbean Catastrophe Risk Insurance Facility: A solution to the short-term liquidity needs of small island states in the aftermath of natural disasters*. World Bank, Washington, DC, siteresources.worldbank.org/PROJECTS/Resources/Catastrophicriskinsurancefacility.pdf.

Glantz, M.H., 2005: Hurricane Katrina rekindles thoughts about fallacies of a so-called "natural" disaster. *Sustainability: Science, Practice and Policy*, **1(2)**, 1-4.

GNDR, 2009: *Clouds but Little Rain. Views from the Frontline: A Local Perspective of Progress towards Implementation of the Hyogo Framework for Action*. Global Network of Civil Society Organisations for Disaster Reduction, Teddington, UK.

Grosse, G., V. Romanovsky, T. Jorgenson, K.W. Anthony, J. Brown, and P.P. Overduin, 2011: Vulnerability and feedbacks of permafrost to climate change. *EOS, Transactions AGU*, **92(9)**, 73-80.

Grossi, P., and H. Kunreuther (eds.), 2005: *Catastrophe Modeling: A New Approach to Managing Risk*. Springer, New York, NY.

GTZ/DKKV, 2007: *National Platforms for Disaster Reduction: Study on current status of disaster reduction, institutional arrangements and potential for national platforms for disaster reduction 3 South and South East Asian Countries*. Gesellschaft für Technische Zusammenarbeit / German Committee for Disaster Risk Reduction, Bonn, Germany.

Guha-Sapir, D. and R. Below, 2002: *Quality and Accuracy of Disaster Data: A Comparative Analysis of Three Global Datasets.* Working document prepared for Disaster Management Facility, World Bank, Washington DC.

Gunderson, L. and C.S. Holling, 2002: *Panarchy Synopsis: Understanding Transformations in Human and Natural Systems.* Island Press, Washington, DC.

Gwimbi, P., 2007: The effectiveness of early warning systems for the reduction of flood disasters: Some experiences from cyclone induced floods in Zimbabwe. *Journal of Sustainable Development in Africa*, **9(4)**, 152-169.

Haasnoot, M., H. Middelkoop, E. van Beek, and W.P.A. van Deursen, 2009: A method to develop sustainable water management strategies for an uncertain future. *Sustainable Development*, **19**, doi:10.1002/sd.438.

Haines, A., R.S. Kovats, D. Campbell-Lendrum, and C. Corvalan, 2006: Climate change and human health: impacts, vulnerability and public health. *Public Health*, **120(7)**, 585-596.

Hallegatte, S., 2009: Strategies to adapt to an uncertain climate change. *Global Environmental Change*, **19(2)**, 240-247.

Hallegatte, S. and M. Ghil, 2007: *Endogenous Business Cycles and the Economic Response to Exogenous Shocks*. Fondazione Eni Enrico Mattei, Milan, Italy.

Hallegatte, S., J.-C. Hourcade, and P. Dumas, 2007: Why economic dynamics matter in assessing climate change damages: Illustration on extreme events. *Ecological Economics*, **62**, 330-340.

Halsnaes, K., and S. Traerup, 2009: Development and climate change: A mainstreaming approach for assessing economic, social, and environmental impacts of adaptation measures. *Environmental Management*, **43**, 765-778.

Hammer, K., N. Arrowsmith, and T. Gladis, 2003: Agrobiodiversity with emphasis on plant genetic resources. *Naturwissenschaften 2003*, **90(6)**, 241-250.

Hammill, A. and T. Tanner, 2010: Climate risk screening and assessment tools: making sense of a crowded field. In: *Meeting of the OECD DAC-EPOC Joint Task Team on Climate Change and Development Co-operation,* Amsterdam, The Netherlands, 12-13 October 2010.

Handmer, J. and S. Dovers, 2007: *Handbook of Disaster and Emergency Policies and Institutions*. Earth Scan, London, UK.

Harris, P. (ed.), 2009: *Climate Change and Foreign Policy: Case Studies from East to West*. Routledge, London, UK.

Harvey, P., 2009: *Towards Good Humanitarian Government: The Role of the Affected State in Disaster Response.* Humanitarian Policy Group, Overseas Development Institute, London, UK.

Hay, J., 2009: *Institutional and Policy Analysis of Disaster Risk Reduction and Climate Change Adaptation in Pacific Island Countries*. A report prepared for the United Nations International Strategy for Disaster Reduction (UNISDR) and the United Nations Development Programme (UNDP). UNISDR and UNDP, Suva, Fiji.

Hayley, D.W. and B. Horne, 2008: Rationalizing climate change for design of structures on permafrost: a Canadian perspective. In: *Proceedings of Ninth International Conference on Permafrost* [Kane, D.L. and K.M. Hinkle (eds.)]. University of Alaska Fairbanks, Fairbanks, AK, **1**, 681-686.

Hazell, P. and U. Hess, 2010: Drought insurance for agricultural development and food security in dryland areas. *Food Security*, **2**, 395-405.

Hedger, M. and J. Cacouris, 2008: *Separate Streams? Adapting Water Resources Management to Climate Change.* Tearfund, Teddington, UK.

Hedger, M., A. Singha, and M. Reddy, 2010: *Building Climate Resilience at State Level: Disaster Risk Management and Rural Livelihoods in Orissa*. Strengthening Climate Resilience Discussion Paper 5, Institute of Development Studies, Brighton, UK.

Heltberg, R., S.L. Jorgensen, and P.B. Siegel, 2008: *Climate Change, Human Vulnerability, and Social Risk Management.* World Bank, Washington, DC.

Heltberg, R., P.B. Siegel, and S.L. Jorgensen, 2009: Addressing human vulnerability to climate change: toward a 'no-regrets' approach. *Global Environmental Change*, **19(1)**, 89-99.

Hess, U. and H. Syroka, 2005: *Weather-based Insurance in Southern Africa. The Case of Malawi*. World Bank, Washington, DC.

HFP, 2007: *Dimensions of Crisis Impacts: Humanitarian Needs by 2015*. Working Paper, Humanitarian Futures Programmes, Kings College London, London, UK.

Hilhorst, D., 2003: Unlocking disaster paradigms: An actor-oriented focus on disaster response. Abstract submitted for Session 3 of the Disaster Research and Social Crisis Network Panels of the *6th European Sociological Conference*, Murcia, Spain 23-26 September 2003.

Hochrainer, S., 2006: *Macroeconomic Risk Management against Natural Disasters*. Deutscher Universita Ts-Verlag, Wiesbaden, Germany.

Hodgson, R. and M. Carter, 1999: Some lessons for a national approach to building for safety in Bangladesh. In: *Natural Disaster Management* [Ingleton, J. (ed.)]. Tudor Rose, Leicester, UK, pp. 160-162.

Hoegh-Guldberg, O., P.J. Mumby, A.J. Hooten, R.S. Steneck, P. Greenfield, E. Gomez, D.R. Harvell, P.F. Sale, A.J. Edwards, K. Caldeira, N. Knowlton, C.M. Eakin, R. Iglesias-Prieto, N. Muthiga, R.H. Bradbury, H. Dubi, and M.E. Hatziolos, 2008: Coral adaptation in the face of climate change. *Science*, **320(5874)**, 315.

Hoeppe, P. and E.N. Gurenko, 2006: Scientific and economic rationales for innovative climate insurance solutions. *Climate Policy*, **6(6)**, 607-620.

Holling, C.S., 1973: Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, **4(1)**, 1-23.

Howden, S.M., J.F. Soussana, F.N. Tubiello, N. Chhetri, M. Dunlop, and H. Meinke, 2007: Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences*, **104(50)**, 19691-19696.

Hughes, T.P., A.H. Baird, D.R. Bellwood, M. Card, S.R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J.B.C. Jackson, and J. Kleypas, 2003: Climate change, human impacts, and the resilience of coral reefs. *Science*, **301(5635)**, 929.

IASC, 2009a: *Addressing the Humanitarian Challenges of Climate Change Regional and National Perspectives*. Preliminary Findings from the IASC Regional and National Level Consultations, Inter-Agency Standing Committee, Geneva, Switzerland, www.humanitarianinfo.org/iasc/pageloader.aspx?page=content-news-newsdetails&newsid=134.

IASC, 2009b: *Letter from the IASC Principals to Yvo de Boer, Executive Secretary of the United Nations Framework Convention on Climate Change*. Inter-Agency Standing Committee, Geneva, Switzerland, www.humanitarianinfo.org/iasc/pageloader.aspx?page=content-news-newsdetails&newsid=134.

Ibarraran, M.E., M. Ruth, S. Ahmad, and M. London, 2009: Climate change and natural disasters: Macroeconomic performance and distributional impacts. *Environment, Development and Sustainability*, **11**, 549-569.

ICHARM, 2009: *Global Trends in Water-Related Disasters: An Insight for Policymakers*. International Centre for Water Hazard and Risk Management, World Water Assessment Programme, UNESCO, Paris, France.

IFRC, 2004: *World Disasters Report 2004: Focus on Community Resilience*. Int'l Federation of the Red Cross and Red Crescent Societies, Geneva, Switzerland.

IFRC, 2009: *World Disasters Report*: *Focus on Early Warning, Early Action*. International Federation of the Red Cross and Red Crescent Societies, Geneva, Switzerland.

IFRC, 2010: *World Disasters Report 2010: Focus on Urban Risk.* International Federation of the Red Cross and Red Crescent Societies, Geneva, Switzerland.

IIED, 2009: *Climate Change and the Urban Poor: Risk and Resilience in 15 of the World's Most Vulnerable Cities.* International Institute for Environment and Development, London, UK.

Ikeme, J., 2003: Climate change adaptational deficiencies in developing countries: The case of sub-Saharan Africa. *Mitigation and Adaptation Strategies for Global Change*, **8**, 29-52.

Imperial, M.T., 1999: Institutional analysis and ecosystem-based management: The institutional analysis and development framework. *Environmental Management*, **24(4)**, 449-465.

Interworks, 1998: *Model for a National Disaster Management Structure, Preparedness Plan, and Supporting Legislation, UNOCHA Disaster Management Training Programme.* UN Office for the Coordination of Humanitarian Affairs, ocha.unog.ch/drptoolkit/PreparednessTools/IL%20Frameworks/Models%20for%20Institutional%20structures%20and%20legislation,%20DMTP,%20InterWorks,1998.pdf.

IRI, 2006: *A Gap Analysis for the Implementation of the Global Climatic Observing System Programme in Africa.* IRI Technical Report No. IRI-TR/06/01, International Research Institute for Climate and Society, Columbia University, New York, NY.

Islam, T., and S. Ferdousi, 2007: Renewable energy development – challenges for Bangladesh. *Energy and Environment*, **18**, 421-430.

Jaspars, S. and D. Maxwell, 2009: *Food Security and Livelihoods Programming in Conflict: A Review*. HPN Network Paper 65. Humanitarian Practice Network, Overseas Development Institute, London, UK.

Johnson, B.L., 1999: Introduction to the special feature: Adaptive management – scientifically sound, socially challenged. *Conservation Ecology*, **3(1)**, 10.

Juhola, S., and L. Westerhoff, 2011: Challenges of adaptation to climate change across multiple scales: a case study of network governance in two European countries. *Environmental Science and Policy*, **14**, 239-247.

Kagiannas, A., D. Askounis, K. Anagnostopoulos, and J. Psarras, 2003: Energy policy assessment of the Euro-Mediterranean Cooperation. *Energy Conversion and Management*, **44(16)**, 2665-2686.

Katz, R. and G.B. Brown, 1992: Extreme events in a changing climate: Variability is more important than averages. *Climatic Change*, **21**, 289-302.

Kay, R. and J. Adler, 2005: *Coastal planning and management.* Third Edition. Routledge, New York, NY.

Kellenberg, D., K. Mobarak, and A. Mushfiq, 2008: Does rising income increase or decrease damage risk from natural disasters? *Journal of Urban Economics*, **63(3)**, 788-802.

Kelman, I., 2008: Relocalising disaster risk reduction for urban resilience. *Urban Design and Planning*, **161(4)**, 197-204.

Kelman, I., J. Lewis, J.C. Gaillard, and J. Mercer, 2011: Participatory action research for dealing with disasters on islands. *Island Studies Journal*, **6**, 59-86.

Kesavan, P.C. and Swaminathan, M.S., 2006: Managing extreme natural disasters in coastal areas. *Philosophical Transactions of the Royal Society A*, **364(1845)**, 2191-2216.

Kiker, C.F., J.W. Milon, and A.W. Hodges, 2001: Adaptive learning for science-based policy: The everglades restoration. *Ecological Economics*, **37(3)**, 403-416.

Kirshen, P., 2007: *Adaptation Options and Costs in Water Supply.* Report to the UNFCCC Secretariat, Financial and Technical Support Division, United Nations Framework Convention on Climate Change, Bonn, Germany.

Klein, R.J.T., R.J. Nicholls, S. Ragoonaden, M. Capobianco, J. Aston, and E.N. Buckley, 2001: Technological options for adaptation to climate change in coastal zones. *Journal of Coastal Research*, **17(3)**, 531-543.

Klein, R.J.T., S. Eriksen, L.O. Næss, A. Hammill, C. Robledo, and K. O'Brien, 2007: Portfolio screening to support the mainstreaming of adaptation to climate change into development. *Climatic Change*, **84**, 23-44.

Klijn, F., M. van Buuren, and S.A.M. van Rooij, 2004: Flood-risk management strategies for an uncertain future: living with Rhine river floods in the Netherlands? *Ambio*, **33**, 141-147.

Krysanova, V., C. Dickens, J. Timmerman, C. Varela-Ortega, M. Schlüter, K. Roest, P. Huntjens, F. Jaspers, H. Buiteveld, E. Moreno, J. de Pedraza Carrera, R. Slámová, M. Martínková, I. Blanco, P. Esteve, K. Pringle, C. Pahl-Wostl, and P. Kabat, 2010: Cross-comparison of climate change adaptation strategies across large river basins in Europe, Africa and Asia. *Water Resources Management*, **24**, 4121-4160.

Kuzak, D., 2004: The application of probabilistic earthquake risk models in managing earthquake insurance risks in Turkey. In: *Catastrophe Risk and Reinsurance: A Country Risk Management Perspective* [Gurenko, E. (ed.)]. Risk Books, London, UK.

Kwadijk, C.J., M. Haaasnoot, J.P.M. Hoogvliet, M.C. Marco, A.B.M. Jeuken, N.G.C. van der Oostrom, H.A. Schelfhout, E.H. van Velzen, H. van Waveren, and M.J.M. de Wit, 2010: Using adaptation tipping points to prepare for climate change and sea level rise: a case study in the Netherlands. *Wiley Interdisciplinary Reviews: Climate Change*, **1**, 729-740.

Ladson, A.R. and R.M. Argent, 2000: Adaptive management of environmental flows: Lessons for the Murray-Darling Basin from three large North American rivers. *Australian Journal of Water Resources*, **5(51)**, 89-101.

Lal, P.N., 2010: Vulnerability to natural disasters: an economic analysis of the impact of the 2009 floods on the Fijian sugar belt. *Pacific Economic Bulletin*, **25(2)**, 62-77.

Larsen, P.H., S. Goldsmith, O. Smith, M.L. Wilson, K. Strzepek, P. Chinowsky, and B. Saylor, 2008: Estimating future costs for Alaska public infrastructure at risk from climate change. *Global Environmental Change*, **18(3)**, 442-457.

Laska, S., 2004: What if hurricane Ivan had not missed New Orleans? *Natural Hazards Observer*, **29(2)**, 5-6.

Lavell, A., 1996. Environmental degradation, risks and urban disasters. In: *Issues and Concepts: Towards the Definition of a Research Agenda*. La Red, Lima, Peru, pp. 19-58.

Lavell, A., 1998. Decision making and risk management. In: *Furthering Cooperation in Science and Technology for Caribbean Development*. Port of Spain, Trinidad, 23-25 September 1998.

Lavell, A., 2009: *Unpacking Climate Change Adaptation and Disaster Management: Searching for the Links and Differences: A Conceptual and Epistemological Critique and Proposal*. FLACSO, Bogota, Colombia.

Lavell, A. and E. Franco, 1996: *Estado, sociedad y gestiãn de loes desastres en america latina: en busqueda del paradigma perdido.* La Red, Bogota, Colombia.

Lee, K., 1993: *Compass and Gyroscope*. Island Press, California.

Lemmen, D., F. Warren, J. Lacroix, and E. Bush, 2008: *From Impacts to Adaptation: Canada in a Changing Climate 2007.* Natural Resources Canada, Ottawa, Canada.

Leslie, H.M. and K.L. Mcleod, 2007: Confronting the challenges of implementing marine ecosystem-based management. *Frontiers in Ecology and the Environment*, **5(10)**, 540-548.

Lewis, J. and M.P. Chisholm, 1996: Cyclone-resistant domestic construction in Bangladesh. In: *Implementing Proceedings of Hazard-Resistant Housing: Proceedings of the First International Housing and Hazards Workshop to Explore Practical Building for Safety Solutions* [Hodgson, R.L.P., S.M. Seraj, and J.R. Choudhury (eds.)]. Dhaka, Bangladesh, 3-5 December 1996.

Linnerooth-Bayer, J. and A. Amendola, 2000: Global change, catastrophic risk and loss spreading. *The Geneva Papers on Risk and Insurance*, **25(2)**, 203-219.

Linnerooth-Bayer, J. and R. Mechler, 2006: Insurance for assisting adaptation to climate change in developing countries: A proposed strategy. *Climate Policy*, **6(6)**, 621-636.

Linnerooth-Bayer, J. and R. Mechler, 2007: Disaster safety nets for developing countries: Extending public-private partnerships. *Environmental Hazards*, **7**, 54-61.

Linnerooth-Bayer, J., R. Mechler, and G. Pflug, 2005: Refocusing disaster aid. *Science*, **309(5737)**, 1044-1046.

Llosa, S. and I. Zodrow, 2011: *Disaster Risk Reduction Legislation as a Basis for Effective Adaptation.* Background Paper prepared for the 2011 Global Assessment Report on Disaster Risk Reduction. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

Longley, C. and D. Maxwell, 2003: Livelihoods, chronic conflict and humanitarian response: A review of current approaches. *Natural Resource Perspectives*, **89,** 1-6.

Low, B., E. Ostrom, C. Simon, and J. Wilson, 2003: Navigating social-ecological systems: Building resilience for complexity and change. In: *Redundancy and diversity: Do they influence optimal management?* [Berkes, F., J. Colding, and C. Folke (eds.)]. Cambridge University Press, Cambridge, UK, pp. 83-114.

Lowe, R., 2003: Preparing the built environment for climate change. *Building Research and Information*, **31(3-4)**, 195-199.

Lu, X., 2011: Provision of climate information for adaptation to climate change. *Climate Research*, **47**, 83-94.

Mahul, O. and F. Ghesquiere, 2007: *Sovereign Natural Disaster Insurance for Developing Countries: A Paradigm Shift in Catastrophe Risk Financing.* Policy Research Working Paper 4345, World Bank, Washington, DC.

Malhi, Y., J.T. Roberts, R.A. Betts, T.J. Killeen, W. Li, and C.A. Nobre, 2008: Climate change, deforestation and the fate of the Amazon. *Science*, **319(5860)**, 169-172.

Mansourian, S., A. Belokurov, and P. Stephenson, 2009: The role of forest protected areas in adaptation to climate change. *Unasylva*, **60**, 63-69.

Manuel-Navarrete, D., J. Gomez, and G. Gallopin, 2007: Syndromes of sustainability of development for assessing the vulnerability of coupled human–environmental systems: The case of hydrometeorological disasters in Central America and the Caribbean. *Global Environmental Change*, **17**, 207-217.

Maréchal, K., 2007: The economics of climate change and the change of climate in economics. *Energy Policy*, **35(10)**, 5181- 5194.

Mastrandrea, M.D., N.E. Heller, T.L. Root, and S.H. Schneider, 2010: Bridging the gap: linking climate-impacts research with adaptation planning and management. *Climatic Change*, **100(1)**, 87-101.

Masumoto, T., T. Yoshida, and T. Kubota, 2006: An index for evaluating flood-prevention function of paddies. *Paddy and Water Environment*, **4(4)**, 205-210.

Masumoto, T., H. Pham Thanh, and K. Shimizu, 2008: Impact of paddy irrigation levels on floods and water use in the Mekong River Basin. *Hydrological Processes*, **22(9)**, 1321-1328.

McBean, G.A., 2008: Role of prediction in sustainable development and disaster management. *Springer- Hexagon Series on Human and Environmental Security and Peace*, **3**, 929-938.

McCarl, B.A., 2007: *Adaptation Options for Agriculture, Forestry and Fisheries*. A Report to the UNFCCC Secretariat Financial and Technical Support Division, United Nations Framework Convention on Climate Change, Bonn, Germany.

McDaniels, T., S. Chang, D. Cole, J. Mikawoz, and H. Longstaff, 2008: Fostering resilience to extreme events within infrastructure systems: characterizing decision contexts for mitigation and adaptation. *Global Environmental Change: Human and Policy Dimensions*, **18**, 310-318.

McEntire, D.A. and V. Myers, 2004: Preparing communities for disasters: Issues and processes for government readiness. *Disaster Prevention and Management*, **13(2)**, 140-152.

McEvoy, D., P. Matczak, I. Banaszak, and A. Chorynski, 2010: Framing adaptation to climate-related extreme events. *Mitigation and Adaptation Strategies to Global Change*, **15**, 779-795.

McGranahan, G., D. Balk, and B. Anderson, 2007: The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanizati*on, **19**, 17-37.

McGray, H., A. Hammill, R. Bradley, E.L. Schipper, and J.E. Parry, 2007: *Weathering the Storm: Options for Framing Adaptation and Development*. World Resources Institute, Washington, DC.

McKenzie, E., B. Prasad, and A. Kaloumaira, 2005: *Economic Impact of Natural Disasters on Development in the Pacific.* Volume I. SOPAC and USP, Suva, Fiji.

MEA, 2005: *Ecosystems and Human Well-Being: Synthesis*. Millennium Ecosystem Assessment, Island Press, Washington, DC.

Mechler, R., 2004: *Natural Disaster Risk Management and Financing Disaster Losses in Developing Countries.* Verlag für Versicherungswirtschaft, Germany.

Mechler, R., J. Linnerooth-Bayer, and D. Peppiatt, 2006a: *Microinsurance for Natural Disasters in Developing Countries: Benefits, Limitations and Viability*. ProVention Consortium, Geneva, Switzerland.

Mechler, R., J. Linnerooth-Bayer, S. Hochrainer, and G. Pflug, 2006b: Assessing financial vulnerability and coping capacity: The IIASA CATSIM model. In: *Measuring Vulnerability and Coping Capacity to Hazards of Natural Origin. Concepts and Methods* [Birkmann, J. (ed.)]. United Nations University Press, Tokyo, pp. 380-398.

Mechler, R., S. Hochrainer, A. Aaheim, Z. Kundzewicz, N. Lugeri, M. Moriondo, H. Salen, M. Bindi, I. Banaszak, A. Chorynski, E. Genovese, H. Kalirai, J. Linnerooth-Bayer, C. Lavalle, D. Mcevoy, P. Matczak, M. Radziejewski, D. Rübbelke, M.J. Schelhaas, M. Szwed, and A. Wreford, 2010: Making climate change work for us: European perspectives on adaptation and mitigation strategies. In: *A Risk Management Approach for Assessing Adaptation to Changing Flood and Drought Risks in Europe* [Hulme, H.N. (ed.)]. Cambridge University Press, Cambridge, UK, pp. 200-229.

Meehl, G.A., F. Zwiers, J. Evans, T. Knutson, L. Mearns, and P. Whetton, 2000: Trends in extreme weather and climate events: Issues related to modeling extremes in projections of future climate change. *Bulletin of the American Meteorological Society*, **81(3)**, 427-436.

Meinke, H., R. Nelson, P. Kokic, R. Stone, R. Selvaraju, and W. Baethgen, 2006: Actionable climate knowledge: From analysis to synthesis. *Climate Research*, **33(1)**, 101.

Menkhaus, K., 2007: Governance without government in Somalia: Spoilers, state building and the politics of coping. *International Security*, **31(3)**, 74-106.

Mercer, J., D. Dominey-Howes, I. Kelman, and K. Lloyd, 2007: The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards*, **7**, 245-256.

Mertz, O., K. Halsnaes, J. Olesen, and R. Rasmussen, 2009: Adaptation to climate change in developing countries: Special feature. *Environmental Management*, **43**, 743-752.

Miller , F., H. Osbahr, E. Boyd, F. Thomalla, S. Bharwani, G. Ziervogel, B. Walker, J. Birkmann, S. van der Leeuw, J. Rockström, J. Hinkel, T. Downing, C. Folke, and D. Nelson, 2010: Resilience and vulnerability: Complementary or conflicting concepts? *Ecology and Society*, **15(3)**, 11.

Mills, E., 2005: Insurance in a climate of change. *Science*, **309(5737)**, 1040-1044.

Mills, E., 2006: Testimony to the National Association of Insurance Commissioners. The Role of NAIC in responding to climate change. *UCLA Journal of Environmental Law and Policy*, **26(1)**, 129-168.

Mills, E., 2007: Synergisms between climate change mitigation and adaptation: An insurance perspective. *Mitigation and Adaptation Strategies for Global Change*, **12(15)**, 809-842.

Mitchell, T. and S. Maxwell, 2010: *Defining Climate Compatible Development*. Policy Brief, Climate and Development Knowledge Network, London, UK.

Mitchell, T. and M. van Aalst, 2008: *Convergence of Disaster Risk Reduction and Climate Change Adaptation: A Review for DFID*. Department for International Development (DFID), London, UK.

Mitchell, T., M. Ibrahim, K. Harris, M. Hedger, E. Polack, A. Ahmed, N. Hall, K. Hawrylyshyn, K. Nightingale, M. Onyango, M. Adow, and M. Sajjad, 2010a: *Climate Smart Disaster Risk Management*. *Strengthening Climate Resilience*. Institute of Development Studies, Brighton, UK.

Mitchell, T., M. van Aalst, and P. Villaneuva, 2010b: *Assessing Progress on Integrating Disaster Risk Reduction and Climate Change Adaptation in Development Processes*. Strengthening Climate Resilience Programme, Institute of Development Studies, Brighton, UK.

MMM, 2005: *Finland's National Strategy for Adaptation to Climate Change*. Ministry of Agriculture and Forestry, Helsinki, Finland, www.mmm.fi/en/index/frontpage/ymparisto/ilmastopolitiikka/ilmastomuutos.html.

Moench, M., R. Mechler, and S. Stapleton, 2007: Guidance note on the costs and benefits of disaster risk reduction. In: *UNISDR High Level Platform on Disaster Risk Reduction*, Geneva , Switzerland, 4-7 June 2007. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland.

Moser, C. and D. Satterthwaite, 2008: *Towards Pro-Poor Adaptation to Climate Change in the Urban Centers of Low- and Middle-Income Countries.* International Institute for Environment and Development, London, UK.

MOSSP, 2010: Draft National Policy for Disaster Management in Kenya. Ministry of State of Special Programs, Kenya, www.kecosce.org/downloads/DRAFT_DISASTER_MANAGEMENT_POLICY.pdf.

Muller, M., 2007: Adapting to climate change: Water management for urban resilience. *Environment and Urbanization*, **19(1)**, 99-113.

Munich Re, 2005: *Short Annual Report 2005: Paving the way for opportunities*. Munich Re Group, Munich, Germany.

Munich Re, 2011: *Topics Geo Natural Catastrophes 2010: Analyses, Assessments, Positions*. Munich Re, Munich, Germany.

Murlidharan, T.L. and H.C. Shah, 2001: Catastrophes and macro-economic risk factors: An empirical study. In: *Conference on Integrated Disaster Risk Management: Reducing Socio-Economic Vulnerability*. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Murray, B.C., W.A. Jenkins, S. Sifleet, L. Pendleton, and A. Baldera, 2010: *Payment for Blue Carbon: Potential for Protecting Threatened Coastal Habitats*. Nicholas Institute for Environmental Policy Solutions, Duke University, Durham, NC.

Musgrave, R.A., 1959: *The Theory of Public Finance.* McGraw Hill, New York, NY.

National Platform for Kenya, 2009: *Interim National Progress Report on Hyogo Framework for Action*. Prepared for the UN Global Assessment Report 2009, United Nations International Strategy for Disaster Reduction, Geneva, Switzerland, preventionweb.net/files/7432_Kenya.pdf.

Neufeldt, H., A. Wilkes, R.J. Zomer, J. Xu, E. Nang'ole, C. Munster, and F. Place, 2009: *Trees on Farms: Tackling the Triple Challenges of Mitigation, Adaptation and Food Security*. Policy Brief 07, World Agroforestry Centre, Kenya.

Neumann, J., 2009: *Adaptation to Climate Change: Revisiting Infrastructure Norms*. Resources for the Future, Washington, DC.

Nicholls, R.J., 2007: *Adaptation Options for Coastal Areas and Infrastructure: An Analysis for 2030*. Report to the United Nations Framework Convention on Climate Change (UNFCCC), UNFCCC, Bonn, Germany.

Nicholls, R.J., P.P. Wong, V. Burkett, C.D. Woodroffe, and J. Hay, 2008: Climate change and coastal vulnerability assessment: scenarios for integrated assessment. *Sustainability Science*, **3**, 89-102.

Nordhaus, W., 2006: *The Economics of Hurricanes in the United States*. National Bureau of Economic Research, Cambridge, MA.

Noy, I., 2009: The macroeconomic consequences of disasters. *Journal of Development Economics*, **88(2)**, 221-231.

NRC (National Research Council), 2009: *Informing Decisions in a Changing Climate*. Panel on Strategies and Methods for Climate-Related Decision Support, NRC, National Academies Press, Washington, DC.

NRTEE, 2009: *True North: Adapting Infrastructure to Climate Change in Northern Canada*. National Round Table on Environment and Economy, Ottawa, Canada.

O'Brien, G., 2006: UK emergency preparedness – A step in the right direction? *Journal of International Affairs*, **59(2)**, 63-85.

O'Brien, G., 2008: UK emergency preparedness – A holistic local response? *Disaster Prevention and Management*, **17(2)**, 232-243.

O'Brien, G. and P. O'Keefe, 2010: Resilient responses to climate change and variability: A challenge for public policy. *International Journal of Public Policy*, **6(3-4)**, 369-385.

O'Brien, G. and P. Read, 2005: Future UK emergency management: New wine, old skin? *Disaster Prevention and Management*, **14(3)**, 353-361.

O'Brien, G., P. O'Keefe, J. Rose, and B. Wisner, 2006: Climate change and disaster management. *Disasters*, **30(1)**, 64-80.

O'Brien, K., L. Sygna,, R. Leichenko, W.N. Adger, J. Barnett, T. Mitchell, L. Schipper, T. Tanner, C. Vogel, and C. Mortreux, 2008: *Disaster Risk Reduction, Climate Change Adaptation and Human Security*. Report prepared for the Royal Norwegian Ministry of Foreign Affairs by the Global Environmental Change and Human Security (GECHS) Project, GECHS Report 2008:3, Oslo, Norway.

OAS, 1991: *Primer on Natural Hazard Management in Integrated Regional Development Planning*. Organization of American States, Washington, DC.

OECD, 2006: *Applying Strategic Environmental Assessment: Good Practice Guidance For Development Co-Operation*. Organisation for Economic Cooperation and Development, Paris, France.

OECD, 2009: *Policy Guidance on Integrating Climate Change Adaptation into Development Co-operation*. Organisation for Economic Cooperation and Development, Paris, France.

Olhoff, A. and C. Schaer, 2010: *Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance – A Stocktaking Report*. United Nations Development Programme, New York, NY.

Olsen, J.R., 2006: Climate change and floodplain management in the United States. *Climatic Change*, **76(3-4)**, 407- 426.

ONERC, 2009: *Climate Change Costs of Impacts and Lines of Adaptation*. A report to the Prime Minister and Parliament, Observatoire National sur les Effets du Réchauffement Climatique, Paris, France.

Ostrom, E., 2005: *Understanding Institutional Diversity.* Princeton University Press, Princeton, NJ.

Otero, R.C. and R.Z. Marti, 1995: The impacts of natural disasters on developing economies: Implications for the international development and disaster community. In: *Disaster Prevention for Sustainable Development: Economic and Policy Issues* [Munasinghe, M. and C. Clarke (eds.)]. World Bank, Washington, DC, pp. 11-40.

Owens, T., T. Hoddinott, and B. Kinsey, 2003: Ex-ante actions and ex-post public responses to drought shocks: Evidence and simulations from Zimbabwe. *World Development*, **31(7)**, 1239-1255.

Oxfam, 2007: *Climate Alarm: Disasters Increase as Climate Change Bites.* Oxfam Briefing Paper 108, Oxfam, Oxford, UK, www.oxfam.org.uk/resources/policy/climate_change/downloads/bp108_weather_alert.pdf.

Oxfam America, 2008: National network for DRR helps curb poverty. In: *Linking Disaster Risk Reduction and poverty: Good practices and Lessons Learnt* [United Nations International Strategy for Disaster Reduction (UNISDR) (ed.)]. UNISDR, Geneva, Switzerland, pp. 11-14.

Pahl-Wostl, C., 2009: A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, **19**, 354-365.

Pahl-Wostl, C., J. Sendzimer, and P. Jeffrey, 2009: Resources management in transition. *Ecology and Society*, **14(1)**, 46, www.ecologyandsociety.org/vol14/iss1/art46/.

Parkes, M.W and P. Horwitz, 2009: Water, ecology and health: Ecosystems as settings for promoting health and sustainability. *Health Promotion International*, **24(1)**, 94.

Parry, M., N. Arnell, P. Berry, D. Dodman, S. Fankhauser, C. Hope, S. Kovats, R. Nichollas, D. Satterthwaite, R. Tiffin, and R. Wheeler, 2009: *Assessing the Costs of Adaptation to Climate Change: A review of the UNFCCC and other recent estimates*. International Institute for Environment and Development and Grantham Institute for Climate Change, London, UK.

Patt, A., R.J.T. Klein, and A. de la Vega-Leinert, 2005: Taking the uncertainty in climate-change vulnerability assessment seriously. *Comptes Rendus Geoscience*, **337(4)**, 411-424.

Patz, J.A., M.A. Mcgeehin, S.M. Bernard, K.L. Ebi, P.R. Epstein, A. Grambsch, D.J. Gubler, P. Reither, I. Romieu, J.B. Rose, J.M. Samet, and J. Trtanj, 2000: The potential health impacts of climate variability and change for the United States: Executive Summary of the report of the health sector of the U.S. National Assessment. *Environmental Health Perspectives*, **108(4)**, 367-376.

Patz, J.A., D. Campbell-Lendrum, T. Holloway, and J.A. Foley, 2005: Impact of regional climate change on human health. *Nature*, **438(7066)**, 310-317.

Pelham, L., E. Clay, and T. Braunholz, 2011: *Natural Disasters: What is the Role for Social Safety Nets?* World Bank, Washington, DC.

Pelling, M., 2003: *The Vulnerability of Cities: Natural Disasters and Social Resilience.* Earthscan, London, UK.

Pelling, M. and A. Holloway, 2006: *Legislation for Mainstreaming Disaster Risk Reduction*. Tearfund, Teddington, UK.

Persson, Å. and R.J.T. Klein, 2009: Mainstreaming adaptation to climate change into official development assistance: challenges to foreign policy integration. In: *Climate Change and Foreign Policy: Case Studies from East to West* [P. Harris (ed.)]. Routledge, London, UK, pp. 162-177.

Phillips, C. and M. Marden, 2005: Landslide hazard and risk. In: *Reforestation Schemes to Manage Regional Landslide Risk* [Glade, T., M. Anderson, and M.J. Crozier (eds.)]. John Wiley and Sons Ltd, Sussex, UK, pp. 517-548.

Pielke, Jr., R.A., J. Rubiera, C. Landsea, M.L. Fernández, and R. Klein, 2003: Hurricane vulnerability in Latin America and the Caribbean: Normalized damage and loss potentials. *Natural Hazards Review*, **4**, 101-114.

Pierro, R. and B. Desai, 2008: Climate insurance for the poor: Challenges for targeting and participation. *Institute of Development Studies Bulletin*, **39**, 4.

Polack, E., 2010: *Integrating Climate Change into Regional Disaster Risk Management at the Mekong River Commission*. Strengthening Climate Resilience Discussion Paper 4, Institute of Development Studies, Brighton, UK.

Polackova Brixi, H. and A. Mody, 2002: Dealing with government fiscal risk: An overview. In: *Government at Risk* [Polackova Brixi, H. and A. Schick (eds.)]. World Bank, Washington, DC.

Pollner, J., 2000: *Managing Catastrophic Risks Using Alternative Risk Financing and Insurance Pooling Mechanisms*. World Bank, Washington, DC.

Prabhakar, S.V.R.K., A. Srinivasan, and R. Shaw, 2009: Climate change and local level disaster risk reduction planning: Need, opportunities and challenges. *Mitigation and Adaptation Strategies for Global Change*, **14(1)**, 7-33.

Practical Action Bangladesh, 2008: Risk reduction boosts livelihood security in disaster-prone District. In: Linking Disaster Risk Reduction and Poverty: Good Practices and Lessons Learnt [United Nations International Strategy for Disaster Reduction (UNISDR) (ed.)]. UNISDR, Geneva, Switzerland, pp. 1-5.

Preston, B.L., R.M. Westaway, and E. Yuen, 2011: Climate adaptation planning in practice: an evaluation of adaptation plans from three developed nations. *Mitigation and Adaptation Strategies for Global Change,* **16(4)**, 407-438.

Priest, G.L., 1996. The government, the market, and the problem of catastrophic loss. *Journal of Risk and Uncertainty*, **12(2)**, 219-237.

ProAct Network, 2008: *Environmental Management, Multiple Disaster Risk Reduction and Climate Change Adaptation Benefits for Vulnerable Communities.* ProAct Network, Switzerland.

ProVention, 2009: Cities and resilience. In: *Climate Policy Brief from Cities and Resilience Dialogue.* Bangkok, Thailand, 28-29 September 2009.

Pulwarty, R.S., and K. Redmond, 1997: Climate and salmon restoration in the Columbia River basin: The role and usability of seasonal forecasts. *Bulletin of the American Meteorological Society,* **78(3)**, 381-397.

Pulwarty, R.S., K. Broad, and T. Finan, 2004: El Niño events, forecasts and decision-making. In: *Mapping Vulnerability: Disasters, Development, and People* [Bankoff, G., G. Frerks, and T. Hilhorst (eds.)]. Earthscan, London, UK, pp. 83-98.

Raddatz, C., 2007: Are external shocks responsible for the instability of output in low-income countries? *Journal of Development Economics*, **84**, 155-187.

Rahaman, M. and O. Varis, 2005: Integrated water resources management: Evolution, prospects and future challenges. *Sustainability: Science, Practice and Policy*, **1(1)**, 15-21.

Rahel, F.J. and J.D. Olden, 2008: Assessing the effects of climate change on aquatic invasive species. *Conservation Biology*, **22(3)**, 521-533.

Ramalingam, B., H. Jones, T. Reba, and J. Youngs, 2008: *Exploring the Science of Complexity: Ideas and Implications for International Development and Humanitarian Efforts*. ODI Working Paper 285, Overseas Development Institute, London, UK.

Ramalingam, B., K. Scriven, and C. Foley, 2009: Innovations in International Humanitarian Action. In: *ALNAP 8th Review of Humanitarian Action*. Active Learning Network for Accountability and Performance in Humanitarian Action (ALNAP), London, UK.

Ranger, N., A. Millner, S. Dietz, S. Fankhauser, A. Lopez, and G. Ruta, 2010: *Adaptation in the UK: a Decision Making Process*. Policy Brief, Grantham Research Institute on Climate Change and the Environment and Centre for Climate change Economics and Policy, London, UK.

Ranger, N. and S.-L. Garbett-Shiels, 2011: *How can Decision-Makers in Developing Countries Incorporate Uncertainty about Future Climate Risks into Existing Planning and Policymaking Processes*? Policy Paper, Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment in collaboration with the World Resources Report, World Resources Institute, Washington, DC, www.worldresourcesreport.org/files/wrr/papers/wrr_ranger_uncertainty.pdf.

Rayner, S., D. Lach, and H. Ingram, 2005: Weather forecasts are for wimps: why water resource managers do not use climate forecasts. *Climatic Change*, **69(**31), 197-227.

Reid, H. and S. Huq, 2005: Tropical forests and adaptation to climate change: In search of synergies. In: *Climate Change – Biodiversity and Livelihood Impacts* [Robledo, C., M. Kanninen, and L. Pedroni, (eds.)]. Center for International Forestry Research, Indonesia.

Reid, H., D. Dodman, R. Janssen, and S. Huq, 2010: Building capacity to cope with climate change in the least developed countries. In: *Changing Climates, Earth Systems and Society* [Dodson, J. (ed.)]. International Year of Planet Earth, Springer, the Netherlands.

Ribeiro, M., C. Losenno, T. Dworak, E. Massey, R. Swart, M. Benzie, and C. Laaser, 2009: *Design of Guidelines for the Elaboration of Regional Climate Change Adaptations Strategies.* Study for the European Commission, Ecologic Institute, Vienna, Austria.

Robledo, C., M. Kanninen, and L. Pedroni (eds.), 2005: *Tropical Forests and Adaptation to Climate Change: In Search of Synergies.* Center for International Forestry Research, Indonesia.

Roeth, H., 2009: *The Development of a Public Partnership Framework and Action Plan for Disaster Risk Reduction in Asia.* United Nations International Strategy for Disaster Reduction, Bangkok, Thailand.

Rogers, D., and V. Tsirkunov, 2010: *Costs and Benefits of Early Warning Systems. Global Assessment Report on Disaster Risk Reduction.* United Nations International Strategy for Disaster Reduction and World Bank, Geneva, Switzerland and Washington, DC.

Romieu, E., T. Welle, S. Schneiderbauer, M. Pelling, and C. Vinchon, 2010: Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications. *Sustainability Science*, **5**, 159-170.

Rosenzweig, C. and F.N. Tubiello, 2007: Adaptation and mitigation strategies in agriculture: An analysis of potential synergies. *Mitigation and Adaptation Strategies for Global Change*, **12(5)**, 855-873.

Rossetto, T., 2007: *Construction Design, Building Standards and Site Selection: Tools for Mainstreaming Disaster Risk Reduction*. ProVention Consortium, Geneva, Switzerland.

Ruth, M., and D. Coelho, 2007: Understanding and managing the complexity of urban systems under climate change. *Climate Policy*, **7**, 317-336.

Sabatier, P.A., 1986: Top-down and bottom-up approaches to implementation research: A critical analysis and suggested synthesis. *Journal of Public Policy*, **6(1)**, 21-48.

Salter, J., 1998. Risk management in the emergency management context. *Australian Journal of Emergency Management*, **13**, 22-28.

Sanders, C.H., and M.C. Phillipson, 2003: UK adaptation strategy and technical measures: The impacts of climate change on buildings. *Building Research and Information*, **31(3-4)**, 210-221.

Sanderson, I., 2000: Cities, disasters and livelihoods. *Environment and Urbanization*, **12(2)**, 93-102.

Satterthwaite, D., 2007. *Adaptation Options for Infrastructure In Developing Countries.* A report to the UNFCCC Financial and Technical Support Division*.* United Nations Framework Convention on Climate Change, Bonn, Germany.

Satterthwaite, D., S. Huq, M. Pelling, H. Reid, and P.R. Lankao, 2007: *Adapting to Climate Change in Urban Areas.* International Institute for Environment and Development, London, UK.

SCBD, 2009: *Connecting Biodiversity and Climate Change Mitigation and Adaptation*. Report of the second ad hoc technical expert group on biodiversity and climate change, Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Schipper, L., 2009: Meeting at the crossroads? Exploring the linkages between climate change adaptation and disaster risk reduction. *Climate and Development*, **1**, 16-30.

Schipper, L., and M. Pelling, 2006: Disaster risk, climate change and international development: Scope and challenges for integration. *Disasters*, **30**, 19-38.

Schwarze, R. and G. Wagner, 2004. In the aftermath of Dresden: New directions in German flood insurance. *The Geneva Papers on Risk and Insurance,* **29(2)**, 154-168.

Scott, Z. and M. Tarazona, 2011: *Decentralization and Disaster Risk Reduction.* Study on disaster risk reduction, decentralization and political economy analysis for UNDP contribution to the 2011 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva, Switzerland.

SDC, 2008: *Natural disaster risk management in Muminabad.* SDC Project Fact Sheet CARITAS, Swiss Development Cooperation, Switzerland.

SEEDS India, 2008: Reducing risk in poor urban areas to protect shelters, hard-won assets and livelihoods. In: *Linking Disaster Risk Reduction and Poverty: Good Practices and Lessons Learnt* [United Nations International Strategy for Disaster Reduction (UNISDR) (ed.)]. UNISDR, Geneva, Switzerland, pp. 20-22.

Sharma, A., 2009: *Progress Review of National Platforms for DRR in the Asia and Pacific Region*. United Nations International Strategy for Disaster Reduction, Bangkok, Thailand.

Shaw, R., Y. Takeuchi, and B. Rouhban, 2009: Education, capacity building and public awareness for disaster reduction. In: *Landslides – Disaster Risk Reduction* [Sassa, P. (ed.)]. Springer-Verlag, Berlin, Germany, pp. 499-515.

Shepherd, G., 2004: *The Ecosystem Approach: Five Steps to Implementation.* World Conservation Union (IUCN), Gland, Switzerland.

Shepherd, G. (ed.), 2008: *The Ecosystem Approach: Learning from Experience.* World Conservation Union (IUCN), Gland, Switzerland.

Shugart, H., R. Sedjo, and B. Sohngen, 2003: *Forests and Global Climate Change: Potential Impacts on U.S. Forest Resources.* Pew Center on Global Climate Change, Arlington, VA.

Sidle, R.C., A.J. Pearce, C.L. O'Loughlin, and A.G. Union, 1985: *Hillslope Stability and Land Use.* American Geophysical Union, Washington, DC.

Skees, J., P. Varangis, D.F. Larson, and P. Siegel, 2005: Can financial markets be tapped to help poor people cope with weather risks? In: *Insurance Against Poverty* [Dercon, S. (ed.)]. Oxford University Press, Oxford, UK, pp. 422-437.

Skidmore, M. and H. Toya, 2002: Do natural disasters promote long run growth? *Economic Inquiry*, **40(4)**, 664-687.

Skoufias, E., 2003: Economic crises and natural disasters: Coping strategies and policy implications. *World Development*, **13(7)**, 1087-1102.

Slim, H., 2006: Global welfare: A realistic expectation for the international humanitarian system? In: *ALNAP Review of Humanitarian Action: Evaluation Utilisation* [Active Learning Network for Accountability and Performance in Humanitarian Action (ed.)]. Overseas Development Institute, London, UK, www.alnap.org/pool/files/ch1-f1.pdf.

Smillie, I., 2001: *Patronage or Partnership: Local capacity building in humanitarian crises.* Kumarian Press , Bloomfield, CT.

Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R. Klein, and G. Yohe, 2001: Adaptation to climate change in the context of sustainable development and equity. In: *Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. Van Der Linde, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 879-906.

Smith, S.L., V.E. Romanovsky, A.G. Lewkowicz, C.R. Burn, M. Allard, G.D. Clow, K. Yoshikawa, and J. Throop, 2010: Thermal state of permafrost in North America: A contribution to the International Polar Year. *Permafrost and Periglacial Processes*, **21**, 117-135.

Sorensen, J., 1997: National and international efforts at Integrated Coastal Management: Definitions, achievements, and lessons. *Coastal Management*, **25**, 3-41.

Soussan, J. and I. Burton, 2002: Adapt and thrive: Combining adaptation to climate change, disaster mitigation, and natural resources management in a new approach to the reduction of vulnerability and poverty. In: *UNDP Expert Group Meeting, Integrating Disaster Reduction and Adaptation to Climate Change*, Havana, Cuba, 17-19 June 2002. United Nations Development Program, Havana, Cuba.

Spence, R., 2004: Risk and regulation: Can improved government action reduce the impacts of natural disasters? *Building Research and Information*, **32(5)**, 391-402.

Sperling, F. and F. Szekely, 2005: *Disaster risk management in a changing climate, vulnerability and adaptation.* Discussion paper prepared for the world conference on disaster reduction – reprint with addendum on conference outcomes. Vulnerability and Adaptation Resource Group, Washington, DC.

Spittlehouse, D.L. and R.B. Stewart, 2003: Adapting to climate change in forest management. *Journal of Ecosystems and Management*, **4**, 7-17.

Stainforth, D.A., T.E. Downing, R. Washington, A. Lopez and M. New, 2007: Issues in the interpretation of climate model ensembles to inform decisions. *Philosophical Transactions of the Royal Society A*, **365**, 2163-2177.

Stern, N.H., 2007: *The Stern Review: The Economics of Climate Change*. Cambridge University Press, Cambridge, UK.

Stevens, L., 2008: *Assessment of Impacts of Climate Change on Australia's Physical Infrastructure.* Academy of Technological Sciences and Engineering, Parksville, Australia.

Stewart, M.G., X. Wang, and M.N. Nguyen, 2011: Climate change impact and risks of concrete infrastructure deterioration. *Engineering Structures*, **33**, 1326-1337.

Sudmeier-Rieux, K. and N. Ash, 2009: *Environmental Guidance Note for Disaster Risk Reduction*. International Union for Conservation of Nature (IUCN), Gland, Switzerland.

Swiss Re, 2000: *Storm over Europe. An underestimated risk*. Swiss Reinsurance Company, Zurich, Switzerland.

Tanner, T.M. and T. Mitchell (eds.), 2008: Poverty in a changing climate. *Institute of Development Studies* (*IDS*) *Bulletin*, **39**, 4.

Tearfund, 2008: Livelihood initiatives helps poor women build community resilience. In: *Linking Disaster Risk Reduction and Poverty: Good Practices and Lessons Learnt* [United Nations International Strategy for Disaster Reduction (UNISDR) (ed.)]. UNISDR, Geneva, Switzerland, pp. 45-50

Tearfund, 2011: *Disasters and the Local Church: Guidelines for church leaders in disaster-prone areas*. Tearfund, Teddington, UK.

TEEB, 2009. *The Economics of Ecosystems and Biodiversity for National and International Policy Makers Summary: Responding to the Value of Nature*. The Economics of Ecosystems and Biodiversity, Geneva, Switzerland, teebweb.org/ForPolicymakers/tabid/1019/Default.aspx.

Telford, J. and J. Cosgrave, 2006: *Joint Evaluation of the International Response to the Indian Ocean Tsunami: Synthesis Report.* Tsunami Evaluation Coalition, London, UK.

Thomalla, F., T. Downing, E. Spanger-Siegfried, G. Han, and J. Rockstrom, 2006: Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, **30(1)**, 39-48.

Thompson, I., B. Mackey, S. McNulty, and A. Mosseler, 2009: *Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems.* Technical Series no. 43, Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Thompson, M. and I. Gaviria, 2004: *Weathering the storm: Lessons in risk reduction from Cuba*. Oxfam, Boston, MA.

Thorne, C., E. Evans, and E. Penning-Rowsell (eds.), 2006: *Future Flooding And Coastal Erosion Risks.* Thomas Telford, London, UK.

Tompkins, E.L., 2005: Planning for climate change in small islands: Insights from national hurricane preparedness in the Cayman Islands. *Global Environmental Change Part A*, **15(2)**, 139-149.

Tompkins, E.L., M.C. Lemos, and E. Boyd, 2008: A less disastrous disaster: Managing response to climate-driven hazards in the Cayman Islands and NE Brazil. *Global Environmental Change*, **18**, 736-745.

Tompkins, E.L., W.N. Adger, E. Boyd, S. Nicholson-Cole, K. Weatherhead, and N. Arnell, 2010: Observed adaptation to climate change: UK evidence of transition to a well-adapting society. *Global Environmental Change*, **20**, 627-635.

Tschoegl, L., R. Below, and D. Guha-Sapir, 2006: *An Analytical Review of Selected Data Sets on Natural Disasters and Impacts*. Centre for Research on the Epidemiology of Disasters, United Nations Development Programme, Brussels, Belgium.

Tsing, A.L., J.P. Brosius, and C. Zerner, 1999: Assessing community-based natural-resource management. *Ambio*, **28(2)**, 197-198.

Twigg, J., 2004: Project planning. In: *Disaster Risk Reduction: Mitigation and Preparedness in Development and Emergency Programming.* Humanitarian Practice Network, Overseas Development Institute, London, UK, pp. 31-60.

UNDP, 2002: A climate risk management approach to disaster reduction and adaptation to climate change. In: *Proceedings of UNDP Expert Group Meeting*, Havana, Cuba, 19-21 June 2002. United Nations Development Programme, New York, NY.

UNDP, 2004a: *Reducing Disaster Risk: A Challenge for Development.* United Nations Development Programme, New York, NY.

UNDP, 2004b: *A Global Review: UNDP Support for Institutional and Legislative Systems for Disaster Risk Management: Executive Summary*. United Nations Development Programme, New York, NY.

UNDP, 2004c: *Adaptation Policy Frameworks for Climate Change. Developing strategies, policies and measures*. Cambridge University Press, Cambridge, UK.

UNDP, 2009: *Indonesia: Institutional and Legal Systems for Early Warning and Disaster Risk Reduction*. Regional Programme on Capacity Building for Sustainable Recovery and Risk Reduction, United Nations Development Programme, New York, NY.

UNEP, 2006: *In the Front Line: Shoreline Protection and Other Ecosystem Services from Mangroves And Coral Reefs.* United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, UK.

UNEP, 2009. *The Role of Ecosystem Management in Climate Change Adaptation and Disaster Risk Reduction*. Issues paper prepared for the global platform for Disaster Risk Reduction. United Nations Environment Programme, Geneva, Switzerland.

UNEP, 2010: *Using Ecosystems to Address Climate Change – Ecosystem Based Adaptation.* UNEP Regional Seas Information Series, United Nations Environment Programme, Nairobi, Kenya.

UNESCAP, 2009: *Case Study: The National Disaster Management System Of China And Its Response To The Wenchuan Earthquake*. United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, Thailand, www.unescap.org/Idd/Events/Cdrr-2009/Cdr_2e.Pdf.

UNFCCC, 2006a: *Application of Environmentally Sound Technologies for Adaptation to Climate Change.* United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2006b. *Technologies for Adaptation to Climate Change*. United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2007a: *Investment and Financial Flows to Address Climate Change*. United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2007b: *National Adaptation Programmes of Action (NAPAs)*. United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2008a: *Disaster Risk Reduction Strategies and Risk Management Practices: Critical Elements for Adaptation to Climate Change*. United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2008b: *Integrating Practices, Tools and Systems for Climate Risk Assessment and Management and Strategies for Disaster Risk Reduction into National Policies and Programmes*. United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2009a: *Potential Costs and Benefits of Adaptation Options: A Review of Existing Literature.* Technical Paper, United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC, 2011a: *NAPA Priorities Database*. United Nations Framework Convention on Climate Change, Bonn, Germany, unfccc.int/cooperation_support/least_developed_countries_portal/napa_priorities_database/items/4583.php.

UNFCCC, 2011b: *Frequently Asked Questions about LDCs, the LEG and NAPAs*. United Nations Framework Convention on Climate Change, Bonn, Germany, unfccc.int/cooperation_support/least_developed_countries_portal/frequently_asked_questions/items/4743.php.

UNISDR, 2004: *Living with Risk: A Global Review of Disaster Reduction Initiative.* United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2005: *Hyogo Framework for Action 2005–2015: Building the resilience of nations and communities to disasters*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2006: *Developing Early Warning Systems: A checklist*. *The conclusions of the third international conference on early warning.* Germany, Bonn, 27-29. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2007a: *Building Disaster Resilient Communities: Good Practices and Lessons Learned*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2007b: *Words into Action: A Guide for Implementing the Hyogo Framework.* United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2007c: *'Acting with Common Purpose'. Proceedings of the first session of the Global Platform on Disaster Risk Reduction.* Geneva, 5-7 June 2007, United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2008a: *Linking Disaster Risk Reduction and Poverty Reduction: Good Practices and Lessons Learnt*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2008b: *Towards National Resilience: Good practices of National Platforms for Disaster Risk Reduction*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2009a: *Adaptation to Climate Change by Reducing Disaster Risks: Country Practices and Lessons*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2009b: *Applying Disaster Risk Reduction for Climate Change Adaptation: Country Practices and Lessons.* United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2009c: *Risk and Poverty in a Changing Climate: Global Assessment Report on Disaster Risk Reduction.* United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2009d: *Recommendations of National Platforms to the Chair and Participants of the Second Session of the Global Platform for Disaster Risk Reduction*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2010: *Early Warning Practices can Save Many Lives: Good Practices and Lessons Learned*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2011a: *2011 Global Assessment Report on Disaster Risk Reduction: Revealing Risk, Redefining Development.* United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR, 2011b: *Hyogo Framework for Action 2005-2015: Mid Term Review*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

UNISDR/DKKV/Council of Europe, 2008: *Disaster risk reduction in Europe: Overview of European National Platforms, Hyogo Framework for Action focal points and regional organisations and institutions*. United Nations International Strategy for Disaster Reduction, German Committee for Disaster Risk Reduction, and Council of Europe.

Urwin, K. and A. Jordan, 2008: Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. *Global Environmental Change*, **18(1)**, 180-191.

Van Buskirk, R., 2006: Analysis of long-range clean energy investment scenarios for Eritrea, East Africa. *Energy Policy*, **34(14)**, 1807-1817.

Varangis, P., J.R. Skees, and B.J. Barnett, 2002: Weather indexes for developing countries. In: *Climate Risk and the Weather Market* [Dischel, B. (ed.)]. Risk Books, London, UK, pp. 279-294.

Venter, O., W.F. Laurance, T. Iwamura, K.A. Wilson, R.A. Fuller, and H.P. Possingham, 2009: Harnessing carbon payments to protect biodiversity. *Science*, **326(5958)**, 1368.

Venton, P. and S. La Trobe, 2008: *Linking Climate Change Adaptation and Disaster Risk Reduction*. Tearfund, Tweddington, UK.

Verdin, J., C. Funk, G. Senay, and R. Choularton, 2005: Climate science and famine early warning. *Philosophical Transactions of the Royal Society B*, **360**, 2155-2168.

Vignola, R., B. Locatelli, C. Martinez, and P. Imbach, 2009: Ecosystem-based adaptation to climate change: What role for policy-makers, society and scientists? *Mitigation and Adaptation Strategies for Global Change*, **8(14)**, 691-696.

Virtanin, P., E. Palmujpki, and D. Gemechu, 2011: Global climate policies, local institutions and food security in a pastoral society in Ethiopia. *Consilience: The Journal of Sustainable Development,* **5**, 96-118.

Vogel, C., and K. O'Brien, 2006: Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. *Climate Research*, **33,** 111-122.

Walters, C., 1997. Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology*, **2(1)**, 1.

Wamsler, C., 2004: Managing urban risk: Perceptions of housing and planning as a tool for reducing disaster risk. *Global Built Environment Review*, **4(2)**, 11-28.

Warhurst, A., 2006: *Disaster Prevention: A Role for Business*? Maplecroft and ProVention Consortium, Geneva, Switzerland.

Warner, K., N. Ranger, S. Surminski, M. Arnold, J. Linnnerooth-Bayer, E. Michel-Kerjan, P. Kovacs, and C. Herweijer, 2009: *Adaptation to Climate Change: Linking Disaster Risk Reduction and Insurance.* United Nations International Strategy for Disaster Reduction Secretariat, Geneva, Switzerland.

Weih, M., 2004: Intensive short rotation forestry in boreal climates: Present and future perspectives. *Canadian Journal of Forest Research*, **34(7)**, 1369-1378.

White, P., M. Pelling, K. Sen, D. Seddon, S. Russell, and R. Few, 2004: *Disaster Risk Reduction: A Development Concern. A Scoping Study on Links between Disaster Risk Reduction, Poverty and Development.* Department for International Development, London, UK.

WHO, 2003: *Climate Change and Human Health - Risks and Responses: Summary.* World Health Organization, Geneva, Switzerland.

WHO, 2005: *Health and Climate Change: The "Now and How": A Policy Action Guide.* World Health Organization Regional Office for Europe, Copenhagen, Denmark.

Wickham, F., J. Kinch, and P.N. Lal, 2009: *Institutional Capacity within Melanesian Countries to Effectively Respond to Climate Change Impacts, with a Focus on Vanuatu and the Solomon Islands*. A report prepared for the Bishop Museum and SPREP. Bishop Museum, Honolulu, Hawaii.

Wilby, R.L., 2007: A review of climate change impacts on the built environment. *Built Environment*, **33(1)**, 31-45.

Wilby, R.L., 2009: *Climate for Development in South Asia (ClimDev-SAsia): An inventory of cooperative programmes and sources of climate risk information to support robust adaptation*. Report prepared on behalf of the UK Department for International Development (DFID), DFID, London, UK.

Wilby, R.L. and S. Dessai, 2010: Robust adaptation to climate change. *Weather*, **65(7)**, 180-185.

Wilby, R.L., J. Troni, Y. Biot, L. Tedd, B.C. Hewitson, D.M. Smith, and R.T. Sutton, 2009: A review of climate risk information for adaptation and development planning. *International Journal of Climatology*, **29(9)**, 1193-1215.

Wilches-Chaux, G., 2008: *¿Qu-ENOS pasa? – Guía de LA RED para la gestión radical de riesgos asociados con el fenómeno ENOS*. LA RED, Bogotá, Colombia.

Wisner, B., 2011: Are we there yet? Reflections on integrated disaster risk management after ten years. *Journal of Integrated Disaster Risk Management*, **1**, 1-14.

Wisner, B. and J. Adams, 2002: *Environmental Health in Emergencies and Disasters: A Practical Guide.* World Health Organization, Geneva, Switzerland.

Wisner, B., P. Blaikie, T. Cannon, and I. Davis, 2004: *At Risk: Natural Hazards, People's Vulnerability And Disasters.* 2nd ed*.* Routledge, London, UK.

WMO, 2004: *Report of the Expert Meeting on Meteorological Information for Locust Control, 18-20 October 2004*. World Meteorological Organization, Geneva, Switzerland.

WMO, 2007: *WMO to Provide Guidance for Heat Health Warning System.* WMO Press Release 781, World Meteorological Organization, Geneva, Switzerland.

Wood, A.P. and Van Halsema, G.E., 2008: *Scoping agriculture, wetland interactions: Towards a sustainable multiple-response strategy.* FAO Water Reports. Rome: Food and Agriculture Organisation (FAO).

World Bank, 1996. *Argentina flood protection project.* Staff Appraisal Report 15354, World Bank, Washington, DC.

World Bank, 2000: *Cities, Seas and Storms: Managing Change in Pacific Island Economies.* World Bank, Washington, DC.

World Bank, 2003: *Protecting New Health Facilities from Natural Disasters: Guidelines for the Promotion of Disaster Mitigation.* World Bank, Washington, DC.

World Bank, 2007: *The Caribbean Catastrophe Risk Insurance Initiative.* Results of preparation work on the design of a Caribbean Catastrophe Risk Insurance Facility, World Bank, Washington, DC.

World Bank, 2008: *The Economics of Adaptation to Climate Change: Methodology Report.* World Bank, Washington, DC.

World Bank, 2009: *Convenient Solutions to an Inconvenient Truth: Ecosystem-Based Approaches to Climate Change.* World Bank, Washington, DC.

World Bank, 2010: *Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects*. Washington D.C.: World Bank.

World Bank and UN, 2010: *Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention*. International Bank for Reconstruction and Development/ World Bank, Washington, DC, 254 pp., gfdrr.org/gfdrr/nhud-home.

World Vision, 2008: Reducing vulnerabilities and poverty through disaster mitigation. In: *Linking Disaster Risk Reduction and Poverty: Good Practices and Lessons Learnt* [United Nations International Strategy for Disaster Reduction (UNISDR) (ed.)]. UNISDR, Geneva, Switzerland, pp. 15-19.

WSSD, 2002: *Report of the World Summit on Sustainable Development*, Johannesburg, South Africa, 26 August – 4 September 2002.

WWAP, 2009: *Water in a Changing World. The United Nations World Water Development Report*. World Water Assessment Programme, Earthscan, London, UK.

WWC, 2009: *Water Supply and Sanitation*. World Water Council, France.

Yamin, F., A. Rahman, and S. Huq, 2005: Vulnerability, adaptation and climate disasters: A conceptual overview. *IDS Bulletin*, **36(4)**, 1-14.

Yodmani, S., 2001: Disaster risk management and vulnerability reduction: Protecting the poor. In: *Proceedings of Asia and Pacific Forum on Poverty: Reforming policies and institutions for poverty reduction.* Manila, Philippines, 5-9 February 2001.

Younger, M., H.R. Morrow-Almeida, S.M. Vindigni, and A.L. Dannenberg, 2008: The built environment, climate change, and health: Opportunities for co-benefits. *American Journal of Preventive Medicine*, **35(5)**, 517-52.