

14

Adaptation Needs and Options

Coordinating Lead Authors:

Ian R. Noble (Australia), Saleemul Huq (Bangladesh/UK)

Lead Authors:

Yuri A. Anokhin (Russian Federation), JoAnn Carmin (USA), Dieudonne Goudou (Niger), Felino P. Lansigan (Philippines), Balgis Osman-Elasha (Sudan), Alicia Villamizar (Venezuela)

Contributing Authors:

Jessica Ayers (UK), Frans Berkhout (Netherlands), Kirsten Dow (USA), Hans-Martin Füssel (Germany), Joel Smith (USA), Kathleen Tierney (USA), Helena Wright (UK)

Review Editors:

Anthony Patt (Austria), Kuniyoshi Takeuchi (Japan)

Volunteer Chapter Scientist:

Eric Chu (USA)

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Executive Summary

Since the Fourth Assessment Report (AR4), the framing of adaptation has moved further from a focus on biophysical vulnerability to the wider social and economic drivers of vulnerability and people's ability to respond (*robust evidence, high agreement*). These drivers include the gender, age, health, social status, and ethnicity of individuals and groups, and the institutions in place locally, nationally, regionally, and internationally. Adaptation goals are often expressed in a framework of increasing resilience, which encourages consideration of broad development goals, multiple objectives, and scales of operation, and often better captures the complex interactions between human societies and their environment. The convergence between adaptation and disaster risk management has been further strengthened since AR4, building on the IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX). {14.1-3}

Adaptation needs arise when the anticipated risks or experienced impacts of climate change require action to ensure the safety of populations and the security of assets, including ecosystems and their services (*medium evidence, medium agreement*).

Adaptation needs are the gap between what might happen as the climate changes and what we would desire to happen. The use of the term needs has also shifted with the framing of adaptation. In the National Adaptation Programmes of Action (NAPAs) "needs" were usually discussed in terms of major vulnerabilities and priority adaptation activities, and, in both developing and developed countries, this hazard-based approach with a focus on drivers of impacts and options to moderate them is still used often for urban or regional programs. But more recently, the focus has been on tackling the underlying causes of vulnerability such as informational, capacity, financial, institutional, and technological needs. {14.2}

Engineered and technological adaptation options are still the most common adaptive responses, although there is growing experience of the value for ecosystem-based, institutional, and social measures, including the provision of climate-linked safety nets for those who are most vulnerable (*robust evidence, high agreement*). Adaptation measures are increasing and becoming more integrated within wider policy frameworks. Integration, though it remains a challenge, streamlines the adaptation planning and decision-making process and embeds climate-sensitive thinking in existing and new institutions and organizations. This can help avoid mismatches with the objectives of development planning, facilitate the blending of multiple funding streams, and reduce the possibility of maladaptive actions. The increasing complexity of adaptation practice means that institutional learning is an important component of effective adaptation. {14.3}

Approaches to selecting adaptation options continue to emphasize incremental change to reduce impacts while achieving co-benefits, but there is increasing evidence that transformative changes may be necessary in order to prepare for climate impacts (*medium evidence, medium agreement*). While no-regret, low-regret, and win-win strategies have attracted the most attention in the past and continue to be applied, there is increasing recognition that an adequate adaptive response will mean acting in the face of continuing uncertainty about the extent of climate change and the nature of its impacts, and that in some cases there are limits to the effectiveness of incremental approaches. While attention to flexibility and safety margins is becoming more common in selecting adaptation options, many see the need for more transformative changes in our perception and paradigms about the nature of climate change, adaptation, and their relationship to other natural and human systems. {14.1, 14.3.4}

Among the many actors and roles associated with successful adaptation, the evidence increasingly suggests two to be critical to progress: those associated with local government and those with the private sector (*medium evidence, high agreement*). These two groups will bear increasing responsibility for translating the top-down flow of risk information and financing and in scaling up the bottom-up efforts of communities and households in planning and implementing their selected adaptation actions. Local institutions, including local governments, non-government organizations (NGOs), and civil society organizations, are among the key actors in adaptation but are often limited by lack of resources and capacity and by continuing difficulties in gaining national government or international support, especially in developing countries. {14.2.3} Private entities, from individual farmers and small to medium enterprises (SMEs) to large corporations, will seek to protect and enhance their production systems, supply lines, and markets by pursuing adaptation-related opportunities. These goals will help expand adaptation activities but they may not align with government or community objectives and priorities without coordination and incentives. {14.2.4}

Adaptation assessments, which have evolved in substance and style since AR4, have demonstrably led to a general awareness among decision makers and stakeholders of climate risks and adaptation needs and options. However, such awareness has often not translated into adaptation action (*medium evidence, high agreement*). Most of the assessments of adaptation done so far have been restricted to impacts, vulnerability, and adaptation planning, with very few assessing the processes of implementation and evaluation of actual adaptation actions. {14.4.1} Assessments that include both top-down assessments of biophysical climate changes and bottom-up assessments of what makes people and natural systems vulnerable to those changes will help to deliver local solutions to globally derived risks. Also, assessments that are linked more directly to particular decisions and that provide information tailored to facilitate the decision-making process appear to have most consistently led to effective adaptation measures. {14.4.3}

The evidence to support the most valuable metrics of adaptation needs and effectiveness is limited, but increasing (*medium evidence, high agreement*). {14.5.2-3} At present, there are conflicting views concerning the choice of metrics, as governments, institutions, communities, and individuals value needs and outcomes differently and many of those values cannot be captured in a comparable way by metrics. {14.5} The demand for metrics to measure adaptation needs and effectiveness is increasing as more resources are directed to adaptation. These indicators that are proving most useful for policy learning are those that track not just process and implementation, but also the extent to which targeted outcomes are occurring. {14.5.2.3}

Maladaptation is a cause of increasing concern to adaptation planners, where intervention in one location or sector could increase the vulnerability of another location or sector, or increase the vulnerability of the target group to future climate change (*medium evidence, high agreement*). {14.7.3} The definition of maladaptation used in AR5 has changed subtly to recognize that maladaptation arises not only from inadvertent badly planned adaptation actions, but also from deliberate decisions where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions. {14.6.1}

14.1. Introduction

This chapter establishes a foundation for understanding adaptation by reviewing core concepts related to adaptation, with a focus on mapping out broad categories of needs and options. Here we use adaptation needs to refer to circumstances requiring information, resources, and action to ensure safety of populations and security of assets in response to climate impacts. Adaptation options are the array of strategies and measures available and appropriate to address needs. Because identifying needs and selecting and implementing options require the engagement of individuals, organizations, and governments at all levels, this chapter also briefly considers the range of actors involved in these processes and summarizes the risks of maladaptation.

Other chapters in this report, namely Chapter 4 and in particular Section 4.4, and supported by Chapters 3, 5, 6, and 7, deal with the threats of climate change on ecosystems and other predominately natural systems and their prospects and options for adaptation. For the sake of space and clarity this chapter focuses on the socioeconomic systems that support human livelihoods, although it also touches on the services provided by ecosystems (including ecosystem-based adaptation).

This chapter also highlights some important tools for implementing adaptation, namely approaches to assessing needs at national, subnational, and sectoral levels, and the challenges of applying metrics to determine adaptation needs and the effectiveness of adaptation actions. In the course of these discussions, this chapter establishes a foundation for the three adaptation chapters that follow. The existence of adaptation options does not necessarily mean that these options can be implemented when the need arises. Therefore, Chapter 15 examines adaptation planning and implementation, including the challenges faced and how these can be addressed. Chapter 16 focuses on adaptation opportunities and constraints, while Chapter 17 assesses the economics

of adaptation to climate change, including the costs and benefits of adaptation and of inaction. This chapter also draws on, and seeks not to repeat, the detailed discussions of human health, well-being, security, livelihoods, and poverty found in Chapters 11, 12, and 13 that are so important to the wider discussion of adaptation. These and other interactions among the adaptation chapters are illustrated in Figure 14-1.

Human and natural systems have a capacity to cope with adverse circumstances but, with continuing climate change, adaptation will be needed to maintain this capacity (IPCC, 2012; see also Section 1.4.1 and Box 2.1). The AR5 definition of adaptation (i.e., “The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects...”) follows the lead of the IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) in introducing a degree of purposefulness by adding the phrase “which seeks to moderate” rather than simply “which moderates” as in AR4.¹ Human ability to cope with climate impacts can also be increased by actions that are not anticipatory or purposefully undertaken in response to observed or anticipated climate change, sometimes called unplanned actions. For example, diversifying livelihoods in response to immediate economic factors can increase long-term ability to cope with a changing climate. Such actions were often referred to as autonomous adaptation. However, the use of the term in the literature, including the IPCC reports, has been inconsistent. The term is often used to refer to purposeful adaptation actions carried out by agents without external inputs such as policies, information, or resources (see Chapters 17, 22; Skoufias, 2012), and sometimes to refer to purposeful actions that are reactive to experienced climate impacts, rather than being proactive or anticipatory of them (see Glossary and WGII AR3 Section 18.2.3).

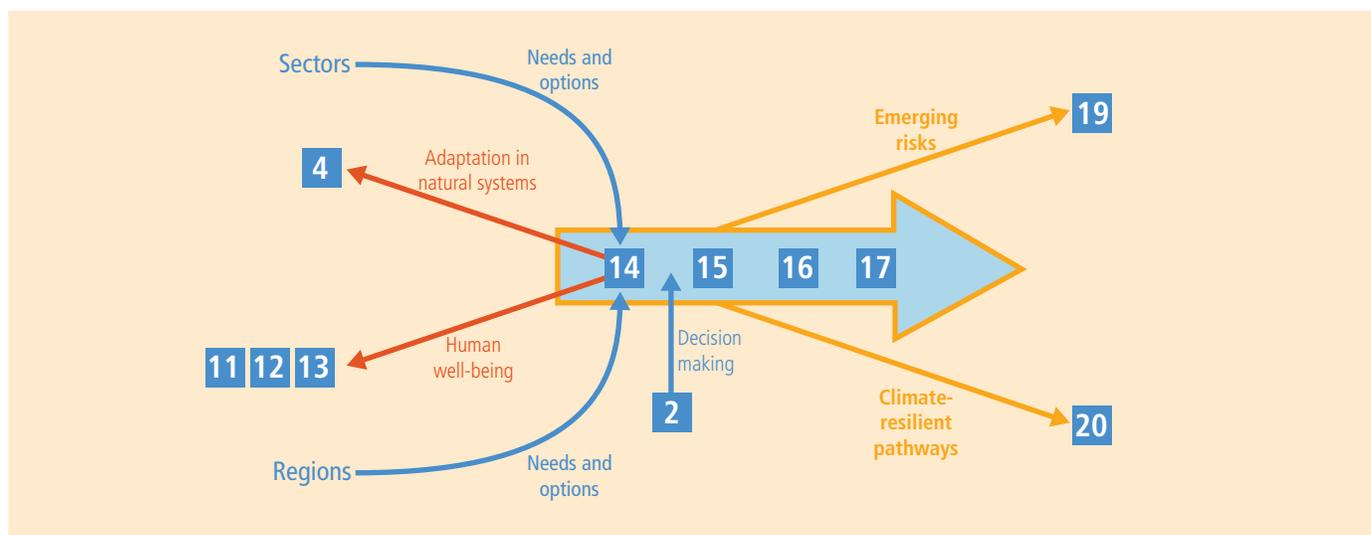


Figure 14-1 | The relationship between the four adaptation chapters (14 to 17) and other closely related chapters. Chapter 14 (Adaptation Needs and Options) draws on and cross-references many of the issues of human well-being, including health, security, and poverty; the treatment of adaptation of natural ecosystems is dealt with mainly in Chapter 4 and is not repeated in Chapter 14. Similarly the needs and options synthesized in Chapter 14 are drawn largely from the sectoral (3 to 10) and regional chapters (21 to 30). Chapter 2 provides input to decision-making approaches relevant to Chapter 15 (Adaptation Planning and Implementation). All the adaptation chapters feed into the synthesis of Chapters 19 (Emerging Risks and Key Vulnerabilities) and 20 (Climate-Resilient Pathways: Adaptation, Mitigation, and Sustainable Development).

The SREX and AR5 definitions of adaptation also clarify the distinction between adaptation in human and natural systems. Natural systems have the potential to adapt through multiple autonomous processes (e.g., phenology changes, migration, compositional changes, phenotypic acclimation, and/or genetic changes), and humans may intervene to promote particular adjustments such as reducing non-climate stresses or through managed migration (see Section 4.5). But successful adaptation will depend on our ability to allow and facilitate natural systems to adjust to a changing climate, thus maintaining the ecosystem services on which all life depends.

Adaptation is becoming increasingly important in climate negotiations and implementation, and integral to AR5 are the terms incremental and transformational adaptation—sometimes referred to as a “paradigm shift” as in the Green Climate Fund Governing Instrument (Green Climate Fund, 2013a). Incremental adaptation refers to actions where the central aim is to maintain the essence and integrity of the existing technological, institutional, governance, and value systems, such as through adjustments to cropping systems via new varieties, changing planting times, or using more efficient irrigation. In contrast, transformational adaptation seeks to change the fundamental attributes of systems in response to actual or expected climate and its effects, often at a scale and ambition greater than incremental activities. It includes changes in activities, such as changing livelihoods from cropping to livestock or by migrating to take up a livelihood elsewhere, and also changes in our perceptions and paradigms about the nature of climate change, adaptation, and their relationship to other natural and human systems (Sections 3.3, 8.6.2.3, 20.5 and FAQ 8.2; IPCC, 2012; Kates et al., 2012; Park et al., 2012; Green Climate Fund, 2013b). Transformational change may be driven by the pursuit of better opportunities or by the realization of the imminent or inevitable limits within existing paradigms (Dow et al., 2013; Section 16.4.2). Transformative change may threaten the status quo for many and require leadership and sometimes triggering events to initiate it (Kates et al., 2012). However, transformational change is not called for in all responses to climate change (Pelling, 2010) and ill-prepared transformative change may bring with it social inequities (O’Brien, 2012). The triggers for transformational change and its implementation are dealt with in more detail in Sections 16.4 and 20.5. Differentiation between incremental and transformative adaptation, although indistinct, is important because it affects how we approach adaptation, how we integrate it into planning and policy, and how we allocate adaptation funding in both developed and developing countries (IPCC, 2012; see also Chapter 17).

Another concept is the adaptation deficit, which is the gap between the current state of a system and a state that would minimize adverse impacts from existing climate conditions and variability (see Glossary); that is, it is essentially inadequate adaptation to the current climate conditions (Burton et al., 2002; Burton, 2004; Burton and May, 2004; Parry et al., 2009; see also Sections 17.2.2.2, 17.6.1). Some have suggested that it is often part of a larger “development deficit” (World Bank, 2010). Delay in action in both mitigation and adaptation will increase the adaptation deficit in many parts of the world (IPCC, 2012).

In the process of building future adaptive capacity it is important to reduce the current adaptation deficit along with designing effective risk management and climate change adaptation measures (Hallegatte, 2011). Failure to close the adaptation deficit, both current and in the future, will result in residual damages from climate change. There have been calls for such residual damages to be evaluated and reported (Parry et al., 2009).

Summary of Key Findings from AR4

In the Working Group II (WGII) Fourth Assessment Report (AR4), the main chapter on adaptation (Chapter 18) refined the basic terminology of adaptation and concluded that adaptation to climate change was already taking place, but on a limited basis. Societies have a long record of adapting to the impacts of weather and climate through a range of practices that include crop diversification, irrigation, water management, disaster risk management, and insurance, but climate change, along with other drivers of change, poses novel risks often outside the range of experience.

WGII AR4 found that deliberate adaptation measures in response to anticipated climate change were being implemented by a range of public and private actors, on a limited basis, in both developed and developing countries. These measures are undertaken through policies, investments in infrastructure and technologies, and behavioral change, and they are seldom undertaken in response to climate change alone. Many actions that facilitate adaptation to climate change are undertaken to deal with current extreme events, such as heat waves and cyclones, and are often embedded within broader sectoral initiatives such as water resource planning, coastal defense, and disaster management planning.

WGII AR4 concluded that there are individuals and groups within all societies that have insufficient capacity to adapt to climate change. The capacity to adapt is dynamic and influenced by economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology. However, high adaptive capacity does not necessarily translate into actions that reduce vulnerability. New planning processes are being implemented to attempt to overcome these barriers at local, regional, and national levels in both developing and developed countries. WGII AR4 noted the establishment of the National Adaptation Programmes of Action (NAPAs) and that some developed countries had established national adaptation policy frameworks. Other conclusions from the WGII AR4 relating to the implementation of adaptation policies and measures, barriers to adaptation, and the economic costs of adaptation are summarized in Chapters 15, 16, and 17 of this report.

14.2. Adaptation Needs

Adaptation involves reducing risk and vulnerability; seeking opportunities; and building the capacity of nations, regions, cities, the private sector, communities, individuals, and natural systems to cope with climate impacts, as well as mobilizing that capacity by implementing decisions and actions (Tompkins et al., 2010). Vulnerability is the “propensity or

¹ Purposefulness was introduced in the SREX definition, which introduced the phrase “in order to moderate”.

predisposition [of a system] to be adversely affected” (see Glossary) and, until AR4, was viewed as comprising three elements: exposure, sensitivity, and adaptive capacity (IPCC, 2007a). However, in IPCC (2012) and in this report, vulnerability focuses only on sensitivity and capacity, with exposure more appropriately incorporated into the concept of risk (see Glossary; IPCC, 2012, Section 2.2).

Adaptation requires adequate information on risks and vulnerabilities in order to identify needs and appropriate adaptation options to reduce risks and build capacity. In framing an approach to adaptation, it is important to engage people with different knowledge, experience, and backgrounds in tackling and reaching a shared approach to addressing the challenges (Preston and Stafford Smith, 2009; Tompkins et al., 2010; Fünfgeld and McEnvoy, 2011; Eakin et al., 2012). Initially, identifying needs was most often based on impact assessments (or risk-hazard approaches), but social vulnerability or resilience assessments are increasingly being used (Fünfgeld and McEnvoy, 2011; Preston et al., 2011b). The risk-hazard framework, drawn primarily from risk and disaster management, focuses on the adverse effects that natural hazards and other climate impacts can have on a given location (Füssel and Klein, 2006). The emphasis in this approach is on the physical and biological aspects of impacts and adaptation (Burton et al., 2002). The social vulnerability framework focuses on the reasons and ways in which individuals, groups, and communities are vulnerable to climate impacts. Here, the focus is on how different factors, such as institutions, shape the socioeconomic conditions that place human populations at risk (Adger and Kelly, 1999; Preston et al., 2011b). There are overlaps and complementarities between these frameworks. Approaches to identifying needs and options are discussed further in the section on assessments (Section 14.4).

Comprehensive assessments typically provide insight into the risks and vulnerabilities that will result from climate change in communities, cities, nations, and ecosystems and, in turn, offer a means to identify the presence of adaptation needs and options for addressing those needs. The term adaptation needs is often used but rarely defined in the adaptation literature. In the wider literature, a need can be seen as a problem that can be solved (McKillip, 1987) or as a gap between current outcomes and desired outcomes (Kaufman and English, 1979). Thus, in this context, adaptation needs are the gap between what might happen as the climate changes and what we would desire to happen. Also, the term adaptation needs is used in several ways in the adaptation literature. A common use is in the sense of the “urgent and immediate needs” relating to the adverse effects of climate change, as in the rationale for the NAPAs, although in this case “needs” were usually discussed in terms of major vulnerabilities and priority adaptation activities (by UNFCCC).² The most effective descriptions of these needs combined discussions of climate and non-climate drivers of impacts, and the resources, capacity, information, finance, etc., needed to implement options to moderate those impacts (e.g., GEF, 2002). Assessments of adaptation needs, both in developing and developed countries, have often taken a hazard-based approach with a focus on drivers of impacts and options to moderate them (Moser, 2009; Finzi Hart et al., 2012). But more recently, the focus has been on tackling the underlying causes of vulnerability

(Füssel, 2007). One of the few categorizations of needs is that of Burton et al. (2006), who recognized information, capacity, financial, institutional, and technological needs. A similar structure is followed in this chapter. We first discuss biophysical and environmental needs on which all lives ultimately depend. Then we discuss social needs and capacities and how they vary throughout society. Third, we discuss our response to climate risks and impacts and how they are modified by the multitude of institutions through which humans work, ranging from international organizations to community-based efforts. Finally, we touch on resources, including societal needs for information and knowledge and financial resources.

Although needs are specific to particular groups and places, they fit into a set of more general categories as summarized in the sections below. For instance, vulnerability at the national and subnational levels is affected by geographic location, biophysical conditions, institutional and governance arrangements, and resource availability, including access to technology and economic stability (Brooks et al., 2005). At the macro-level, two broad classes of determinants of vulnerability are recognized: biophysical determinants and socioeconomic determinants (Preston et al., 2011a). However, adaptation needs are highly diverse and context specific, for instance, varying between islands even within nations such as the Solomon Islands (Section 29.6.1). Different stakeholder groups and individuals have differential adaptation needs and vulnerabilities. Adaptation needs are also dynamic, and future adaptation needs are highly dependent on the mitigation pathway that is taken. Furthermore, the constraints and limits to adaptation (see Chapter 16) are likely to mean that not all needs will be met, thereby emphasizing the need for monitoring to avoid crossing critical thresholds (Section 19.7.3).

14.2.1. Biophysical and Environmental Needs

Climate change is altering ecological systems, biodiversity, genetic resources, and the benefits derived with ecosystem services (Convention on Biological Diversity, 2009; Mooney et al., 2009; Hoegh-Guldberg, 2011). Climate change is inducing shifts in habitats that often cannot be followed by species (Section 4.3.4.1), leading to changed ecosystems, to local and global extinctions, and to the permanent loss of unique combinations of genes. For instance, González et al. (2010) used observed and modeled changes of global patterns of biome shifts under climate change to conclude that up to half of the terrestrial ecosystems were vulnerable as a result of changes from secondary stressors, such as wildfire and disease, and suggested significant changes to natural resource management plans. In addition to the responses of ecosystems to climatic change, a number of studies have identified impacts on ecosystem services, particularly the effects of climate change on agricultural productivity (Coles and Scott, 2009), freshwater ecosystems (Ormerod et al., 2010), and downstream industries and enterprises (Preston and Stafford Smith, 2009). Ecosystem services that are already under threat from the impacts of climate change include pollination, pest, and disease regulation (Section 4.3.4.4); climate regulation services; and potable water supply (Section 4.3.4.5). Further stressors will limit our options to respond to climate change (Section 14.3.2).

² https://unfccc.int/files/cooperation_support/least_developed_countries_portal/napa_project_database/application/pdf/napa_index_by_country.pdf.

Natural systems underpin human livelihoods, health, welfare, food security, and prosperity. Vital ecosystem services that need to be maintained include provisioning services such as food, fiber, and potable water supply; regulating services such as climate regulation, pollination, disease control, and flood control; and supporting services such as primary production and nutrient cycling (Section 4.3.4). Much of the water for human consumption originates on forested lands and the quality of the water is heavily dependent on the conditions of the ecosystems through which it flows. Ocean systems also provide climate regulation services, while coral reefs act as ecological buffers (Section 6.4.1.4). For instance, healthy coastal wetlands and coral reefs can help to protect against storm surges and rising sea levels (Hoegh-Guldberg, 2011), while the maintenance of wetlands and green spaces can control runoff and flooding associated with increases in precipitation (Jentsch and Beierkuhnlein, 2008; Mooney et al., 2009). Meanwhile, fisheries and aquaculture contribute more than 20% to the dietary animal protein of nearly 1.5 billion people (Section 5.4.3.3).

Consequently, there is a need to protect these systems and resources within the changing climate. Goldman et al. (2008) found that research projects focusing on delivering ecosystem services, rather than on biodiversity goals, attracted a wider set of funders and better encompassed the landscapes and the people within them. However, many practices to intervene to improve and maintain ecosystem services are based on limited experience and thus still untested assumptions and limited information (Carpenter et al., 2009). Hence, there is a need to improve understanding and valuation of ecosystem services provided by different adaptation options. There is also an urgent need for appropriate ecosystem monitoring to avoid crossing critical thresholds (see Section 19.7.4).

14.2.2. Social Needs

From a social perspective, vulnerability varies as a consequence of the capacity of groups and individuals to reduce and manage the impacts of climate change. Among the key factors determining vulnerability are gender, age, health, social status, ethnicity, and class (Smit et al., 2001; Adger et al., 2009a). For instance, the vulnerability to health-related impacts of climate change varies as a consequence of geographical location (Section 11.3.1), gender and age (Section 11.3.3), and socioeconomic status (Section 11.3.4). Poverty and persistent inequality may be the most salient of the conditions that shape climate-related vulnerability (Section 13.1.4). Climate change is expected to have a relatively greater impact on the poor as a consequence of their lack of financial resources, poor quality of shelter, reliance on local ecosystem services, exposure to the elements, and limited provision of basic services and their limited resources to recover from an increasing frequency of losses through climate events (Tol et al., 2004; Huq et al., 2007; Kovats and Akhtar, 2008; Patz et al., 2008; Revi, 2008; Allison et al., 2009; Shikanga et al., 2009; Gething et al., 2010; Moser and Satterthwaite, 2010; Rosenzweig et al., 2010; Skoufias et al., 2012). Owing to limited financial resources and often compromised health and nutritional status, the poor, along with the sick and elderly, are at increased risk from trauma, physical and mental illness, and death from climate impacts such as increased pollution, higher indoor temperatures, exposure to toxins and pathogens from floods, and the emergence of new disease vectors (Kasperson and Kasperson, 2001; Haines et al., 2006; Costello et al., 2009, 2011; O'Neill

and Ebi, 2009; Tonnang et al., 2010; Ebi, 2011; Harlan and Ruddell, 2011; Huang et al., 2011; McMichael and Lindgren, 2011; Semenza et al., 2012). Climate change, climate variability, and extreme events can erode natural, physical, financial, human, and social and cultural assets (Section 13.2.1.1), and poverty traps arise when climate change, variability, and extreme events make the poor even poorer (Section 13.2.1.4).

Social needs under climate change include understanding emotional and psychological needs. In Australia, it has been found that extreme events such as floods, drought, and bushfire can lead to mental suffering, including post-traumatic stress disorder, resulting in the need for psychological support and counseling (The Climate Institute, 2011). For example, drought can increase suicide rates by 8% (Nicholls et al., 2006). Social psychological adaptation processes powerfully mediate public risk perceptions and understanding, psychological and social impacts, and coping responses, as well as behavioral adaptation (Reser and Swim, 2011). Yet little collaborative work or research has so far focused on the nature and dynamics of individual-level coping and adaptation processes and how they influence responses (Reser et al., 2012).

These individual factors also are often associated with and compounded by community-level conditions. Women often have unequal access to and control over resources, including land titles and water rights (UNDP, 2010; CGIAR, 2012; Verner 2012). Many poor and ethnic minorities live in substandard housing; lack access to basic services, savings, and insurance; have compromised health; and are at threat due to excessive densities, poor access roads, and inadequate access to safe water, sanitation, and drainage (Huq et al., 2007; Kovats and Akhtar, 2008; Revi, 2008; Shikanga et al., 2009; Moser and Satterthwaite, 2010). In rural areas, adaptation needs also are linked to the viability of agricultural activity (Bosello et al., 2009). Climate change will lead to higher prices and increased volatility in agricultural markets, which might undermine global food supply security (Section 9.3.3.3). Geographically, highly vulnerable regions are those exposed to sea level rise and extreme events, overlaid with high concentrations of multidimensional poverty (Section 13.2.2.1). There will be disproportionate impacts on developing countries that are dependent on climate-sensitive activities such as agriculture (Cline, 2007). However, middle-income populations can also be adversely impacted by climate change as a stressor adding to other effects.

The causes and solutions of vulnerability take place at different social, geographic, temporal, and political scales (Ribot, 2010). Therefore, to identify critical needs of populations, and the underlying conditions giving rise to these needs, some social assessments can benefit by looking across institutional domains and by spanning from the local to the national. Local assessments provide a means to identify existing vulnerabilities; the policies, plans, and natural hazards contributing to these vulnerabilities; as well as identifying adaptation actions. Social needs include the range of needs for human security (see Section 12.1.2), which include the universal and culturally specific, material, and non-material elements necessary to people to act on behalf of their interests. More specifically, at this level, social needs can be evaluated in terms of availability of natural, physical, human, political, and financial assets; stability of livelihood; and livelihood strategies (Moser, 2006; Heltberg et al., 2009). Alternatively, regional and national assessments

can provide a basis for ascertaining institutional conditions associated with long-standing inequities and development paths that may need to be addressed in order to generate robust options.

Although different stakeholder groups have specific needs, an overarching adaptation need for communities, households, private sector, and institutions is the need for shared learning on adaptation. Adaptation has itself been referred to as a social learning process (Sections 15.6, 22.4.5.3). In particular, there is the need for human capacity and social capital to implement adaptation actions, including education and access to information (Brooks et al., 2005; Adger, 2006; Smit and Wandel, 2006). Improved information for adaptation can benefit from efforts to combine indigenous and scientific knowledge (Section 12.3).

14.2.3. Institutional Needs

Institutions, informal and formal, are enduring regularities of human action in situations structured by rules, norms, and shared strategies, as well as by the physical world (Crawford and Ostrom, 1995) and as such they provide the enabling environment for implementing adaptation actions (Bryan et al., 2009; Chuku, 2009; Aakre and Rübhelke, 2010; Compston, 2010; Moser and Ekstrom, 2011). These institutions provide the guides, incentives, or constraints that shape the distribution of climate risks, establish incentive structures that can promote adaptation, foster the development of adaptive capacity, and establish protocols for both making and acting on decisions (see Section 14.2.3.2; Chuku, 2009; Agrawal, 2010; Compston, 2010). In many instances, international and national-level policies and programs can facilitate localized strategies through the creation of legal frameworks and the allocation of resources (Adger, 2001; Bulkeley and Betsill, 2005; Corfee-Morlot et al., 2011). Overall, there is a need for effective institutions to identify, develop, and pursue climate-resilient pathways for sustainable development (Sections 20.2, 20.4.2), including strengthening the ability to develop new options through social, institutional, and technological innovation (Section 20.4.3). Chapter 15 further considers the institutional needs to mainstream adaptation into government planning.

Governments at all levels play important roles in advancing adaptation and in enhancing the adaptive capacity and resilience of diverse stakeholder groups. National governments are integral to advancing an adaptation agenda as they decide many of the funding priorities and tradeoffs, develop regulations, promote institutional structures, and provide policy direction to district, state, and local governments. In developing countries, national governments are usually the contact point and initial recipient of international adaptation financing. In some countries, both developed and developing, state governments lead the national government in promoting and implementing adaptation (Mertz et al., 2009). The engagement of national government actors can help mobilize political will, support the creation and maintenance of climate research institutions, establish horizontal networks that promote information sharing (Westerhoff et al., 2011), and, in some cases, facilitate the coordination of budgets and financing mechanisms (Alam

et al., 2011; Kalame et al., 2011). Governments have the potential to directly reduce the risk and enhance the adaptive capacity of vulnerable areas and populations by developing and implementing locally appropriate regulations including those related to zoning, storm water management and building codes, and attending to the needs of vulnerable populations through measures such as basic service provision and the promotion of equitable policies and plans (Adger et al., 2003b; Brooks et al., 2005; Nelson et al., 2007; Agrawal and Perrin, 2008; Agrawal, 2010).

Among the important institutions in both developed and developing countries are those associated with local governments³ as they have a major role in translating goals, policies, actions, and investments between higher levels of international and national government to the many institutions associated with local communities, civil society organizations, and non-government organizations (NGOs). SREX Chapter 5 (IPCC, 2012) extensively assesses the role and importance of the local scale institutions when adapting to extreme weather and climate events, highlighting that extreme weather and climate events are acutely experienced at local levels, and that local knowledge is important for managing impacts (Cutter et al., 2009). As institutional actors, local governments and community institutions influence the distribution of climate risks, mediate between levels of government as well as between social and political processes, and establish incentive structures that affect both individual and collective action at all levels (Agrawal and Perrin, 2008). They are in a pivotal position to promote widespread support for adaptation initiatives, foster intergovernmental coordination, and facilitate implementation, both directly and through mainstreaming into ongoing planning and work activities (Anguelovski and Carmin, 2011; Carmin et al., 2012).

There are a number of ongoing political issues that shape the relationships national and local governments have in managing climate risks (Corfee-Morlot et al., 2011). Governance failure has a significant influence on institutional vulnerability (see Section 19.6.1.3.3). For instance, short-term interests, when dealing with long-term issues, can limit incentives to make investments. Similarly, the proximity that authorities have to interest groups can sway their decisions toward other issues, while the drive to engage the public in planning and other activities can orient priorities in ways that do not support adaptation (Corfee-Morlot et al., 2011). Local governments also may lack institutional capacity or have difficulty gaining coordination among departments as conflicts emerge to obtain scarce resources (Satterthwaite and Dodman, 2009; Hardoy and Romero Lankao, 2011). In Bangladesh, the limited access of local governments to resources has been cited as a barrier to local adaptation (Christensen et al., 2012).

Tompkins et al. (2010) found from a survey of 300 projects identified as adaptive at local government level in the UK that more than half were driven by concerns not directly related to climate change. Nevertheless, there are a number of indicators that demonstrate whether local government has institutionalized and mainstreamed adaptation. These include the presence of an identifiable champion from within government, climate change being an explicit issue in municipal plans, resources

³ Here local government is used to refer to second or third tiers or lower of government, below national and state or provincial government levels; it includes county, district, council, municipal, and similar levels of government.

dedicated to adaptation, and adaptation incorporated into local political and administrative decision making (Roberts, 2008, 2010).

Overall, it is important to match the appropriate institutional scale with the scale of implementation. For example, the Murray-Darling Basin in Australia includes significant water resources across four states requiring management institutions involving federal, state, and local governments to manage and allocate water use (Hussey and Dovers, 2006; see also Box 25-2). While governments have the potential to influence adaptive capacity, local governments often lack the human and technological capacity or mandate to develop and enforce regulations. Local governments, particularly those in developing countries, are faced with numerous challenges that limit their ability to identify needs and pursue adaptation options. Often, these governments must attend to backlogs of basic and critical services such as housing and water supply or focus their attention on addressing outmoded and outdated infrastructure. They also may lack institutional capacity or have difficulty gaining coordination among departments as conflicts emerge to obtain scarce resources (Hardoy and Romero Lankao, 2011, Villamizar, 2011). Adaptation will require an approach that devolves relevant decision making to the levels where the knowledge and capacity for effective adaptations reside (see Box 25-5). Sowers et al. (2011) maintain that, in the Middle East and North Africa, the largely centralized systems of planning, taxation, and revenue distribution lead to a focus on supply-side issues with little consideration of changing climates and demand management, which renders their populations vulnerable to climate-induced impacts on water resources due to weak integration with local constituencies.

There are critical institutional design issues that can be evaluated in order to understand institutional needs (Agrawal, 2010; Gupta et al., 2010). The first is the extent to which institutions are flexible to handle uncertainty. This includes flexibility across and within institutions to evaluate and reorganize delivery where necessary. The uncertainty associated with climate change, presence of rapidly changing information and conditions, and emerging ideas on how best to foster adaptation requires continual evaluation, learning, and refinement (Agrawal, 2010; Gupta et al., 2010). Second is the extent to which adaptation is or has the potential to be integrated into short- and long-term policy making, planning, and program development (Conway and Schipper, 2011). Third is the potential for effective coordination, communication, and cooperation within and across levels of government and sectors (Schipper, 2009; Agrawal, 2010; Conway and Schipper, 2011). Finally, to promote adaptive capacity, it is important to identify the extent to which institutions are robust enough to attend to the needs of diverse stakeholders and foster their engagement in adaptation decisions and actions (Urwin and Jordan, 2008; Gupta et al., 2010).

14.2.4. Need for Engagement of the Private Sector

The role of the private sector is important in delivering adaptation. Often, the focus falls on the role of the private financial sector in providing risk management options including insurance and finance for large projects (see Sections 15.4.4, 17.5.1). However, the delivery of adaptation actions ranges more widely and spans different types of private enterprise, from small farmers, to small to medium enterprises (SMEs), to multinational companies. KPMG International (2008) used published reports and

interviews to identify the sectors where businesses considered they face the greatest climate-related risks. In order of perceived importance, the core risks were regulatory, physical, reputational, and litigation risks. The sectors identified as most at risk included an expected cluster around oil and gas and aviation, and also a group less commonly perceived to be at risk, including health care, the financial sector, tourism, and transport.

Khattari et al. (2010) have described three general ways in which the private sector can become involved in adaptation. The first, internal risk management, is critical to firms and enterprises protecting their own interests and ensuring continuity of supply and markets. The second form of involvement recognizes that business is a stakeholder and therefore needs to participate in public sector and civil society initiatives, such as The New York City Panel on Climate Change, which consists of diverse stakeholders, including representatives from the private sector (Rosenzweig et al., 2011). Third, climate adaptation also provides a wide range of new opportunities to the business community. Even in developing countries, where regulations and markets are often underdeveloped and business risks are high, Khattari et al., (2010) identified opportunities for working in the health care, waste and water management, sanitation, housing, energy, and information sectors through fostering cooperation across government departments and NGOs and promoting public-private partnerships.

Despite broad-scale recognition of the need to adapt, such as the World Economic Forum's (2012) ranking of the failure to adapt as one of the highest global risks and on a par with terrorism, and despite some examples of private sector engagement in adaptation, most assessments conclude that action in each of the potential arenas has been slow to emerge and that sharing of knowledge and experience has been limited (Khattari et al., 2010; Agrawala et al., 2011). KPMG International (2008) concluded that, while companies are well used to managing business risk, they have yet to integrate the long-term risks of climate change into these systems. Nor are they preparing to grasp the competitive advantages that will accrue to those taking early action. Most of the businesses interviewed appeared to be unsure of the scale of the threat and opportunities for their businesses or are awaiting further guidance and action by governments. They have trouble in accessing and applying information on the extent of the threats and impacts from climate change and have yet to engage in the detailed cost-benefit analysis of adaptive actions or inaction. The European Commission (2009), using case studies of both the public and private sectors, in eight countries, came to similar conclusions. A survey by West and Brereton (2013) of Australian businesses also concluded that most were only vaguely aware of the breadth of adaptation actions that may be required and concerned about information sharing and disclosure. The authors suggest a framework for disclosures of relevant business activities to both improve practice and cater for the needs of company boards, investors, and stakeholders. A survey commissioned by the Carbon Disclosure Project (Gardiner et al., 2007) found that among Standard and Poor's (S&P) 500 companies many more (about two-thirds of respondents) were prepared to report and share information on managing climate risks and adaptation plans than they were on mitigation.

Also, there are still questions of whether and how adaptation finance should be made available to the private sector in developing countries

and under what circumstances (Persson et al., 2009; IFC, 2010; Agrawala et al., 2011), although this is being piloted through the Pilot Program for Climate Resilience (World Bank, 2008; IFC, 2010). Private sector engagement and investment in adaptation is expected to make a substantial contribution to reducing climate risk, but the distribution of its investments will be selective and will be unlikely to match government and civil priorities (Atteridge, 2011).

14.2.5. Information, Capacity, and Resource Needs

Successful implementation of adaptation actions depends on the availability of information, access to technology and funding (Yohe and Tol, 2001; Adger, 2006; Eakin and Lemos, 2006; Smit and Wandel, 2006; World Bank, 2010). In some cases a supposed lack of relevant and legitimate information has been used as a rationale for inaction (Moser and Ekstrom, 2011). To address this concern, the Nairobi Work Program—established at COP-12 in 2006, with a goal of helping developing countries make better informed decisions based on sound scientific, technical, and socioeconomic data—has included repeated calls for better observation systems, information sharing, and modeling capacity (UNFCCC/SBSTA/2008/3). Developed and developing countries have acted on this priority by establishing institutions to provide information services at national, regional, and global scales (CCCC, 2011; UKCIP, 2011; NCCARF, 2012), and there is an ongoing need to promote information acquisition and dissemination (OECD, 2009). For example, information-related adaptation needs in Africa include additional vulnerability and impact assessments with greater continuity, country-specific socioeconomic scenarios, and greater knowledge on costs and benefits of different adaptation measures (Section 22.4.2). Research and development, knowledge, and technology transfer are also important for promoting adaptive capacity. However, providing information does not mean that users will be able to make effective use of it, and this information will often have to be tailored or translated to the individual context (Webb and Beh, 2013). Efficacy of scientific knowledge can be improved by calibration with indigenous knowledge (Section 20.4.2). There are also opportunities for technology transfer and innovation to be enhanced through information technologies (Section 20.4.3).

Financial resources for adaptation have been slower to become available for adaptation than for mitigation in both developed and developing countries (see Chapter 17). Adaptation finance made up probably only a fifth of initial allocations of fast-start funding (Ciplet et al., 2012); and much of this funding has been directed toward capacity-building, standalone projects, or pilot programs. This not only has left financial needs, but has also meant that there is less expertise in adaptation assessment and implementation, which is further confounded by the complex relationship between adaptation and more common sustainable development and/or poverty reduction planning (McGray et al., 2007). Adaptation cost estimates have been used to estimate the financial needs for adaptation, and these may well have been underestimated (see Section 17.4).

Overall, at both international and national levels there is a need to develop financial instruments that are equitable in both their delivery of resources and in sharing the burden of supporting the instruments

(Levina, 2007; World Bank, 2010; see also Chapters 16, 17). In this regard, the Green Climate Fund (GCF) was established in 2010, based on the commitment by developed country parties to mobilize jointly US\$100 billion per year by 2020 to address the needs of developing countries (UNFCCC, 2007). Deliberation over how adaptation finance needs will be met has become central to the UNFCCC policy agenda (Section 16.3.4). Also, financial mechanisms for disaster risk management are also inextricably linked with those for adaptation (Mechler et al., 2010). Lessons from recent recovery operations have emphasized the need for disaster preparedness along with longer term goals directed to building resilience, including maximizing the employment-creation benefits of adaptation measures (Harsdorff et al., 2011.)

Finances required in the future for climate change are estimated to approach levels on the order of current development expenditure, and there is a large gap in funding available for climate change responses in developing countries (Peskett et al., 2009). Therefore, there is a related need to design delivery channels so that funding benefits the poor, as they often are most vulnerable to the impacts of climate change and climate-related disasters. As well as channeling adaptation finance to governments, there is a need for finance to reach the most vulnerable people and for approaches to enable stakeholder participation (Section 15.2.3). For example, for adaptation financing, working at the subnational level will be important and mechanisms such as microfinance may be effective (Agrawala and Carraro, 2010). Another important concern is that, with new money being made available for climate change research, policy development, and practice, people may place too much emphasis on addressing climate change as an isolated priority to the detriment of other equally pressing social, economic, and environmental issues (Ziervogel and Taylor, 2008). For example, in small islands, there are concerns that placing adaptation above the critical development needs of the present could inadvertently reduce resilience (see Section 29.6).

14.3. Adaptation Options

Identifying needs stemming from climate risks and vulnerabilities provides a foundation for selecting adaptation options. Over the years, a number of categories of options have been identified. These options include a wide range of actions that, as summarized in Table 14-1, are organized into three general categories: structural/physical, social, and institutional.

There are many different ways that the range of adaptation options available could be categorized (Burton, 1996), thus any categorization is unlikely to be universally agreed on; but this aims to take into account the diversity of adaptation options for different sectors and stakeholders. Some options cut across several categories. National, sectoral, or local adaptation plans are likely to include a number of measures that are implemented jointly from across various categories including structural, institutional, and social options. Furthermore, some adaptation options are interrelated. For instance, institutions and information are prerequisites for effective early warning systems.

Adaptation constraints and limits mean not all adaptation needs will be met, and not all adaptation options will be possible (see Chapter 16,

Table 14-1 | Categories and examples of adaptation options.

Category		Examples of options*
Structural/ physical	Engineered and built environment	Sea walls and coastal protection structures (5.5.2 and 24.4.3.5; Figure 5-5); flood levees and culverts (26.3.3); water storage and pump storage (Section 23.3.4); sewage works (3.5.2.3); improved drainage (24.4.5.5); beach nourishment (5.4.2.1); flood and cyclone shelters (11.7); building codes (Section 8.1.5); storm and waste water management (8.2.4.1); transport and road infrastructure adaptation (8.3.3.6); floating houses (8.3.3.4); adjusting power plants and electricity grids (10.2.2; Table 10-2)
	Technological	New crop and animal varieties (7.5.1.1.1, 7.5.1.1.3, 7.5.1.3; Box 9-3; Table 9-7); genetic techniques (27.3.4.2); traditional technologies and methods (7.5.2, 27.3.4.2, 28.2.6.1, and 29.6.2.1); efficient irrigation (10.3.6 and 22.4.5.7; Box 20-4); water saving technologies (24.4.1.5 and 26.3.3) including rainwater harvesting (8.3.3.4); conservation agriculture (9.4.3.1 and 22.4.5.7); food storage and preservation facilities (22.4.5.7); hazard mapping and monitoring technology (15.3.2.3 and 28.4.1); early warning systems (7.5.1.1, 8.1.4.2, 8.3.3.3, 11.7.3, 15.4.3.2, 18.6.4, 22.2.2.1, 22.3.5.3, and 22.4.5.2); building insulation (8.3.3.3); mechanical and passive cooling (8.3.3.3); renewable energy technologies (29.7.2); second-generation biofuels (27.3.6.2)
	Ecosystem-based ^b	Cross Chapter Box CC-EA, Ecological restoration (5.5.2, 5.5.7, 9.4.3.3, and 27.3.2.2; Box 15-1) including wetland and floodplain conservation and restoration; increasing biological diversity (26.4.3); afforestation and reforestation (Box 22-2); conservation and replanting mangrove forest (15.3.4 and 29.7.2); bushfire reduction and prescribed fire (Section 24.4.2.5; Box 26-2); green infrastructure (e.g., shade trees, green roofs) (8.2.4.5, 8.3.3, 11.7.4, and 23.7.4); controlling overfishing (28.2.5.1 and 30.6.1); fisheries co-management (9.4.3.4 and 27.3.3.1); assisted migration or managed translocation (4.4.2.4, 24.4.2.5, 24.4.3.5, and 25.6.2.3); ecological corridors (4.4.2.4); ex situ conservation and seed banks (4.4.2.5); community-based natural resource management (CBNRM) (22.4.5.6); adaptive land use management (Section 23.6.2)
	Services	Social safety nets and social protection (Box 13-2; 8.3, 17.5.1, and 22.4.5.2); food banks and distribution of food surplus (29.6.2.1); municipal services including water and sanitation (3.5.2.3 and 8.3.3.4); vaccination programs (11.7.1), essential public health services (11.7.2) including reproductive health services (11.9.2) and enhanced emergency medical services (8.3.3.8); international trade (9.3, 9.4, and 23.9.2)
Social	Educational	Awareness raising and integrating into education (11.7, 15.2, and 22.4.5.5); gender equity in education (Box 9-2); extension services (9.4.4); sharing local and traditional knowledge (12.3.4 and 28.4.1) including integrating into adaptation planning (29.6.2.1); participatory action research and social learning (22.4.5.3); community surveys (Section 8.4.2.2); knowledge-sharing and learning platforms (8.3.2.2, 8.4.2.4, 15.2.4.2, and 22.4.5.4); international conferences and research networks (8.4.2.5); communication through media (22.4.5.5)
	Informational	Hazard and vulnerability mapping (11.7.2, 8.4.1.5); early warning and response systems (15.4.2.3 and 22.4.5.2) including health early warning systems (11.7.3, 23.5.1, 24.4.6.5, and 26.6.3); systematic monitoring and remote sensing (15.4.2.1 and 28.6); climate services (2.3.3) including improved forecasts (27.3.4.2); downscaling climate scenarios (8.4.1.5); longitudinal data sets (26.6.2); integrating indigenous climate observations (22.4.5.4, 25.8.2.1, and 28.2.6.1); community-based adaptation plans (5.5.1.4 and 24.4.6.5) including community-driven slum upgrading (8.3.2.2) and participatory scenario development (22.4.4.5)
	Behavioral	Accommodation (5.5.2); household preparation and evacuation planning (23.7.3); retreat (5.5.2) and migration (29.6.2.4), which has its own implications for human health (11.7.4) and human security (12.4.2); soil and water conservation (23.6.2 and 27.3.4.2); livelihood diversification (7.5.1.1, 7.5.2, and 22.4.5.2); changing livestock and aquaculture practices (7.5.1.1); crop-switching (22.3.4.1); changing cropping practices, patterns, and planting dates (7.5.1.1.1, 23.4.1, 26.5.4, and 27.3.4.2; Table 24-2); silvicultural options (25.7.1.2); reliance on social networks (Section 29.6.2.2)
Institutional	Economic	Financial incentives including taxes and subsidies (Box 8-4; 8.4.3 and 17.5.6); insurance (8.4.2.3, 13.3.2.2, 15.2.4.6, 17.5.1, 26.7.4.3, and 29.6.2.2; Box 25-7) including index-based weather insurance schemes (9.4.2 and 22.4.5.2); catastrophe bonds (8.4.2.3 and 10.7.5.1); revolving funds (8.4.3.1); payments for ecosystem services (9.4.3.3 and 27.6.2; Table 27-7); water tariffs (8.3.3.4.1 and 17.5.3); savings groups (8.4.2.3 and 11.7.4; Box 9-4); microfinance (Box 8-3; 22.4.5.2); disaster contingency funds (22.4.5.2 and 26.7.4.3); cash transfers (Box 13-2)
	Laws and regulations	Land zoning laws (22.4.4.2 and 23.7.4); building standards (8.3.2.2, 10.7.5, and 22.4.5.7); easements (27.3.3.2); water regulations and agreements (26.3.4 and 27.3.1.2); laws to support disaster risk reduction (8.3.2.2); laws to encourage insurance purchasing (10.7.6.2); defining property rights and land tenure security (22.4.6 and 24.4.6.5); protected areas (4.4.2.2); marine protected areas (Box CC-CR Chapter 6; 23.6.5 and 27.3.3.2); fishing quotas (23.9.2); patent pools and technology transfer (15.4.3 and 17.5.5)
	Government policies and programs	National and regional adaptation plans (15.2 and 22.4.4.2; Box 23-3) including mainstreaming climate change; sub-national and local adaptation plans (15.2.1.3 and 22.4.4.4; Box 23-3); urban upgrading programs (8.3.2.2); municipal water management programs (8.3.3.4; Box 25-2); disaster planning and preparedness (11.7); city-level plans (8.3.3.3 and 27.3.5.2; Boxes 26-3 and 27-1), district-level plans (26.3.3), sector plans (26.5.4), which may include integrated water resource management (3.6.1 and 23.7.2), landscape and watershed management (4.4.2.3), integrated coastal zone management (2.4.3, 5.5.4.1, and 23.7.1), adaptive management (2.2.1.3 and 5.5.1.4; Box 5-2), ecosystem-based management (6.4.2.1), sustainable forest management (2.3.4), fisheries management (7.5.1.1.3 and 30.6.2.1), and community-based adaptation (5.5.4.1, 8.4, 15.2.2, 21.3.2, 22.4.4.5, 24.5.2, 29.6.2.2, and 29.6.2.3; Tables 5-4 and 8-4; FAQ 15.1)

Notes: These adaptation options should be considered overlapping rather than discrete, and are often pursued simultaneously as part of adaptation plans. Examples given can be relevant to more than one category.

^aA number of these would fall under the term “green infrastructure” in some European Commission documents (European Commission, 2009).

^bWGII AR5 sections containing representative sample of adaptation options.

particularly Section 16.7.1). Moreover, adaptation options are not available to meet all adaptation needs. For instance, adaptation options are poorly developed for the broader set of impacts on ocean systems (see Section 30.6). There is also often going to be a gap between adaptation needs and the effectiveness of the options to meet these needs even when well resourced and well implemented. Some of this gap may be met by procedures to deal with loss and damage (Section 19.7) and some adaptation deficit will remain with us. Many of the adaptation options intersect with vulnerability reduction and development options that build adaptive capacity and address the “adaptation deficit” which may be seen as part of a wider “development deficit” (McGray et al., 2007; see also Section 2.4.2).

14.3.1. Structural and Physical Options

This category highlights adaptation options that are discrete, with clear outputs and outcomes that are well defined in scope, space, and time. They include structural and engineering options; the application of discrete technologies; the use of ecosystems and their services to serve adaptation needs; and the delivery of specific services at the national, regional, and local levels. This category includes much of the notion of “concrete activities” that reflect the priority of the Adaptation Fund, where the focus is on “discrete activities with a collective objective(s) and concrete outcomes and outputs that are more narrowly defined in scope, space, and time” (Adaptation Fund Board, 2013).

14.3.1.1. Engineering and Built Environment

Engineering, and the multidisciplinary teams engineers work with (architects, planners, legal experts, etc.), is often at the forefront of delivering adaptation technologies and strategies (Dawson, 2007). Most engineering options are expert driven, capital-intensive, large-scale, and highly complex (McEvoy et al., 2006; Morecroft and Cowan, 2010; Sovacool, 2011). While many of the engineering options—including management of storm and waste water flow (both inland and coastal), flood levees, seawalls, upgrading existing infrastructures to improve wind and flooding resilience, beach nourishment, and retrofitting buildings (Blanco et al., 2009; Koetse and Rietveld, 2012; Ranger and Garbett-Shiels, 2012)—are extensions and improvements of existing practices, plans, and structures; some newer projects are now integrating changed climate risk into the initial design. For example, during the engineering design of the Qinghai-Tibet Railway, various measures were proposed to ensure the stability of the railway embankment in permafrost regions (Wu et al., 2008). Section 5.5.4.1 describes how new coastal protection structures in Japan are being upgraded to take into account future sea level rise.

Engineered adaptation options typically have two general limitations. First, they often must cope with uncertainties associated with projecting climate impacts arising from assumptions about future weather, population growth, and human behavior (Dawson, 2007; Furlow et al., 2011). Second, the longevity and cost of engineered infrastructure affect the feasibility at the outset (Koetse and Rietveld, 2012). They also are subject to consequences that were not anticipated. For example, after coastal eastern England was devastated by the North Sea storm surge in 1953, hard-engineered sea walls were put in place to protect the coast from erosion and inundation. However, the engineered alterations resulted in a new array of coastal instabilities, including disturbances in sediment supply and damages to coastal ecosystems (Adger et al., 2009b; Turner et al., 2010). As a result, many have promoted a “phased capacity expansion” strategy, which allows engineered projects to undertake design modification as conditions or knowledge change and facilitate incremental project construction to ease the burden of upfront financing (Colombo and Byer, 2012). An example is the Thames Estuary 2100 Plan (see Box 5-1) and, in the Netherlands, the Delta Works (Arnold et al., 2011).

14.3.1.2. Technological Options

Recent advances in technology and information are being combined with engineering structural adaptation measures in various applications. In the food and agriculture sector, a suite of adaptation options have been developed and applied to reduce the adverse impacts of climate change on production (FAO, 2007; Stokes and Howden, 2010; see also Chapters 7, 9). Technologies range from more efficient irrigation and fertilization methods, plant breeding for greater drought tolerance, and adjusting planting based on projected yields (Semenov, 2006, 2008; Bannayan and Hoogenboom, 2008) to transfers of traditional technologies such as floating gardens (Irfanullah et al., 2011a,b). Technology options for climate change adaptation include both “hard” and “soft” technologies, and not only new technologies but also indigenous and locally made appropriate technology (Glatzel et al., 2012). For example,

traditional construction methods have been identified across the Pacific as a means of adapting to tropical cyclones and floods, including building low aerodynamic houses and the use of traditional roofing material such as sago palm leaves to reduce the hazard of iron roofing being blown away in high winds (see Section 29.6.2.1). Centralized high-technology systems can increase efficiency under normal conditions, but also risk cascading malfunctions in emergencies (Section 15.4.3).

With the rapid diffusion of Information and Communication Technologies (ICT) such as mobile phones and the Internet, the unprecedented speed at which information is produced and shared is posing a new set of possibilities for communication. ICT provides opportunities for top-down dissemination of relevant information such as weather forecasts, hazard warnings, market information, information sharing, and advisory services. It can also generate essential information through bottom-up processes such as “crowd sourcing” of useful information such as local flood levels, disease outbreaks, and the management of disaster responses. MacLean (2008) identifies three kinds of effects of the rapid advances in ICT on adaptation and development in general: direct use for monitoring and measuring climate change as described earlier, as a medium for raising awareness, and as an enabler for a “networked governance” based on networked open organizations. Pant and Heeks (2011) emphasize the difficulty in foreseeing additional applications arising from planned ICT applications exploiting local creativity and entrepreneurship, but warn that ICT itself is not a panacea and that the most effective applications are embedded in other societal behaviors.

There are repeated calls for technology transfer to and sharing between developing countries in adaptation to match the programs associated with mitigation (UNFCCC, 2006). Unlike mitigation, where low-carbon technologies are often new and protected by patents held in developed countries, in adaptation the technologies are often familiar and applied elsewhere. For example, agricultural practices that are well known in a region some distance away may now be applicable but unfamiliar within a region of interest (Irfanullah et al., 2011a). Thus, technology transfer in adaptation may be easier than for mitigation. For example, to address water scarcity issues in many places, water storage, use, and water efficiency technologies will all need to be more widely available. See also Section 15.3.4 on technology transfer and diffusion.

14.3.1.3. Ecosystem-Based Adaptation

Ecosystem-based adaptation (EBA)—which is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change (Convention on Biological Diversity, 2009)—is becoming an integral approach to adaptation (see Box CC-EA). Often, when faced with climate-related threats, first consideration is given to engineered and technological approaches to adaptation. However, working with nature’s capacity and pursuing ecological options, such as coastal and wetland maintenance and restoration, to absorb or control the impact of climate change in urban and rural areas can be efficient and effective means of adapting (Huntjens et al., 2010; Jones et al., 2012). The use of mangroves and salt marshes as a buffer against damage to coastal communities and infrastructure has been well researched and found to be effective both physically and financially in appropriate locations (Day et al., 2007;

Morris, 2007). They can also provide biodiversity co-benefits, support fish nurseries, and have carbon sequestration value (Adger et al., 2005; Reid and Huq, 2005; Convention on Biological Diversity, 2009). Other EBA activities include integrative adaptive forest management (Bolte et al., 2009; Guariguata, 2009; Reyser et al., 2009), and the use of agro-ecosystems in farming systems (Tengö and Belfrage, 2004), ecotourism activities (Adler et al., 2013), land and water protection and management, and direct species management (Mawdsley et al., 2009). An analysis of the 44 submitted NAPAs showed that the value of ecosystem services was acknowledged in 50% of the national proposals and, in 22% of the proposals, included the use of ecosystem services mostly in support of other adaptation activities including infrastructure, soil conservation, and water regulation (Pramova et al., 2012).

Green infrastructure (including the use of green roofs, porous pavements, and urban parks) can improve storm water management and reduce flood risk in cities, and can moderate the heat-island effect, as well as having co-benefits for mitigation (Section 8.3.3.7). For example, New York City has a well-established program to enhance its water supply through watershed protection that is cost-effective compared to constructing a filtration plant (Section 8.3.3.7). However, there are trade-offs relating to land use and the availability of space for people and social, economic, and environmental activities. For example, providing an effective wetland buffer for coastal protection may require emphasis on silt accumulation possibly at the expense of wildlife values and recreation (Convention on Biological Diversity, 2009; Dudley et al., 2010). Similarly Goldstein et al. (2012) found that in land use decision making in Hawaii trade-offs existed between carbon storage and water quality, and between environmental improvement and financial returns. A further consideration is that ecosystem-based approaches are often more difficult to implement and assess as they usually require cooperation across institutions, sectors, and communities, and their benefits are also spread across a similarly wide set of stakeholders (Jones et al., 2012). One of the major barriers to EBA is the lack of comparable standards and methodologies applied to engineering approaches, thus demonstrating the need for more dialog between engineering and ecological communities.

14.3.1.4. Service Options

Service provision consists of a diverse range of specific and measurable activities. For instance, one measure to support the most vulnerable populations is social safety nets. Efforts to address child malnutrition, which often result from loss of livelihood due to extreme weather events, particularly floods and droughts (Hoddinott et al., 2008; Alderman et al., 2009), offer an example of how safety nets can serve as a climate adaptation measure. While some studies have shown that food programs can be counterproductive to promoting livelihoods over the longer term or may not prevent malnutrition in non-emergency situations (e.g., Bhutta et al., 2008), programs designed to provide support via food programs, micro-finance, or insurance at times of extreme events can provide an important bridge for vulnerable populations (Hoeppe and Gurenko, 2006; Hochrainer et al., 2007; Alderman et al., 2009; Meze-Hausken et al., 2009).

Public health services also are important for tackling projected increases of disease incidences spurred on by climate change (Ebi and Burton, 2008;

Garg et al., 2009; Edwards et al., 2011; Huang et al., 2011). For example, in countries where malaria is endemic, frequent adaptation options for addressing possible outbreaks include increasing use of mosquito nets, insecticides sprays, and controlling mosquito breeding by reclaiming land and filling drains (Garg et al., 2009). Governments at all levels are often also responsible for maintaining adequate access to services that are projected to be further stressed due to climate change (Laukkonen et al., 2009). Frequently cited options in this domain include, among others, clearing drainage systems to prevent floods, diversifying water supply services to account for changing water supplies (Kiparsky et al., 2012), and maintaining open public spaces dedicated for disaster recovery and other emergency purposes (Hamin and Gurran, 2009).

At the local level, infrastructure associated with the provision of basic services, such as water, sanitation, solid waste disposal, power, storm water and roadway management, and public transportation are integral to increasing adaptive capacity (Paavola, 2008; Bambrick et al., 2011; Barron et al., 2012; see also Section 8.2.4.1). Transport links enable households to take part in trade, for example, to access agricultural markets (Section 9.3.3.3.2) although supply chains can be vulnerable to climate disruption. Housing services are particularly critical because new patterns in temperature and precipitation will alter the habitability and stability of residences while increased frequency and intensity of natural disasters will place settlements and homes on both stable and unstable land at greater risk (Satterthwaite and Dodman, 2009; see also Section 8.3.3.3). Although one option is to relocate people inhabiting vulnerable areas, some argue that *in situ* upgrading may be more cost-effective, especially for addressing informal settlements in developing countries (Revi, 2008).

14.3.2. Social Options

There are various adaptation options that target the specific vulnerability of disadvantaged groups, including targeting vulnerability reduction and social inequities. Community-based adaptation (CBA) refers to the generation and implementation of locally driven adaptation strategies, operating on a learning-by-doing, bottom-up, empowerment paradigm that cuts across sectors and technological, social, and institutional processes. Social protection schemes (see also Section 14.3.1 on services) include public and private initiatives that transfer income or assets to the poor, protect against livelihood risks, and raise the social status and rights of those who are marginalized (see Box 13-2). An example of a social protection scheme aimed at moving beyond repeated relief interventions is Ethiopia's Productive Safety Net Program (PSNP) (Section 22.4.5.2).

The complexity of climate adaptation means that adaptation options are heavily influenced by forms of learning and knowledge sharing (Collins and Ison, 2009). Many scholars have noted that education is a key indicator for how people select adaptation options (Chinowsky et al., 2011; Sovacool et al., 2012), while a lack of education is a constraint that contributes to vulnerability (Paavola, 2008). For example, in a study of how farmers in the Nile Basin of Ethiopia select adaptation options, the researchers found a positive relationship between the education level of the household head and the adoption of improved technologies and adaptation to climate change (Deressa et al., 2009a,b). In Bangladesh,

education about disaster responses was greatly assisted by rising literacy rates, especially among women (Section 11.7).

Awareness raising, extension, outreach, community meetings, and other educational programs are important for disseminating knowledge about adaptation options (Aakre and Rübhelke, 2010; Birkmann and Teichman, 2010) as well as for helping to build social capital that is critical for social resilience (Adger, 2003; Krasny et al., 2010; Wolf et al., 2010). In this regard, education can be seen as a public good that promotes dialog and networks (Boyd and Osbahr, 2010), and therefore allows the development of resilience at both the level of the individual learner and at the level of socio-ecological systems (Krasny et al., 2010). Research partnerships and networks can facilitate knowledge-sharing and awareness raising at all levels from small groups of individuals to large institutions (Section 8.4.2.5). Communication and dialog on adaptation can be a two-way flow of information. Adaptation has itself been described as a social learning process (Section 15.3.1.2), and a number of initiatives in Africa emphasized the importance of iterative and experiential learning for flexible adaptation planning (Suarez et al., 2009; see also Section 22.4.5.3). In Maryland a half-day role-playing process has been designed to both help local people, working with key local and state experts and planners, to plan and prepare for sea level rise and other coastal impacts. It allows them to experience first hand the diversity of stakeholders, the conflicting decisions to be made, and the need to communicate throughout their community to adapt to new risks (Anon, 2009). A similar role-playing game has been developed for the Chesapeake Bay of the eastern United States (Learmonth et al., 2011).

Informational strategies are integral to adaptation. Early warning systems are critical to ensuring awareness of natural hazards and to promoting timely response, including evacuation. A number of approaches are being employed around the world, including tone alert radio, emergency alert system, presentations, and briefings (Van Aalst et al., 2008; Ferrara de Giner et al., 2012). Heat wave and health warning systems (HHWS) can be designed to prevent negative health impacts, by predicting possible health outcomes, identifying triggers, and communicating prevention responses (Section 11.7.3).

Climate services initially emerged as an expansion of the tasks provided by weather services, and can act as “knowledge brokers” that establish a dialog between science and the public, to facilitate decision support (Section 2.4.1.2). Linking indigenous and conventional climate observations can add value, for example, in western Kenya, where scientists have worked with local rainmakers to develop consensus forecasts (Section 22.4.5.4). Awareness raising through scenario development, computer modeling, and role playing is effective in preparing both responsible authorities and the public. As previously noted, ICT is facilitating rapid dissemination of information. However, low-tech measures such as brochures, public service announcements, and direct contact with local residents also are important to fostering awareness and response especially where access to ICT is limited or expensive (National Research Council, 2011).

Behavioral measures are among the suite of options that are integral to advancing climate adaptation. Government incentives can spark behavioral change. For example, to slow runoff into storm sewers and

reduce flooding, a number of cities in the USA run “Disconnect your Downspout” programs to urge homeowners to redirect water from their roof into a storage tank or small wetlands. These programs will provide information to households and some offer rebates on supplies. Many poor and vulnerable communities have taken steps to adapt to changes in climate, particularly those in flood-prone areas. For instance, some local communities in Manila are increasing the number of floors in homes and building makeshift bridges (Porio, 2011). Behavioral adaptation can include livelihood diversification, which has long been used by African households to cope with climate shocks and spread risk (Section 22.4.5.2). Labor migration can be an important strategy for reducing vulnerability to different sources of stress as it helps households diversify their livelihoods (Banerjee et al., 2013). However, migration and relocation do have implications for family relations, health, and human security (see Sections 11.7.4, 12.4.2).

14.3.3. Institutional Options

Numerous institutional measures can be used to foster adaptation. These range from economic instruments such as taxes, subsidies, and insurance arrangements to social policies and regulations (de Bruin et al., 2009; Hallegatte, 2009; Heltberg et al., 2009). For instance, in the USA, post-disaster funds for loss reduction are added to funds provided for disaster recovery and can be used to buy out properties that have experienced repetitive flood losses and to relocate residents to safer locations, to elevate structures, and to assist communities with purchasing property and altering land-use patterns in flood-prone areas, as well as undertaking other activities designed to lessen the impacts of future disasters not only on habitation but also on more effective food production and other livelihoods (FEMA, 2010). Uptake of climate risk insurance is hindered by expensive premiums. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) pools together country-level risks into a more diversified portfolio to offer lower premiums for immediate post-disaster responses (Section 29.6.2.2).

Laws, regulations, and planning measures such as protected areas, building codes, and re-zoning are institutional measures that can improve the safety of hazard-prone communities by designating land use to support resilience (Biderman et al., 2008; Bartlett et al., 2009). For example, marine protected areas (MPAs) have the potential to increase ecosystem resilience and increase recovery of coral reefs after mass coral bleaching (see Chapter 6, Box CC-CR). While zoning can be used to procure sites for low-income populations (Biderman et al., 2008; Bartlett et al., 2009; Satterthwaite and Dodman, 2009), if it increases property and housing values it also has the potential to exclude the poor from these areas. Legal rights can also determine adaptive capacity as well as access to resources. Land tenure security in Africa is widely accepted as being critical for enabling people to make longer-term decisions, such as changing farming practices (Section 22.4.6).

A number of funding and financial issues are linked to institutions. At the international level, agreements and donors have a critical role to play in promoting and supporting the allocation and flow of financial resources (OECD, 2011). For instance, the Adaptation Fund, which is set up under the Kyoto Protocol and funded through a levy on most Clean Development Mechanism (CDM) projects, is of particular importance to

developing countries as it is pioneering the direct access mechanism which allows countries to access funds without having to work through a multilateral development agency. The direct access mechanism highlights the role of institutions in building and maintaining capacity, not just in the technical aspects of adaptation assessment and project design, but also in financial management and due diligence (Brown et al., 2011).

Effective governance is important for efficient operations of institutions. In general, governance rests on the promotion of democratic and participatory principles as well as on ensuring access to information, knowledge, and networks. Institutional strengthening and capacity building has been highlighted as a priority need in developing countries (Kumamoto and Mills, 2012). In assessment of river basin planning in Brazil, Engle and Lemos (2010) found that improving governance mechanisms appears to enhance adaptive capacity. Similarly water-trading schemes facilitated by new government measures reduced the impact of a major drought on the economy in Australia (Mallawaarachchi and Foster, 2009). The effectiveness of such approaches depends on both government will and capacity building among those affected.

In terms of national or local adaptation planning and policy making, Chapter 15 emphasizes that it can be challenging for governments to move beyond adaptation planning to implementation (Section 15.2.2). In an evaluation of one of the earliest national adaptation strategies for Finland, it was found that few measures had been implemented except in the water sector (see Box 23-2). Adaptation planning can occur at a number of spatial scales including at the national, regional, city, district, or local community level. Action plans can include a range of adaptation options including structural, social, and regulatory measures. For example, the city of Quito has proposed developing dams, encouraging a culture of rational water use, reducing water losses, and developing mechanisms to reduce water conflicts (Section 8.3.3.4). Table 25-5 lists various urban climate change adaptation options and their barriers to adoption. See also Section 15.3 on local adaptation plans.

Institutional adaptation options include the use of various decision-making and adaptation planning tools (Chapter 15) including iterative risk management (Chapter 2). There are various decision-making paradigms that can guide adaptation actions. For example, prominent institutional frameworks used for management of coastal areas include Integrated Coastal Zone Management (ICZM) and Adaptive Management (see Section 5.5.1.4). At the local scale, community-based adaptation refers to the generation and implementation of locally driven adaptation strategies through a learning-by-doing, bottom-up approach (Section 5.5.1.4). Community-based approaches to adaptation can also be mainstreamed into local or regional plans. Refer to Table 5-4 for a description of community-based adaptation options for coastal areas.

14.3.4. Selecting Adaptation Options

Selecting specific adaptation options can be challenging partly due to the rate, uncertainty, and cumulative impacts of climate change. How adaptation is framed will have an impact on how adaptation options are selected (Fünfgeld and McEvoy, 2011). Policy and market conditions

may be a stronger driver of behavior than the observed climate itself (Berkhout et al., 2006). Also, rarely will adaptation options be designed to address climate risks or opportunities alone (IPCC, 2007b); instead actions will often be undertaken with other goals (such as profit or poverty reduction) in mind, while also achieving climate-related co-benefits. Gains in reduced vulnerability, enhanced resilience, or greater welfare will often be co-benefits generated as a result of changes and innovations driven by other factors (Khan et al., 2013). Rather than focusing on adaptation options addressing specific dimensions of climate change, more attention is being paid to mainstreaming climate change into wider government policy and private sector activities (see Sections 15.2.1, 15.5.1; Sietz et al., 2011a).

Selection and prioritization of adaptation options is important because not all adaptation options will be possible owing to constraints such as insufficient local resources, capacities, and authority (see Section 16.7). Furthermore, some adaptation options can be maladaptive if they foreclose other options (see Section 14.7). The viability of adaptation options is dependent on the time scale and climate scenario, emphasizing that selecting adaptation options is an iterative process.

A variety of systematic techniques have been developed for selecting options (e.g., see Section 15.4; De Bruin et al., 2009; Füssel, 2009; Ogden and Innes, 2009). Quantification and other systematic approaches to selecting options have many virtues. However, they also have limitations. For instance, most of these methodologies do not account for a range of critical factors such as leadership, institutions, resources, and barriers (Smith et al., 2009). For example, cost-benefit analysis of adaptation options requires valuation of non-market costs and benefits, which can be impractical (Section 17.3.2). Strategies dominating the early adaptation literature emphasized maintaining the current system and minimizing costs while achieving some form of benefit. For instance, no-regrets measures both reduce climate risk and provide other social, economic, or environmental benefits (Hallegatte, 2009). Risk management approaches often lead to no-regrets, low-regrets, or win-win options, while multi-criteria analysis (MCA) allows assessment of options against different criteria, as was used in the preparation of NAPAs (UNFCCC, 2011).

As ideas about adaptation have evolved, there has been a shift in ambition from traditional approaches that emphasize maintaining the status quo to more dynamic and integrative strategies (see also Sections 2.4.3, 14.1, 16.4.2, 20.5). Adaptive management places an emphasis on taking action and then using the lessons learned to inform future actions in order to make better informed, and often incremental, decisions in the face of uncertainty (Sections 2.2.1.3, 14.4). Lempert and Schlesinger (2000) have proposed that adaptation options should be robust against a wide range of plausible climate and societal change futures. Emerging trends in adaptation place an emphasis on the need for more transformational changes, which has a distinct logic that differs from traditional strategies (see Section 14.1).

As research and experience in the practice of adaptation grows, an ever increasing number of considerations have been advanced as being important in guiding the selection and sequencing of adaptation options. It is unlikely that every adaptation program can ever fully meet each of these considerations, especially as they are increasingly integrated with

Table 14-2 | Considerations when selecting adaptation options.

Consideration	Source (section) within this volume and selected references
Effective in reducing vulnerability and increasing resilience	9.3.5, 11.3; UNFCCC (2007); Brooks et al. (2011)
Efficient (increase benefits and reduce costs)	17.2, 17.4; Stern (2006); IFC (2010)
Equitable, especially to vulnerable groups	Chapter 12; 13.2.1; Huq and Khan (2006)
Mainstreamed/integrated with broader social goals, programs, and activities	15.1, 15.5; Agrawala (2005); Dowlatabadi (2007); Swart and Raes (2007); Agrawala and van Aalst (2008); Ayers and Dodman (2010)
Stakeholder participation, engagement, and support	12.3.1, 13.3, 15.1, 15.2; Swart and Raes (2007)
Consistent with social norms and traditions	12.3.1, 13.1.2; Moser (2006); O'Brien et al. (2007); Alexander et al. (2011)
Legitimacy and social acceptability	20.3.2; UNFCCC (2007); Brooks et al. (2011)
Sustainable (environmental and institutional sustainability)	13.1, 15.3; Brooks et al. (2007); Brown et al. (2011)
Flexible and responsive to feedback and learning	2.3.2, 2.3.3, 16.3, 20.2.3.2; Suarez et al. (2009); Agrawal (2010)
Designed for an appropriate scope and time frame	15.2.3.2, 16.1; Preston and Stafford-Smith (2009); Stafford-Smith et al. (2010); Brown et al. (2012)
Likely to avoid maladaptive traps	14.6; Grothmann and Patt (2005); Repetto (2008)
Robust against a wide range of climate and social scenarios	2.1.1, 17.2.5, 17.3.2; Lempert and Schlesinger (2000); Carmin and Dodman (2013)
Resources available (including information, finance, leadership, management capacity)	14.2.4; UNFCCC (2007); Martens et al. (2009); Brooks et al. (2011); Webb and Beh (2013)
Need for transformative changes considered	14.1; Wilbanks and Kates (2010); Park et al. (2012)
Coherence and synergy with other objectives, such as mitigation	14.6; Klein et al. (2007); UNFCCC (2007); Barnett and O'Neill (2010)

wider social or development goals, but Table 14-2 seeks to outline the most common considerations and point to sources in this volume and the literature for a discussion of some of the core issues.

combining elements of top-down and bottom-up approaches (e.g., Dessai et al., 2005). Decision makers use both in the policy process (Kates and Wilbanks, 2003; McKenzie Hedger et al., 2006).

14.4. Adaptation Assessments

14.4.1. Purpose of Assessments

Identifying adaptation needs requires an assessment of the factors that determine the nature of, and vulnerability to, climate risks (climate change assessments, climate impacts and risk assessments, and vulnerability assessments) and an assessment of adaptation options to reduce risks (adaptation assessment). The various types of climate change assessments differ in that they pursue different goals, are underpinned by different theoretical frameworks, and rely on different forms of data and ultimately may lead to different adaptation responses (Fünfgeld and McEvoy, 2011).

Assessments help decision makers understand the impacts, vulnerability, and adaptation options in a region, country, community, or sector. They are often characterized into “top-down” and “bottom-up” assessments. Top-down assessments are used to measure the potential impacts of climate change using a scenario and modeling driven approach. Bottom-up assessments begin at the local scale, address socioeconomic responses to climate, and tend to be location specific (Dessai and Hulme, 2004). They are often used to determine the vulnerability of different groups to current and/or future climate change and their adaptation options, using stakeholder intervention and analyzing socioeconomic conditions and livelihoods (UNFCCC, 2010). There are also policy-based assessments, which assess current policy and plans for their effectiveness under climate change within a risk-management framework (UNDP, 2004, 2005). The evolution of assessments has led to a more thorough assessment of society’s ability to respond to risks through various adaptations, which can help guide allocation of adaptation resources (Füssel and Klein, 2006). In practice assessments have become increasingly complex, often

14.4.2. Trends in Assessments

A variety of frameworks have been developed for the assessment of climate impacts, vulnerability, and adaptation (Fünfgeld and McEvoy, 2011). “Impacts-based” approaches focus primarily on the biophysical climate change impacts to which people and systems need to adapt. “Vulnerability-based” approaches focus on the risks themselves by concentrating on the propensity to be harmed, then seeking to maximize potential benefits and minimize or reverse potential losses (Adger, 2006; IPCC, 2007b). “Adaptation-based” approaches examine the adaptive capacity and adaptation measures required to improve the resilience or robustness of a system exposed to climate change (Smit and Wandel, 2006). In practice these approaches are interrelated, especially with regard to adaptive capacity (O'Brien et al., 2007). An evolution in the conceptualization of risk and vulnerability in the past decade has led to more holistic and integrated approaches to assessment, aiming toward a more systemic understanding of the complexity of human-environment interactions (Preston et al., 2011b).

The “standard approach” to assessment has been the climate scenario-driven impacts-based approach, which developed from the seven-step assessment framework of the IPCC (Carter et al., 1994; Parry and Carter, 1998): (1) define the problem (including study area and sectors to be examined), (2) select method of problem assessment, (3) test methods/ conduct sensitivity analyses, (4) select and apply climate change scenarios, (5) assess biophysical and socioeconomic impacts, (6) assess autonomous adjustments, and (7) evaluate adaptation strategies. This approach dominated the assessment sections of the first three IPCC reports, and aims to evaluate the impacts of climate change under a given scenario and to assess the need for adaptation and/or mitigation

to reduce any resulting vulnerability to climate risks (IPCC, 2007a). These frameworks are described as “first generation” or “type 1” assessment studies (Burton et al., 2002). The standard impact approach is often described as top-down because it combines scenarios downscaled from global climate models to the local scale with a sequence of analytical steps that begin with the climate system and move through biophysical impacts toward socioeconomic assessment (IPCC, 2007b). The process of downscaling of global climate models leads to issues of uncertainty and limited statistical confidence (Füfngeld and McEvoy, 2011).

A new generation of scenario-based impact assessments has also emerged linking biophysical, economic, and social analysis tools. Refer to Section 2.3.2 for examples of large-scale and regional-scale scenario-based vulnerability assessments that have taken place linking biophysical and socioeconomic futures. In Europe, a study by Ciscar et al. (2011) estimated economic welfare losses over four sectors of 0.2 to 1% by the 2080s (Section 2.3.2.1). In Australia, socioeconomic considerations are beginning to be used to inform assessments of adaptive capacity and vulnerability (Section 25.3.2). A risk-based framework, based on the risk management approach, can also be used for assessing adaptation opportunities, constraints, and limits (Section 16.2). Economic assessments are also used to estimate the impacts of climate change, including distributional impacts and adaptation costs and benefits (Chapter 17).

The “second generation” vulnerability and adaptation assessments (Burton et al., 2002) pay greater attention to information around vulnerability to inform decisions on adaptation. They are characterized by the intensive involvement of stakeholders and the participation of vulnerable groups in decision making around adaptation options (Füssel and Klein, 2006; LDC Expert Group, 2012). Local projects often use participatory vulnerability assessment (PVA) methods. In Bangladesh,

community-based adaptation has combined consensus-building and participatory rural appraisal (PRA) to assess needs of the communities and propose adaptation actions (Section 15.2.1). In activities by CARE, vulnerability assessments were undertaken with men and women’s groups separately to ensure activities were gender sensitive (see Section 7.5.2). Participatory vulnerability assessments offer an opportunity to avoid maladaptation by involving stakeholders, for example, in a vulnerability assessment of tourism in the Mamanuca Islands in Fiji, where stakeholders were explicitly integrated into each step of the process (Section 29.8).

Adaptation assessments continue to evolve, but most syntheses now include “top-down” and “bottom-up” approaches, and include the assessment of both biophysical climate change risks and the factors that make people vulnerable to those risks. There is a shift toward integrating community-based planning into national adaptation plans. The Government of Nepal proposes “LAPA assessments” (Local Adaptation Plans of Action) that seek to integrate top-down and bottom-up models (Government of Nepal, 2011). There is also increasing attention to institutional capacity assessments and policy environments as key factors that can both drive vulnerability and also determine the type and success of different adaptation options. The generic elements of adaptation and vulnerability assessment are reflected in the the UK Climate Impacts Program (UKCIP) guidelines presented in Figure 14-2.

14.4.3. Issues and Tensions in the Use of Assessments

Adaptation and risk assessments give rise to various tensions, three of which are discussed here. The first is the adaptation paradox, which recognizes that climate change is a global problem while vulnerability

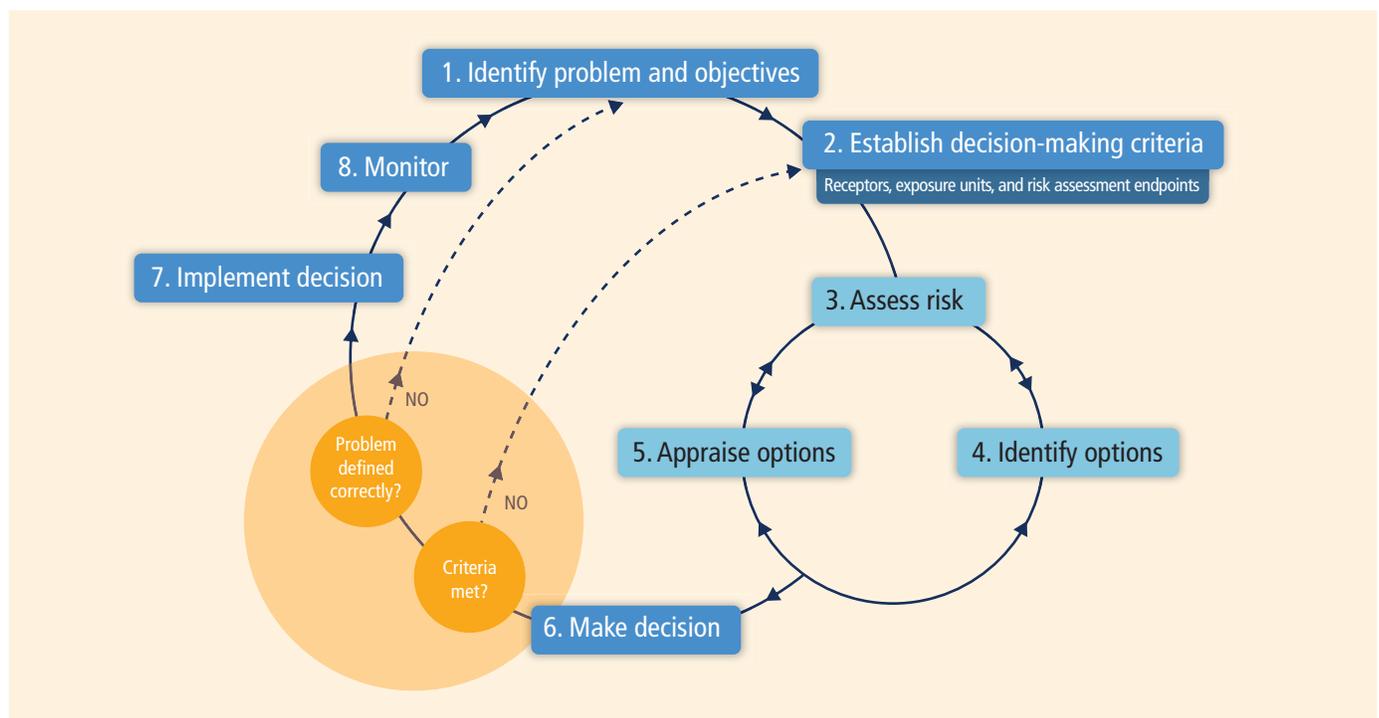


Figure 14-2 | A generic framework for vulnerability and adaptation assessments (UKCIP, 2011).

is locally experienced (Ayers, 2011). Top-down assessments of climate scenarios are deemed necessary in order to understand the climate change scenarios that render climate risk. However, the factors that make people vulnerable to climate risks are often locally generated, so require locally driven bottom-up analysis, while factors at the national and regional levels also determine vulnerabilities. Bottom-up analysis tends to prioritize groups based on factors related to poverty and development that drive vulnerability. Top-down assessments tend to prioritize those most exposed to climate risks. Analysis in Nepal that assessed both under-development and climate change impacts showed that, at the household scale, there was a strong correlation between local measures of poverty and vulnerability to climate change (Ghimire et al., 2010). However, when indicators were aggregated at district scale, the correlation was weaker—even when the vulnerability index used included poverty as a proxy for adaptive capacity alongside climate hazard risk and exposure (Ghimire et al., 2010).

There are also tensions around ownership and participation. Assessments managed under global climate change governance structure of the UN Framework Convention on Climate Change are developed under an “impacts-based” paradigm (Burton et al., 2002). This impacts-based approach requires external scientific and technological expertise for defining climate change problems, and formulating technological adaptation solutions, based on specific knowledge of future climate conditions. Such assessments are necessarily “top-down” because this expertise exists at the global and national level. At the local level, the capacity to adapt is based on the underlying securities that determine vulnerability to these impacts in the first place (Adger et al., 2003a). Accessing this information requires “bottom-up” and participatory assessments that engage local vulnerable people. These vulnerable groups and institutions often do not have access to the climate impacts science necessary to fully apply top-down impacts-based assessments. Some places also do not have accurate historical weather data, making it difficult to validate climate trends and models and hence develop evidence-based scenarios of what will happen with any degree of accuracy (Conway, 2009).

The numerous assessments that have been carried out have led to increased awareness among decision makers and stakeholders of climate risks and adaptation needs and options. But this awareness is often not translated into the implementation of even simple adaptation measures within ongoing activities or within risk management planning. There is a bottleneck in adaptation assessments, which may need to be overcome by linking more directly to particular decisions and tailoring the information to local contexts to facilitate the decision-making process (Preston and Stafford Smith, 2009; Brown et al., 2011). Specific techniques such as decision scaling, which seeks to understand which climate conditions would result in hazardous conditions of concern for particular stakeholder groups, are a step in this direction (Brown et al., 2012; Moody and Brown, 2012). Decision support must recognize that human psychological dimensions play a crucial role in the way people perceive risks and make decisions (Section 2.2.1.2). Impacts and adaptation options will also have to be successfully communicated to the local scale. One example of this is local-scale visualization of impacts and adaptation measures, as has taken place in British Columbia, Canada (see Section 2.2.1.3). Use of ICT tools can foster new ways to assimilate or translate information (see Box 15-1). Vulnerability mapping, including

the use of geographic information systems (GIS), can help stakeholders to visualize the impacts of climate change on the landscape, while integration with participatory processes can facilitate learning and deliberation (Preston et al., 2011a).

14.4.4. National Assessments

Under the UNFCCC, all parties are encouraged (Annex 1 countries are required) to report on activities in relation to “vulnerability assessment, climate change impacts and adaptation measures” (FCCC/CP/1999/7). Parties are encouraged to use the IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations (Carter et al., 1994) and the UNEP Handbook on Methods for Climate Change Impacts Assessment and Adaptation Strategies, which focuses on the impacts of sea level rise and uses the seven-step assessment framework (described previously). Annex 1 countries are due to submit their sixth Communications by 2014 and most non-Annex I countries are due to have submitted at least one Communication; some are on their fifth. As such, National Communications have formed the first avenue for assessing and reporting on climate risk and vulnerability assessments at the national level. Most initial National Communications to the UNFCCC produced by developing countries were first-generation vulnerability assessments, which did not seek to assess the feasibility of implementing adaptations (Füssel and Klein, 2006). Undertaking such assessment is resource intensive, underscoring the need for further resources, training, and expertise.

There is a range of emerging national experiences on adaptation and vulnerability assessments. For coastal areas under sea level rise, a summary of the results from coastal vulnerability assessments is shown in Table 5-5. Such assessments show that vulnerability is highly dependent on the greenhouse gas (GHG) mitigation scenario. In Kenya, a study by the Stockholm Environment Institute (SEI) estimated the economics of climate change under a range of scenarios (see Figure 22-6) and estimated that, by 2050, more than 300,000 people could be flooded per year under a high-emissions scenario. In 2012, the UK’s first Climate Change Risk Assessment (CCRA) was undertaken based on a similar framework to that shown in Figure 14-2, to assess risks in and across eleven sectors to inform priorities for action and appropriate adaptation measures (DEFRA, 2012).

National Adaptation Programmes of Action are designed as a vehicle for Least Developed Countries (LDCs) to communicate their most “urgent and immediate adaptation needs” to the UNFCCC for funding from the Least Developed Countries Fund (LDCF). “Urgent and immediate needs” are defined as those for which further delay in implementation would increase vulnerability or increase adaptation costs at a later stage (LDC Expert Group, 2009). The approaches adopted for vulnerability assessment under NAPAs vary. Although the guidelines call for more participatory and “bottom-up” mechanisms to be adopted, time and funding limitations have meant that often the NAPA process remains largely top-down, focused on impacts and consulting the communities only to verify this information (Huq and Khan, 2006; Ayers, 2011). Moreover, available financial resources were too limited to fully assess and address the needs of all sectors and all vulnerable regions of the country (LDC Expert Group, 2012; see also Section 15.2.1.2).

Frequently Asked Questions

FAQ 14.1 | Why do the precise definitions about adaptation activities matter?

Humans have always adapted to changing conditions: personal, social, economic, and climatic. The rapid rate of climate change now means that many groups, ranging from communities to parliaments, now have to factor climate change into their deliberations and decision making more than ever before. Having a term and working definition is always useful in discussing how to tackle a challenge as it helps define scope. Is adaptation all about minimizing damage or are there opportunities as well? Can adaptation proceed only through deliberately planned actions focused specifically on adaptation to climate change? How much must be known about future climates to make decisions about adaptation? How does the adaptation of humans systems differ from adaptation in natural systems? Can adaptation to climate change be distinguished from normal development and planning processes? Need it be? Are we adequately adapted to current climates, or do we have an “adaptation deficit”? The phrase “maladaptation” immediately turns thoughts to how could plans go wrong and possibly cause greater suffering. A definition does not answer all these questions but it provides a framework for discussing them.

There is also a political reason for needing a precise definition of adaptation. Developed countries have agreed to bear the adaptation costs of developing countries to human-induced climate change and that these funds should represent “new and additional resources,”⁴ and the Cancun Agreement and subsequent discussions suggest that for adaptation these funds could amount to tens of billions US\$ per year.⁵ In most cases adaptation is best carried out when integrated with wider planning goals such as improved water allocation, more reliable transport systems, and so forth. How much of the cost of upgrading a coastal road that is already subject to frequent damage from bad weather should be attributed to normal development and how much to adaptation to climate change? A precise answer may never be possible but the closer we agree as to what constitutes adaptation, the easier it will be to come to workable agreements.

Under the Cancun Adaptation Framework (CAF), a process was established to enable LDC parties to formulate and implement National Adaptation Plans (NAPs). NAPs are intended to build on NAPAs but shift the focus toward identifying medium- and long-term adaptation needs and developing and implementing strategies and programs to address those needs. NAPs are intended to facilitate the integration of climate change adaptation into relevant national and subnational development and sectoral planning (LDC Expert Group, 2012). Other developing country parties are also invited to employ the modalities formulated to support the national adaptation plans in the elaboration of their planning efforts. Early guidelines (LDC Expert Group, 2009) propose a country-specific approach tailored to national circumstances, mixing top-down policy-first assessments with bottom-up approaches. Recent guidelines propose that this should be non-prescriptive and should facilitate country-driven, gender-sensitive, participatory action, taking into consideration vulnerable groups, communities, and ecosystems (LDC Expert Group, 2012). Refer also to Sections 2.4.3 and 15.2.1.2 for further details of national and subnational adaptation planning including NAPAs and NAPs.

14.5. Measuring Adaptation

Adaptation has tended to lag behind mitigation efforts both in research and in the climate negotiations. In part this is because adaptation and development specialists, governments, NGOs, and international agencies have found it difficult to clearly define and identify precisely what constitutes adaptation, how to track its implementation and effectiveness, and how to distinguish it from effective development (Burton et al., 2002; Arnell, 2009; Doria et al., 2009). A contributing reason is that adaptation has no common reference metrics in the same way that tonnes of GHGs or radiative forcing values are for mitigation. This section seeks to explore the feasibility of finding metrics for measuring adaptation effectiveness.

The search for metrics⁶ for adaptation will remain contentious, with many alternative uses competing for attention. This is inevitable as there are multiple purposes and viewpoints in approaching the measurement of adaptation (Hulme, 2009). Brooks et al. (2011) asked “what constitutes successful adaptation” and suggested that the criteria by which success

⁴ Bali Action Plan, 2007; FCCC/CP/2007/6/Add.1.

⁵ Cancun Agreements 2010, FCCC/CP/2010/7/Add.1, paras 98 & 102.

⁶ There is no consistent use of the terms metric, measure, and indicator in the literature. Here we try to stay as close as possible to the dictionary meanings (although they overlap). A measure is the amount or degree of something, that is, a description of its (presumably current) state. A metric is often a group of values (measures) that taken together give a broader indication of the state or the degree of progress to some desired state. An indicator is a sign, or estimate of the state of something and often of the future state of something. Most often in seeking to understand the state of vulnerability or adaptation, etc., we need a metric (i.e., a group of measures) and we use the term in that way. In describing the components of a metric we will give preference to the term indicator over measure.

might be assessed include feasibility, efficacy/effectiveness, efficiency, acceptability/legitimacy, and equity (derived from Yohe and Tol, 2001; Adger et al., 2005; Stern, 2006), to which they added sustainability (Fankhauser and Burton, 2011). Effective integration and coherence with wider national policies and development goals is another often sought criterion (World Bank, 2010). Also institutions, communities, and individuals value things differently and many of those values cannot be captured in a comparable way within metrics (Adger and Barnett, 2009).

At least three uses of metrics for adaptation are relevant, each requiring different characteristics of the indicators used. The first use seeks metrics to help determine the need or determinates of that need for adaptation. These metrics usually focus on measuring vulnerability, but that term is not well defined. For example, Hinkel (2011) identifies six uses that vulnerability indicators are sometimes expected to serve and concludes that they can truly serve only their core purpose, that is, to identify vulnerable people, communities, and regions. Further, even with metrics focusing on vulnerability the goal often is not to produce a score or rating to identify vulnerable groups but to elucidate information on the nature of vulnerability and to better identify adaptation options (Smit and Wandel, 2006; Sietz et al., 2011b). The second use of metrics relates to measuring and tracking the process of implementing adaptive actions, such as spending on coastal protection, the number of early warning plans implemented as part of a program, or the number of agricultural specialists with appropriate training in climate risks. Here the selection of appropriate metrics is usually less contentious but there is disagreement as to how much they capture adaptation rather than normal development. The third use of metrics relates to measuring the effectiveness of adaptation such as in monitoring and evaluation. This set is essential to help measure progress and provide feedback on the effectiveness of actions, but is among the most difficult to identify as adaptation outcomes take time to become identifiable and are often subject to evolving conditions and objectives.

14.5.1. What Is to Be Measured?

The measurement of vulnerability is central to many adaptation metrics and initially it was approached from an impacts point of view. Here vulnerability is usually defined as a function of (1) exposure to specific hazards or stressors, (2) sensitivity to their impacts, and (3) the target population's capacity to adapt (IPCC, 2001, Chapter 17). This approach continues to be used as the basis of many assessments and adaptation prioritization efforts. Recently the emphasis has moved from better defining exposure and potential impacts to a better understanding of the factors that affect societies' sensitivity to those impacts and their capacity to adapt. This reflects the increasing recognition of the importance of considering social vulnerability alongside biophysical vulnerability. Various terms have been used to describe these different emphases including biophysical versus social vulnerability, outcome versus contextual vulnerability (Section 14.2.1.1; Eakin and Luers, 2006; Füssel and Klein, 2006; Eriksen and Kelly, 2007; Füssel, 2010), and scientific framing versus a human-security framing of vulnerability (O'Brien, 2007). O'Brien et al. (2007) argue that scientific and human-security frameworks affect the way we approach adaptation, with the scientific framework leading to building local and sectoral capacity to make changes rather than address the fundamental causes of vulnerability,

or climate change itself, within their broader geopolitical and economic contexts.

Other questions also arise even within a given conceptual framework for considering vulnerability. A system of measurement is usually developed to allow comparisons between different places, social groups, or sectors of activity, although experience repeatedly cautions us to be careful in doing so (Schröter et al., 2005). The challenge is as much of integration across widely differing research domains and traditions (Polksy et al., 2007). Also, a system's vulnerability is not static but can respond rapidly to changes in economic, social, political, and institutional conditions over time (Smit and Pilifosova, 2003; Smit and Wandel, 2006). Much of the effort in relation to estimating social vulnerability is reviewed in Cutter et al. (2009).

It has also been suggested that a framework based on the concept of resilience is more appropriate than a vulnerability framework in many contexts (see IPCC, 2012, Chapter 2 and Section 8.3.3 for more details). For example, in a development context resilience "evokes positive and broad development goals (e.g., education, livelihood improvements, food security), includes multiple scales (temporal and spatial) and objectives, better captures the complex interactions between human societies and their environments, and emphasizes learning and feedbacks" (Berkes, 2007; Moss et al., 2012, p. 6). A resilience approach also leads to more focus on interactions between social and biophysical systems (Nelson et al., 2007). However, others feel that resilience promotes too great a focus on the return of the overall system to pre-impact conditions and not enough on the human agents and their need to adapt to changing conditions (Nelson et al., 2007; IPCC, 2012, Section 8.3.3). The concept of resilience has been difficult to apply in practice and is particularly resistant to attempts to establish commonly accepted sets of indicators. Some (e.g., Klein et al., 2003) have suggested that resilience has become an umbrella concept that has not been able to support effectively planning or management.

Recently Brooks et al. (2011) have outlined a framework tracking adaptation that combines the establishment of upstream metrics to assess how well risks are being managed by institutions, and downstream metrics to track whether the interventions are reducing the vulnerability of affected groups. The upstream metrics would focus on assessments of institutional capacity, managerial performance, and integration of climate risk management into planning processes and tracking and feedback processes. The downstream metrics would focus on indicators to track development performance and changes in vulnerability. Attribution of these changes to particular interventions would be desirable but not essential to track progress.

But understanding vulnerability does not necessarily translate to effective adaptation. Smit et al. (2001), Osman-Elasha et al. (2009), and others have suggested that the focus should be on increasing adaptive capacity within the context of the full range of biophysical and socioeconomic stressors. However, as the scope of the metrics is widened to include aspects of development and sustainability they often become less suitable for other purposes such as helping to identify "the full and additional costs of adaptation" (McGray et al., 2007). In deriving indices of vulnerability there are again several broadly different approaches. One is to deductively identify indicators that theoretically should be strongly

Table 14-3 | Criteria for the selection of indicators (based on multiple sources).

	Criterion	Explanation
Validity	Not ambiguous	Agreement on the direction of influence between the indicator and what is sought to be measured (target measure)
	Well founded	Based on a tested theoretical framework
	Well defined	So that unwitting errors are minimized (e.g., measuring a family or a household)
	Purpose known	This helps fix problems in data collection; misunderstandings between different collecting agencies, etc.
	Accurate	Measuring what it should, and responds quickly
	Precise	Statistical variation between measurements is low
	Quality checked	Ideally subject to independent checking; is there a cross checking mechanism?
	Transparent	Information source and control of information flow is known
	Honest	There should be no rationale or opportunity for individuals to manipulate or distort the data (e.g., manipulating rain-gauges used for weather index insurance)
Value	Comprehensible	Relatively easy for user to understand
	Relevant	Applicable to a wide range of circumstances (geographic, social, economic)t
	Responsive	Can measure usefully small changes in the target measure
	Actionable	The quality/quantity of what is being measured can be affected by human appropriate actionst
	High information content	Usually quantitative is more useful than qualitative, than binary data; and real measurements more useful than modeled estimates or expert judgment
	Disaggregatable	Can the indicator be collected for specific groups (e.g. children, women, and men)
	Participatory	Can local people be involved in the data collecting; does the data help inform and possibly empower them
Data	Available	Data is publicly and easily available; affordable
	Homogenous	Data collection is consistent across location and time, including matching season or time-of-day if necessary
	Periodic	Data is collected at a frequency that is suitable for tracking changes
	Long time course	Data has been consistently collected for some years
	Spatial coverage	Spatial coverage must be sufficient to provide a fair representation of the measure (e.g. density of rain gauges)

related to vulnerability (e.g., Dolan and Walker, 2003; Polsky et al., 2007), while the other is inductive and uses observed data to seek correlations between indicators and observed consequences of vulnerability, such as the number of people killed or affected by climate-related events in recent history. There is some commonality in identifying the desirable criteria for selecting indicators, and though no list can ever be complete, Table 14-3, based initially on Perch-Nielsen (2010), seeks to bring together some of the most common criteria.

14.5.2. Established Metrics

Numerous metrics continue to be prepared for a variety of purposes and at scales ranging from estimating the vulnerability of individuals and communities to comparing countries. Several reviews, including Moss (2001, 2012), Srinivasan and Prabhakar (2009), and Prabhakar and Srinivasan (2011), discuss both the design and effectiveness of many of the existing proposals for adaptation metrics.

14.5.2.1. Vulnerability Metrics

Eriksen and Kelly (2007) found strong divergence among five metrics (or indices) for comparing national vulnerability published over the period 1995–2003: the Dimensions of Vulnerability of Downing et al. (1995); the Index of Human Insecurity (IHI) of Lonergan et al. (1999); the Vulnerability-Resilience Indicators of Moss et al. (2001); the Environmental Sustainability Index of the World Economic Forum (2002); and the Country-Level Risk Measures of Brooks and Adger (2003). Between them,

29 indicators were used, with only five indicators appearing in more than one study. They were able to compare the 20 countries ranked as most vulnerable from three of the studies and found little overlap, with only five countries ranked in the top 20 in more than one study. However, it must be noted that the metrics were developed at different times and for different purposes. They concluded that the indices focused on measuring a snapshot of aggregate conditions rather than on delivering guidance on societal processes that can be targeted to reduce vulnerability.

There are a series of disaster-related indices designed to assess relative risks across countries and regions, and to provide benchmarks on which to assess progress. Among them are the Disaster Risk Index (UNDP, 2004); Hotspots Index (Dilley et al., 2005); the Americas Index (Cardona, 2005); and an index for South Asia (Moench et al., 2009). Again, there has been little effort to further analyze, validate, or compare these metrics.

14.5.2.2. Metrics for Resource Allocation

Vulnerability indices have usually been selected to better understand the drivers of vulnerability or to compare countries, regions, communities, and so forth in terms of the risks they face from climate change and their capacity to deal with them. This is not necessarily the same as designing an allocation index or rule to be used to allocate limited resources equitably and efficiently among entities (countries, regions or other administrative groups, or different proponents of adaptation). For allocation, vulnerability and coping/adaptive capacity might be

expected to remain a core consideration, but so also should the relative costs of implementation in relation to the potential benefits and the ability of the recipients to absorb the funding and implement policies and projects to actually achieve the projected benefits (UNFCCC, 2007; Parry et al., 2009; Wheeler, 2011).

One of the longest running and prominent uses of metrics in funding is the World Bank's process of allocating IDA concessional funds to developing countries, which faces many issues analogous to the same process for adaptation. The World Bank uses the Country Policy and Institutional Assessment (CPIA) based on 16 criteria, many qualitative, to estimate the extent to which a country's policy and institutional framework supports sustainable growth and poverty reduction, and consequently the effective use of development assistance. These criteria are the main components used to calculate a Country Performance Rating, which in turn is a major component, along with population and recent performance measures, in calculating allocations to the poorest developing countries with long-term, no interest (IDA) loans. The CPIA and the ultimate IDA allocation formulae are controversial, much debated (Alexander, 2010), and often fine-tuned (IEG, 2009) but still commonly used as a reference point for this type of procedure (GTZ, 2008).

An explicit example of the use, and non-use, of adaptation metrics was in establishment of the Pilot Program for Climate Resilience (PPCR). The governing body, made up of contributors, recipients, and other stakeholders, set up an independent expert group to make recommendations as to which countries might be included as pilots within the approximately US\$1 billion program (Climate Investment Funds, 2009). The expert group refrained from using a simple index, but instead country selection was done across nine regions and each based on a suite of indicators appropriate for the region using expert judgment. It is interesting to note that on moving to the next step of deciding on allocation of financial resources to the selected pilot countries the governing body of the PPCR chose not to use an approach based on indicators, but to provide guidance to the countries of the possible range of funding and to base allocations on the quality of the proposals brought forward (Climate Investment Funds, 2009). Similarly, none of the other governing bodies of international adaptation funding mechanisms (e.g., the Global Environment Facility, the Adaptation Fund) has chosen to use a defined set of metrics within their decision making.

Wheeler (2011) has developed an index of vulnerability based on weather-related disasters, sea level rise, and agricultural productivity. The index can be adjusted according to user preferences to develop allocation formulas based only on biophysical vulnerability, further adjusted for economic development and governance, and finally for project costs and probability of success. Klein and Möhner (2011) have discussed the options for the Green Climate Fund based on experience to date and conclude that science cannot be relied on for a single objective ranking of vulnerability.

14.5.2.3. Metrics for Monitoring and Evaluation

The IPCC's Fourth Assessment Report provided little discussion of the role of evaluation and monitoring of adaptation responses as a component of building adaptive capacity (Adger et al., 2007). Preston et al. (2011a)

identify three specific roles of evaluation: (1) ensuring reduction in societal and ecological vulnerability, (2) facilitating learning and adaptive management, and (3) providing accountability for adaptation investments (see also GIZ, 2011). A central challenge in developing robust monitoring and evaluation frameworks for adaptation is the existence of multiple, valid points of view that can be used to evaluate adaptation actions and their continuing effectiveness (Gagnon-Lebrun and Agrawala, 2006; Perkins et al., 2007; Füssel, 2008; Smith et al., 2009; Ford et al., 2011; Preston et al., 2011b). This challenges the selection of appropriate metrics for the monitoring and evaluation of adaptation and its contribution to vulnerability reduction (Burton and May, 2004; Gagnon-Lebrun and Agrawala, 2007; McKenzie Hedger et al., 2008; Ford et al., 2011).

One of the central unresolved tensions in progressing evaluation is the relative merit of comparatively easy and objective targeting of the completion of the processes and outputs needed to implement an adaptation program versus the outcomes, such as changes in livelihoods or reduction in risks. Assessment of outcomes is less objective, subject to whether appropriate circumstances occur (e.g., that floods occur so that risk reduction can be demonstrated) and usually take much longer to establish. Preston et al. (2011b) suggest the evaluation of adaptation processes may be a more robust approach to evaluation, owing to the difficulties in attributing future outcomes to adaptation strategies and the long-time lags that may be needed to assess the performance of a particular strategy (Berkhout, 2005; Dovers and Hezri, 2010; Ford et al., 2011). The OECD analyzed the monitoring and evaluation processes across 106 adaptation projects across six development agencies and found that Results Based Management and Logical Framework approaches dominated, as they do in normal development projects (Lamhauge et al., 2011). They also drew attention to the need for appropriate baselines and complementary sets of indicators that track not just process and implementation, but also the extent to which targeted changes are occurring. Monitoring programs themselves will need careful design to ensure that they remain in place over the long time frames needed for the outcomes to be identified; that they contain incentives for beneficiaries to comply with conditions; and that compliance itself does not impose undue burdens.

A number of national and international organizations have guides to monitoring and evaluating adaptation activities (McKenzie Hedger et al., 2008; UNDP, 2008; WRI, 2009; World Bank, 2010; GIZ, 2011). These guides tend to focus on the wider framework of identifying and managing adaptation-related activities and within that the criteria for the selection of metrics for monitoring and evaluating those activities. These issues are dealt with in Chapters 15 and 16.

14.5.3. Validation of Metrics

The practice of developing and applying metrics in adaptation has been subject to much scrutiny. Eakin and Luers (2006) express serious concerns about national-scale vulnerability assessments ranging from the quality of the available data, the selection and creation of indicators, the assumptions used in weighting of variables, and the mathematics of aggregation. Nevertheless metrics will continue to be used and the challenge is to identify and maintain basic standards of best practice.

One of the most comprehensive attempts to validate a system for measuring important components of adaptation is that of Brooks et al. (2005). They used the probability of national climate-related mortality from the CRED database of climate-related disasters⁷ as a proxy for risk and selected a set of 46 social, governance, economic, and biophysical measures as indicators of social vulnerability. They found that 11 were effective indicators of mortality rates and these were confirmed as useful by a small focus group of seven adaptation experts. These experts also ranked the variables in terms of their perception of their usefulness leading to a total of 12 different rankings to which was added an equal ranked set to give 13 measures of vulnerability. Countries were then scored against these 13 rankings, and the number of times a country appeared in the top quintile of countries in a particular ranking was used as an indicator of its overall vulnerability.

Progress continues to be made in the methodologies of deriving vulnerability metrics. For example, Rygel et al. (2006) have demonstrated the value of using a Pareto method for combining scores from a collection of indices without having to apply either implicit or explicit weightings. Alcamo et al. (2008) sought to increase the consistency of incorporating expert opinion on different disciplinary approaches (sociology, environmental psychology, economics, and political science) to the estimate of vulnerability, in this case of drought events, in three regions. Based on inference models about what contributes to vulnerability to drought and using fuzzy set theory (Eierdanz et al., 2008) to compute susceptibilities, they were able to show that high combined susceptibilities were associated with water stress crises.

Perch-Nielsen (2010) developed an index to estimate the vulnerability of beach tourism using a systematic approach by establishing a framework to identify the types of indicators needed and a systematic approach to identify indicators that covered the range of countries and time scales. The derivation of the index from the separate indicators was also subjected to robustness (sensitivity) testing to determine the most appropriate methods of scaling and combining the measures.

14.5.4. Assessment of Existing and Proposed Metrics for Adaptation

Srinivasan and Prabhakar (2009) conducted a wide-ranging stakeholder survey to assess the attitudes to, and requirements for, indicators of adaptation. Stakeholders agreed that no single metric can capture the multiple dimensions of adaptation and that refinements of methodologies (e.g., rationale for index selection, aggregation methods, and data checking) are badly needed. Preston et al. (2009) have suggested that, rather than seeking particular metrics, researchers should focus on developing rigorous processes for selecting metrics that can be applied in a range of contexts. But metrics for adaptation remain a necessity. Their derivation challenges the adaptation community to clarify its goals, conceptual models, definitions, and applications. But both theory and practice have shown indices alone are not sufficient to guide decisions on which adaptation actions to take, on how to modify sustainable

development activities, or on resource allocation. Downing (2003) noted that the climate change community was far from adopting common standards, paradigms, or analytic language. This still appears to be true, making the search for commonly accepted metrics, even within well-specified contexts, a challenging task.

14.6. Addressing Maladaptation

The adaptation literature is replete with advice to avoid maladaptation, but it is less clear precisely what is included as “maladaptation.” In a general sense maladaptation refers to actions, or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future (see Glossary). For example, the construction of well-engineered climate-resilient roads designed to withstand current and future climate extremes may foster new settlement into areas highly exposed to the impacts of future climates; or increased water harvesting upstream to cope with erratic rainfall may harm and reduce the opportunities for communities downstream to manage their own risks. Actions that are potentially maladaptive need not be inadvertent (as in the IPCC AR3 and AR4 definition), nor be “taken ostensibly to avoid or reduce vulnerability to climate change” (Barnett and O’Neill, 2010) as the actions may be assessed as appropriate in the context of the full range of climate and non-climate considerations and pressures that apply to the decision. There should be clarity as to what is maladaptive action, or lack of action, lest the avoidance of potential maladaptation becomes a barrier to effective implementation of adaptation. In the road example above, the immediate and multiple benefits to the community of a reliable road system (including as evacuation route in floods, etc.) might be judged as outweighing the longer term risk of inappropriate settlement patterns (Lamhauge et al., 2011). This may be seen as an example of an “unavoidable” *ex post* maladaptation (see Section 16.3.6.1) as it is an appropriate decision based on the information and circumstances at the time. The true maladaptation in this case would be the failure to implement appropriate incentives or regulations to avoid vulnerable settlements in the highly exposed areas.

The wide range of actions and circumstances that have been described as maladaptive demonstrates the complexity of the concept and terminology. Thomsen et al. (2012) describe actions that are not respectful of the intrinsic integrity and internal self-regulation of social-ecological systems as manipulative and likely to prove maladaptive. Their example is the management of Noosa Beach in northern Australia, where the coastline is characterized by cycles of erosion and depletion of beach sands. Rather than enhance the self-regulatory processes and adapting by managed retreat and expansion according to the cycle, management has sought to maintain a static beach profile through hard constructions and beach nourishment. Niemeyer et al. (2005) also describe the state of individual beliefs about climate change that might change from adaptive to inaction and possibly maladaptive behaviors as the perceived magnitude of climate change increases, while Eriksen et al. (2011) and Brown (2011) discuss avoiding outcomes that are

⁷ CRED, the Centre for Research on the Epidemiology of Disasters, has maintained a database of disasters, including those that are climate related. Rationale, methodologies, and data are available at <http://www.cred.be/>.

essentially maladaptive as they run counter to sustainable development goals.

14.6.1. Causes of Maladaptation

Maladaptation arises in many forms but several broad causes can be identified. Actions that may benefit a particular group, or sector, at a particular time may prove to be maladaptive to those same groups or sectors in future climates or to other groups or sectors in existing climates. For example, some development policies and measures that deliver short-term benefits or economic gains but lead to greater vulnerability in the medium to long term, such as in cases where the construction of “hard” infrastructure reduces the flexibility and the range of future adaptation options (Adger et al., 2003b; Eriksen and Kelly, 2007; OECD, 2009), or the failure to encompass the full range of risks in the design of new structures, such as the effects of increasing storm surge in the design of a coastal defense system (UNFCCC, 2007). Adaptation efforts aimed at armoring the coastline may result in coastal erosion elsewhere while building levees along a flood-prone area provides protection to coastal population and infrastructure but might encourage unwanted development within that area, often accentuated by an exaggerated sense of safety (Grothmann and Patt, 2005; Repetto, 2008; National Research Council, 2011) and the levees may increase damage when they fail, as in Bangladesh in 1999 and New Orleans in 2003 (Huq and Khan, 2006; Masozera et al., 2007; Pouliotte et al., 2009). Similarly, agricultural policies that promote the growing of high-yielding crop varieties through subsidies with the objective of boosting production and increasing revenues may achieve these objectives in the short term, but will also reduce agro-biodiversity and increase exposure and vulnerability of mono-crops to climate change and finally undermine the adaptive capacity of farmers in the long term (World Bank, 2010).

Another cause of maladaptation is the failure to account for multiple interactions and feedbacks between systems and sectors leading to inadequate or inaccurate information for developing adaptive responses

and strategies that are maladaptive (Scheraga et al., 2003; Satterthwaite et al., 2009; Pittock, 2011). An assessment of the downstream impacts of upstream rainwater harvesting in a semiarid basin in southern India showed that, once the full range of externalities were accounted for, the net benefits were insufficient to pay back investment costs (Bouma et al., 2011). Similarly, the conversion of coastal mangroves into shrimp farms may lead to increased economic productivity and improved livelihoods, but could also lead to increased vulnerability to flooding and storm surges (Klein, 2010). Maladaptation may also occur if the true potential of an option or a technology is unduly over-emphasized, making it over-rated. Floating gardening has been suggested as an example in this connection (Irfanullah, 2009, 2013). Further examples of the range of maladaptive actions across a range of sectors and regions in this report are outlined in Table 14-4.

14.6.2. Screening for Maladaptation

Five dimensions of maladaptation were identified by Barnett and O’Neill (2010), including actions that, relative to alternatives: (1) increase emissions of GHGs, (2) disproportionately burden the most vulnerable, (3) have high opportunity costs, (4) reduce incentives and capacity to adapt, and (5) set paths that limit future choices. These dimensions are useful pointers to the potential for maladaptation but their application depends on subjective assessments. The first suggests that any action that increases GHG emissions is maladaptive, whereas a judgment on the relative benefits and dis-benefits will need to be made in such cases; the second turns on the interpretation of “disproportionately;” and the third on “high” and on how opportunity costs are compared with current benefits. The dimensions were used by Barnett and O’Neill (2010) to describe maladaptive potential of the Wonthaggi desalination plant to improve water supply to Melbourne, Australia. The plant was included as part of a wider water management plan for Melbourne that includes both demand- and supply-side management and incentives (Heffernan, 2012; Porter, 2013). Barnett and O’Neill (2010) argue that the plant (1) will increase GHG emissions (even if the planned wind power

Table 14-4 | A selection of examples of actual or potential maladaptive actions from this report.

Broad type of maladaptive action	Examples in AR5
Failure to anticipate future climates. Large engineering projects that are inadequate for future climates. Intensive use of non-renewable resources (e.g., groundwater) to solve immediate adaptation problem	22.3, 22.4.8.5
Engineered defenses that preclude alternative approaches such as EBA	Box CC-EA; 15.2.2
Adaptation actions not taking wider impacts into account	22.4.5.8, 25.4.2, and 26.9.4
Awaiting more information, or not doing so, and eventually acting either too early or too late. Awaiting better “projections” rather than using scenario planning and adaptive management approaches	7.5.1.2.2, 8.5.2, and 16.5.2
Forgoing longer term benefits in favor of immediate adaptive actions; depletion of natural capital leading to greater vulnerability	13.2.1.3; 22.4.5.8; 25.9.1
Locking into a path dependence, making path correction difficult and often too late	16.3.2; FAQ 25.1
Unavoidable ex post maladaptation, e.g., expanding irrigation that eventually will have to be replaced in the distant future	17.5; see also 5 and 6 above
Moral hazard, i.e., encouraging inappropriate risk taking based, e.g., on insurance, social security net, or aid backup	17.5 and 29.8
Adopting actions that ignore local relationships, traditions, traditional knowledge, or property rights, leading to eventual failure	12.3, 12.5.2; 26.9.4
Adopting actions that favor directly or indirectly one group over others leading to breakdown and possibly conflict	13.1.1 and 13.1.4
Retaining traditional responses that are no longer appropriate	21.3.2 and 22.4.5.8
Migration may be adaptive or maladaptive or both depending on context and the individuals involved	26.2.1, 26.8.3, 29.3.3, 29.6.2.4

Note: These examples of maladaptation represent a set of cases found in the report that might help the readers to understand the rich range of circumstances in which maladaptive actions might arise. They do not represent a formal categorization of type of maladaptation.

energy source is completed); (2) may lead to higher water costs that will disproportionately affect the poorer households; (3) may divert money and attention from more cost-effective recycling and rainwater harvesting; (4) may reduce incentives to adapt through water conservation approaches; and (5) as a large sunk cost has locked out other options. The plant also affected significant cultural sites of the Bunorong Aboriginal community (Lee and Chung, 2007).

14.6.3. Experiences with Maladaptation

Maladaptation is a cause of increasing concern to adaptation planners, where intervention in one sector could increase vulnerability of another sector or increase the vulnerability of a group to future climate change. An example is the situation experienced by subsistence and smallholder agriculturalists in Palca, Bolivia, who in the face of stressors relating to land access, small holdings, and so forth moved away from their long established practices of diversification of crop varieties and planting locations to more intensive farming practices and cash cropping. They are now seeing evidence of climate change, and the new practices make them more vulnerable to these changes, leading to a risk of insufficient adaptation and maladaptation (McDowell and Hess, 2012). But there can also be tensions between development goals and climate change goals, where people may be aware of a climate related risk but are willing to take that risk (or they may have limited choice) given their current circumstances (IPCC, 2012, Section 4.2.2).

Some studies warn against the simplistic use of maladaptation to communicate the state of high exposure to risks resulting from certain type of livelihoods. For example, the periodic movement of the nomadic pastoralists following the grass and water is a traditional and effective way of dealing with climate variability (Agrawal and Perrin, 2008), but is increasingly being described by some as maladaptive. More focused studies such as Young et al. (2009) put the breakdown of traditional pastoralism in the Sudan into the wider social and political context that led to restrictions on movement, asset stripping, and escalating violence and was undermined by policies not conducive to mobility.

14.7. Research and Data Gaps

A long list of research questions could be identified and prioritized to address gaps and assist the practice of adaptation, and many of these are found in the subsequent adaptation chapters. In this chapter research priorities would range from metrics for adaptation to the psychology of communication about livelihood and life-threatening events. But, the preparation of this report has shown that the practice of adaptation has outstripped the rate at which relevant peer-reviewed research can be produced and disseminated.

Many dedicated researches have become engaged in smaller, often community-based or urban activities where results can be gathered in relatively short time frames and direct interactions between the researchers and the implementers are common. Here research and action can, and are, serving each other and these interactions can be encouraged with support for further cross-community, cross-cultural, and cross-sectoral comparisons.

Effective and timely interaction is more difficult at larger scales. National or multinational programs are often longer and complex and it is difficult to identify the “adaptation” effort within a wider set of policy objectives. Research inputs into decision making too often centers only on better projections of future conditions or *post hoc* assessments of completed projects. The task is made more difficult by relatively short-term research grants, often starting late in the process, or after the process is finished, and by the often rapid turnover of planning and implementation staff, making a close working relationship difficult. But there are models that work. Models based on established and ongoing research teams with a close link to policy such as the EC programs and its formation of targeted research teams across the European Union, CSIR in South Africa, Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the National Climate Change Research Facility (NCCARF) in Australia, the Corps of Engineers and the Regional Integrated Sciences and Assessments (RISAs) in the USA, and UKCIP and its successors in the UK do appear to be more effective in maintaining a dialog with those “on the ground,” and this shows in the number of well designed, insightful, and reviewed documents arising from these collaborations.

Unfortunately this model has not been replicated at scale in most developing countries. One might ask why is there only one reference in this volume to any lesson learned from the PPCR – a billion dollar program set up to better understand the challenges of integrating, or mainstreaming, adaptation into development planning with on the ground implementation of many larger than normal adaptation activities? The planning for the PPCR started only in 2008, but the planning process itself is of research relevance, and over the past 2 to 3 years 18 countries have been working through how to bring adaptation into their national planning programs; it is surely a core research interest and opportunity and one whose lifespan already exceeds that of many research projects. Similarly the Adaptation Fund is mentioned only descriptively in these chapters. So where were the groups of independent researchers observing from their point of view, comparing and contrasting countries, and simply conducting the process of independent and collaborative research? The benefit would flow not just from the research itself but also from the interactions with those charged with implementing adaptation and from the challenge to interpret that research so that its implications are relevant to the users, be they government officials or smallholder farmers.

There are models in developing countries. The Consultative Group on International Agricultural Research (CGIAR) network is already making contributions, albeit in the broad domain of agriculture which may be another model. The Coordinated Regional Climate Downscaling Experiment (CORDEX) project will make high-quality high-resolution climate projections available to all countries. The NEPAD Framework for African Agricultural Productivity is another, and there are numerous smaller and effective research efforts too numerous to list here, but few can claim even regional coverage. The Cancun Agreement has already raised the prospect of establishing in a developing country “an international centre to enhance adaptation research and coordination.” This may provide the vehicle to tackle some of the problems described above. The UN Agencies, the MDBs, and many bilateral agencies, which are heavy users and sometimes producers of “research,” could be major beneficiaries and supporters.

Two points in a review of a decade of experience in the RISA process in the USA stand out. One was an insistence that research team members should primarily be residents in their region of study, and to paraphrase another insight, “knowing what one ought to do is not the same as knowing how to do it” (Pulwarty et al., 2009). In arguing for the establishment of the skills to establish an Australian film industry, Phillip Adams advised the Prime Minister,⁸ “It’s time to see our own landscapes, hear our own voices and dream our own dreams.” Those words could just as well apply to tackling adaptation.

References

- Aakre, S. and D.T.G. Rübhelke, 2010: Objectives of public economic policy and the adaptation to climate change. *Journal of Environmental Planning and Management*, **53**, 767-791.
- Adaptation Fund Board, 2013: *Operational Policies and Guidelines for Parties to Access Resources from the Adaptation Fund*. The Adaptation Fund, Washington, DC, USA, 52 pp.
- Adger, W.N., 2001: Scales of governance and environmental justice for adaptation and mitigation of climate change. *Journal of International Development*, **13**(7), 921-931.
- Adger, W.N., 2003: Social capital, collective action, and adaptation to climate change. *Economic Geography*, **79**, 387-404.
- Adger, W.N., 2006: Vulnerability. *Global Environmental Change*, **16**, 268-281.
- Adger, W.N. and J. Barnett, 2009: Four reasons for concern about adaptation to climate change. *Environment and Planning A*, **41**(12), 2800-2805.
- Adger, W.N. and P.M. Kelly, 1999: Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, **4**, 253-266.
- Adger, W.N., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen, 2003a: *New Indicators of Vulnerability and Adaptive Capacity*. Technical Report No. 7, Tyndall Centre for Climate Research, School of Environmental Sciences, University of East Anglia, Norwich, UK, 128 pp.
- Adger, W.N., S. Huq, K. Brown, D. Conway, and M. Hulme, 2003b: Adaptation to climate change in the developing world. *Progress in Development Studies*, **3**(3), 179-195.
- Adger, W.N., N.W. Arnell, and E.L. Tompkins, 2005: Successful adaptation to climate change across scales. *Global Environmental Change*, **15**(2), 77-86.
- Adger, W.N., S. Agrawala, M. 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 Linden, and C.E. Hanson (eds)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 717-743.
- Adger, W.N., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. Nelson, L.-O. Naess, J. Wolf, and A. Wreford, 2009a: Are there social limits to adaptation to climate change? *Climatic Change*, **93**(3-4), 335-354.
- Adger, W.N., I. Lorenzoni, and K. O'Brien (eds.), 2009b: *Adapting to Climate Change: Thresholds, Values, Governance*. Cambridge University Press, Cambridge, UK and New York, NY, USA, 514 pp.
- Adler, C.E., D. McEvoy, P. Chhetri, and E. Kruk, 2013: The role of tourism in a changing climate for conservation and development. A problem-oriented study in the Kailash Sacred Landscape, Nepal. *Policy Sciences*, **46**, 160-178.
- Agrawal, A., 2010: Local institutions and adaptation to climate change. In: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World* [Mearns, R. and A. Norton (eds.)]. World Bank Publications, Washington, DC, USA, pp. 173-197.
- Agrawal, A. and N. Perrin, 2008: *Climate Adaptation, Local Institutions, and Rural Livelihood*. IFRI Working Paper W08I-6, International Forestry Resources and Institutions Program (IFRI), School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, USA, 17 pp.
- Agrawala, S., 2005: Putting climate change in the development mainstream: introduction and framework. In: *Bridge Over Troubled Waters: Linking Climate Change and Development* [Agrawala, S. (ed.)]. Organization for Economic Co-operation and Development (OECD), OECD Publishing, Paris, France, pp. 23-43.
- Agrawala, S. and M. Carraro, 2010: *Assessing the Role of Microfinance in Fostering Adaptation to Climate Change*. ENV/WKP(2010)1, OECD Environment Working Paper No. 15, Organization for Economic Co-operation and Development (OECD), OECD Publishing, Paris, France, 37 pp.
- Agrawala, S. and M. van Aalst, 2008: Adapting development cooperation to adapt to climate change. *Climate Policy*, **8**(2), 183-193.
- Agrawala, S., M. Carraro, N. Kingsmill, E. Lanzi, M. Mullan, and G. Prudent-Richard, 2011: *Private Sector Engagement in Adaptation to Climate Change: Approaches to Managing Climate Risks*. OECD Environment Working Paper No. 39, Organization for Economic Co-operation and Development (OECD), OECD Publishing, Paris, France, 55 pp.
- Alam, K., M. Shamsuddoha, T. Tanner, M. Sultana, M.J. Huq, and S.S. Kabir, 2011: The political economy of climate resilient development planning in Bangladesh. *IDS Bulletin*, **42**(3), 52-61.
- Alderman, H., H. Hoogeveen, and M. Rossi, 2009: Preschool nutrition and subsequent schooling attainment: longitudinal evidence from Tanzania. *Economic Development and Cultural Change*, **57**, 239-260.
- Alcamo, J., L. Acosta-Michlik, A. Carius, D. Krömker, F. Eierdanz, R. Klein, D. Kromker, and D. Tänzler, 2008: A new approach to quantifying and comparing vulnerability to drought. *Regional Environmental Change*, **8**, 137-149.
- Alexander, C., N. Bynum, E. Johnson, U. King, T. Mustonen, P. Neofotis, N. Oettle, C. Rosenzweig, C. Sakakibara, V. Shadrin, M. Vicarelli, J. Waterhouse, and B. Weeks, 2011: Linking indigenous and scientific knowledge of climate change. *BioScience*, **61**(6), 477-484.
- Alexander, N., 2010: *The Country Policy and Institutional Assessment (CPIA) and Allocation of IDA Resources: Suggestions for Improvements to Benefit African Countries*. Economic Governance Program, Heinrich Bell Foundation, Washington, DC, USA, 43 pp.
- Allison, E.H., A.L. Perry, M.-C. Badjeck, W.N. Adger, K. Brown, D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds, N.L. Andrew, and N.K. Dulvy, 2009: Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, **10**, 173-196.
- Angelovski, I. and J. Carmin, 2011: Climate action planning in Quito, Ecuador. In: *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network* [Rosenzweig, C., W.D. Solecki, S.A. Hammer, and S. Mehotra (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 262 pp.
- Anon, 2009: *Building Coast Smart Communities: How Will Maryland Adapt to Climate Change?* Consensus Building Institute and MIT-USGS Science Impact Collaborative, Cambridge, MA, USA and the Maryland Department of Natural Resources, Annapolis, MD, USA, 21 pp.
- Arnell, N.W., 2009: Adapting to climate change: an evolving research programme. *Climatic Change*, **100**(1), 107-111.
- Arnold, G., H. Bos, R. Doef, R. Goud, N. Kielen, and F. van Lujin, 2011: *Water Management in the Netherlands*. This report is a joint publication of the Ministry of Infrastructure and Environment, Directorate-General Water and Rijkswaterstaat, Centre for Water Management, The Hague, Netherlands, 80 pp.
- Atteridge, A., 2011: *Will Private Finance Support Climate Change Adaptation in Developing Countries? Historical Investment Patterns as a Window on Future Private Climate Finance*. SEI Working Paper No. 2011-5, Stockholm Environment Institute (SEI), Stockholm, Sweden, 35 pp.
- Ayers, J., 2011: Resolving the adaptation paradox: exploring the potential for deliberative adaptation policy-making in Bangladesh. *Global Environmental Politics*, **11**(1), 62-88.
- Ayers, J. and D. Dodman, 2010: Climate change adaptation and development I: the state of the debate. *Progress in Development Studies*, **10**(2), 161-168.
- Bambrick, H.J., A.G. Capon, G.B. Barnett, R.M. Beatty, and A.J. Burton, 2011: Climate change and health in the urban environment: adaptation opportunities in Australian cities. *Asia Pacific Journal of Public Health*, **23**(2), 67-79.
- Banerjee, S., J.-Y. Gerlitz, and D. Kniveton, 2013: A methodology for assessing patterns of labour migration in mountain communities exposed to water hazards. In: *Disentangling Migration and Climate Change: Methodologies, Political*

⁸ http://www.abc.net.au/dimensions/dimensions_in_time/Transcripts/t796788.htm, accessed 3rd Oct 2013.

- Discourses and Human Rights* [Faist, T. and J. Schade (eds.)]. Springer International, Heidelberg, Germany and New York, NY, USA, pp. 81-100.
- Bannayan, M.** and G. Hoogenboom, 2008: Weather analogue: a tool for real-time prediction of weather data realizations based on a modified *k*-nearest neighbor approach. *Environmental Modeling and Software*, **23(6)**, 703-713.
- Barnett, J.** and S. O'Neill, 2010: Maladaptation. *Global Environmental Change*, **20(2)**, 211-213.
- Barron, S., G. Canete, J. Carmichael, D. Flanders, E. Pond, S. Sheppard, and K. Tatebe**, 2012: A climate change adaptation planning process for low-lying, communities vulnerable to sea level rise. *Sustainability*, **4(12)**, 2176-2208.
- Bartlett, S., D. Dodman, J. Hardoy, D. Satterthwaite, and C. Tacoli**, 2009: *Social Aspects of Climate Change in Urban Areas in Low- and Middle-Income Nations*. Paper presented at the World Bank Fifth Urban Research Symposium, "Cities and Climate Change: Responding to an Urban Agenda," 28-30 June 2009, Marseilles, France, Research Cluster 5, 44 pp.
- Berkes, F.**, 2007: Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural Hazards*, **41(2)**, 283-295.
- Berkhout, F.**, 2005: Rationales for adaptation in EU climate change policies. *Climate Policy*, **5(3)**, 377-391.
- Berkhout, F., J. Hertin, and D.M. Gann**, 2006: Learning to adaptation: organizational adaptation to climate change impacts. *Climatic Change*, **78(1)**, 135-156.
- Bhutta, Z.A., T. Ahmed, R.E. Black, S. Cousens, K. Dewey, E. Giugliani, B.A. Haider, B. Kirkwood, S.S. Morris, H.P.S. Sachdev, and M. Shekar**, 2008: What works? Interventions for maternal and child undernutrition and survival. *Lancet*, **371(9610)**, 417-440.
- Biderman, C., M. Smolka, and A. Sant'Anna**, 2008: *Urban Housing Informality: Does Building and Land Use Regulation Matter?* Lincoln Institute of Land Policy, *Land Lines*, July 2008, Cambridge, MA, USA, 6 pp.
- Birkmann, J.** and K. von Teichman, 2010: Integrating disaster risk reduction and climate change adaptation: key challenges – scales, knowledge, and norms. *Sustainability Science*, **5(2)**, 171-184.
- Blanco, H., M. Alberti, A. Forsyth, K.J. Krizek, D.A. Rodriguez, E. Talen, and C. Ellis**, 2009: Hot, congested, crowded and diverse: emerging research agendas in planning. *Progress in Planning*, **71(4)**, 153-205.
- Bolte, A., C. Ammer, M. Löf, P. Madsen, G. Nabuurs, P. Schall, P. Spathelf, and J. Rock**, 2009: Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. *Scandinavian Journal of Forest Research*, **24(6)**, 473-482.
- Bosello, F., C. Carraro, and E. De Cian**, 2009: *An Analysis of Adaptation as a Response to Climate Change*. Report prepared for the Copenhagen Consensus 2009, Copenhagen Consensus Center, Copenhagen Business School, Frederiksberg, Denmark, 76 pp.
- Bouma, J.A., W. Trent, and M. Laurens**, 2011: The downstream externalities of harvesting rainwater in semi-arid watersheds: an Indian case study. *Agricultural Water Management*, **98(7)**, 1162-1170.
- Boyd, E.** and H. Osbahr, 2010: Responses to climate change: exploring organisational learning across internationally networked organisations for development. *Environmental Education Research*, **16(5-6)**, 629-643.
- Brooks, N.** and W.N. Adger, 2003: *Country Level Risk Measures of Climate-related Natural Disasters and Implications for Adaptation to Climate Change*. Tyndall Centre for Climate Research Working Paper No. 26, University of East Anglia, Norwich, UK, 25 pp.
- Brooks, N., W.N. Adger, and P.M. Kelly**, 2005: The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change Part A*, **15(2)**, 151-163.
- Brooks, N., S. Anderson, J. Ayers, I. Burton, and I. Tellam**, 2011: *Tracking Adaptation and Measuring Development*. IIED Working Paper No. 1, Climate Change Group, International Institute for Environment and Development (IIED), London, UK, 35 pp.
- Brown, A., M. Gawith, K. Lonsdale, and P. Pringle**, 2011: *Managing Adaptation: Linking Theory and Practice*. UK Climate Impacts Programme (UKCIP), School of Geography and the Environment, Oxford University Centre for the Environment (OUCE), Oxford, UK, 47 pp.
- Brown, C., Y. Ghile, M. Laverly, and K. Li**, 2012: Decision scaling: linking bottom-up vulnerability analysis with climate projections in the water sector. *Water Resources Research*, **48(9)**, W09537, doi:10.1029/2011WR011212.
- Brown, K.**, 2011: Sustainable adaptation: an oxymoron? *Climate and Development*, **3(1)**, 21-31.
- Bryan, E., T.T. Deressa, G.A. Gbetibouo, and C. Ringler**, 2009: Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science and Policy*, **12(4)**, 413-426.
- Bulkeley, H.** and M. Betsill, 2005: Rethinking sustainable cities: multilevel governance and the 'urban' politics of climate change. *Environmental Politics*, **14**, 42-63.
- Burton, I.**, 1996: The growth of adaptation capacity: practice and policy. In: *Adapting to Climate Change: An International Perspective* [Smith, J., N. Bhatti, G. Menzhulin, R. Benioff, M.I. Budyko, M. Campos, B. Jallow, and F. Rijsberman (eds.)]. Springer-Verlag, Berlin Heidelberg, Germany, pp. 55-67.
- Burton, I.**, 2004: *Climate Change and the Adaptation Deficit*. Occasional Paper 1, The Adaptation and Impacts Research Group (AIRG), Meteorological Service of Canada, Environment Canada, Toronto, ON, Canada, 6 pp.
- Burton, I.** and E. May, 2004: The adaptation deficit in water resources management. *IDS Bulletin*, **35(3)**, 31-37.
- Burton, I., S. Huq, B. Lim, O. Pilifosova, and E.L. Schipper**, 2002: From impacts assessment to adaptation priorities: the shaping of adaptation policy. *Climate Policy*, **2(2)**, 145-159.
- Burton, I., E. Diring, and J. Smith**, 2006: *Adaptation to Climate Change: International Policy Options*. The Pew Center on Global Climate Change, Arlington, VA, USA, 28 pp.
- Cardona, O.D.**, 2005. *Indicators of Disaster Risk and Risk Management: Program for Latin America and the Caribbean Summary Report*. Environment Division, Sustainable Development Department, Inter-American Development Bank, Washington, DC, USA, 43 pp.
- Carmin, J.** and D. Dodman, 2013: Engaging science and managing scientific uncertainty in urban climate adaptation planning. In: *Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly Changing World* [Moser, S.C. and M.T. Boykoff (eds.)]. Routledge, Abingdon UK and New York, NY, USA, pp. 220-234.
- Carmin, J., I. Anguelovski, and D. Roberts**, 2012: Urban climate adaptation in the global south: planning in an emerging policy domain. *Journal of Planning Education and Research*, **32(1)**, 18-32.
- Carpenter, S.R., H.A. Mooney, J. Agard, D. Capistrano, R.S. DeFries, S. Diaz, T. Dietz, A.K. Duraiappah, A. Oteng-Yeboah, H.M. Pereira, C. Perrings, W.V. Reid, J. Sarukhan, R.J. Scholes, and A. Whyte**, 2009: Science for managing ecosystem services: beyond the millennium ecosystem assessment. *Proceedings of the National Academy of Sciences of the United States of America*, **106(5)**, 1305-1312.
- Carter, T.R., M.L. Parry, H. Harawasa, and S. Nishioka**, 1994: *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*. CGER-I015-'94, Climate Change Impacts and Adaptations, Intergovernmental Panel on Climate Change, World Meteorological Organization (WMO)/United Nations Environment Programme (UNEP), Published by the Department of Geography, University College London, London, UK and the Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Japan, 59 pp.
- CCCCC**, 2011: *Developing an Implementation Plan for the CARICOM "Regional Framework for Achieving Development Resilient to Climate Change"*. Feedback report from in-country dialogues, produced by Climate Risk Management, Ltd., (Acclimatise), for the Caribbean Community Climate Change Centre (CCCCC), Acclimatise, Newark, UK, 138 pp.
- CGIAR**, 2012: *Gender and Climate Change Research in Agriculture and Food Security for Development*. Training Guide, The CGIAR Program on Climate Change, Agriculture and Food Security (CCAFFS), Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 127 pp.
- Chinowsky, P., C. Hayles, A. Schweikert, N. Strzepek, K. Strzepek, and C.A. Schlosser**, 2011: Climate change: comparative impact on developing and developed countries. *Engineering Project Organization Journal*, **1(1)**, 67-80.
- Christensen, K., S. Raihan, R. Ahsan, A.M.N. Uddin, C.S. Ahmed, and H. Wright**, 2012: *Ensuring Access for the Climate Vulnerable in Bangladesh: Financing Local Adaptation*. ActionAid Bangladesh (AAB), Action Research for Community Adaptation in Bangladesh (ARCAB), Bangladesh Centre for Advanced Studies (BCAS), and International Centre for Climate Change and Development (ICCCAD), AAB, Dhaka, Bangladesh, 126 pp.
- Chuku, C.A.**, 2009: Pursuing an integrated development and climate policy framework in Africa: options for mainstreaming. *Mitigation and Adaptation Strategies for Global Change*, **15(1)**, 41-52.
- Cipler, D., S. Fields, K. Madden, M. Khan, and J.T. Roberts**, 2012: *The Eight Unmet Promises of Fast Start Climate Finance*. IIED Briefing, International Institute for Environment and Development (IIED), London, UK, 8 pp.

- Ciscar, J.-C., A. Iglesias, L. Feyen, L. Szabó, D. Van Regemorter, B. Amelung, R. Nicholls, P. Watkiss, O.B. Christensen, and R. Dankers, 2011: Physical and economic consequences of climate change in Europe. *Proceedings of the National Academy of Sciences of the United States of America*, **108**, 2678-2683.
- Climate Investment Funds**, 2009: *The Selection of Countries to Participate in the Pilot Program for Climate Resilience (PPCR)*. Report of the Expert Group (established by the Pilot Programme on Climate Resilience Subcommittee, PPCR-SC), to the PPCR Subcommittee, Climate Investment Funds, The World Bank Group, Washington, DC, USA, 61 pp.
- Cline**, W.R., 2007: *Global Warming and Agriculture: Impact Estimates by Country*. The Center for Global Development (CGD) and the Peterson Institute for International Economics, Washington, DC, USA, 186 pp.
- Coles**, A.R. and C.A. Scott, 2009: Vulnerability and adaptation to climate change and variability in semi-arid rural southeastern Arizona, USA. *Natural Resources Forum*, **33(4)**, 297-309.
- Collins**, K. and R. Ison, 2009: Jumping off Arnstein's ladder: social learning as a new policy paradigm for climate change adaptation. *Environmental Policy and Governance*, **19(6)**, 358-373.
- Colombo**, A.F. and P.H. Byer, 2012: Adaptation, flexibility and project decision-making with climate change uncertainties. *Impact Assessment and Project Appraisal*, **30(4)**, 229-241.
- Compston**, H., 2010: The politics of climate policy: strategic options for national governments. *Political Quarterly*, **81(1)**, 107-115.
- 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.
- Conway**, G., 2009: *The Science of Climate Change in Africa: Impacts and Adaptation*. Grantham Institute for Climate Change Discussion Paper No. 1, Imperial College, London, UK, 24 pp.
- Convention on Biological Diversity**, 2009: *Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*. CBD Technical Series No. 41, Secretariat of the CBD, Montreal, QC, Canada, 126 pp.
- Corfee-Morlot**, J., I. Cochran, S. Hallegatte, and P.-J. Teasdale, 2011: Multilevel risk governance and urban adaptation policy. *Climatic Change*, **104(1)**, 169-197.
- Costello**, A., M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friedl, N. Groce, A. Johnson, M. Kett, M. Lee, C. Levy, M. Maslin, D. McCoy, B. McGuire, H. Montgomery, D. Napier, C. Pagel, J.A. Puppim de Oliveira, N. Redclift, H. Rees, D. Rogger, J. Scott, J. Stephenson, J. Twigg, J. Wolff, and C. Patterson, 2009: Managing the health effects of climate change. *Lancet*, **373**, 1693-1733.
- Costello**, A., M. Maslin, H. Montgomery, A.M. Johnson, and P. Ekins, 2011: Global health and climate change: moving from denial and catastrophic fatalism to positive action. *Philosophical Transactions of the Royal Society A*, **369(1942)**, 1866-1882.
- Crawford**, S.E.S. and E. Ostrom, 1995: A grammar of institutions. *American Political Science Review*, **89**, 582-600.
- Cutter**, S.L., C.T. Emrich, J.J. Web, and D. Morath, 2009: *Social Vulnerability to Climate Variability Hazards: A Review of the Literature*. Final Report to Oxfam America, Hazards Vulnerability Research Institute, University South Carolina, Columbia, SC, USA, 44 pp.
- Dawson**, R., 2007: Re-engineering cities: a framework for adaptation to global change. *Philosophical Transactions of the Royal Society A*, **365(1861)**, 3085-3098.
- Day**, J.W., D.F. Boesch, E.J. Clairain, G.P. Kemp, S.B. Laska, W.J. Mitsch, K. Orth, H. Mashriqui, D.J. Reed, L. Shabman, C.A. Simenstad, B.J. Streever, R.R. Twilley, C.C. Watson, J.T. Wells, and D.F. Whigham, 2007: Restoration of the Mississippi Delta: lessons from Hurricanes Katrina and Rita. *Science*, **315(5819)**, 1679-1684.
- De Bruin**, K., R.B. Dellink, A. Ruijs, L. Boldwidt, 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, 2009: Adapting to climate change in the Netherlands: an inventory of climate adaptation options and ranking of alternatives. *Climatic Change*, **95(1-2)**, 23-45.
- DEFRA**, 2012: *UK Climate Change Risk Assessment: Government Report*. Presented to Parliament pursuant to Section 56 of the Climate Change Act 2008, Department for Environment, Food and Rural Affairs (DEFRA), The Stationery Office (TSO), Norwich, UK, 43 pp.
- Deressa**, T., R. Hassan, and C. Ringler, 2009b: *Assessing Household Vulnerability to Climate Change: The Case of Farmers in the Nile Basin of Ethiopia*. IFPRI Discussion Paper 00935, International Food Policy Research Institute (IFPRI), Washington, DC, USA, 18 pp.
- Deressa**, T.T., R.M. Hassan, C. Ringler, T. Alemu, and M. Yesuf, 2009a: Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, **19(2)**, 248-255.
- Dessai**, S. and M. Hulme, 2004: Does climate adaptation policy need probabilities? *Climate Policy*, **4(2)**, 107-128.
- Dessai**, S., X. Lu, and J.S. Risbey, 2005: On the role of climate scenarios for adaptation planning. *Global Environmental Change*, **15(2)**, 87-97.
- Dilley**, M., R.S. Chen, U. Deichmann, A.L. Lerner-Lam, and M. Arnold, with J. Agwe, P. Buys, O. Kjekstad, B. Lyon, and G. Yetman, 2005: *Natural Disaster Hotspots: A Global Risk Analysis*. Disaster Risk Management Series No. 5, The International Bank for Reconstruction and Development / The World Bank and Columbia University, World Bank, Washington, DC, USA, 132 pp.
- Dolan**, A.H. and I.J. Walker, 2003: Understanding vulnerability of coastal communities to climate change related risks. *Journal of Coastal Research*, **39(S1)**, 1317-1324.
- Doria**, M.D., E. Boyd, E.L. Tompkins, and W.N. Adger, 2009: Using expert elicitation to define successful adaptation to climate change. *Environmental Science and Policy*, **12(7)**, 810-819.
- Dovers**, S.R. and A.A. Hezri, 2010: Institutions and policy processes: the means to the ends of adaptation. *Climate Change*, **1(2)**, 212-231.
- Dow**, K., F. Berkhout, B.L. Preston, R.J.T. Klein, G. Midgeley, and M.R. Shaw, 2013: Limits to adaptation. *Nature Climate Change*, **3**, 305-307.
- Dowlatabadi**, H., 2007: On integration of policies for climate change global change. *Mitigation and Adaptation Strategies for Global Change*, **12**, 651-663.
- Downing**, T., 2003: Toward a vulnerability/adaptation science: lessons from famine early warning and food security. In: *Climate Change Adaptive Capacity and Development* [Smith, J., R. Klein, and S. Huq (eds.)]. Imperial College Press, London, UK, pp. 77-100.
- Downing**, T.E., M.J. Watts, and H.G. Bohle, 1995: Climate change and food insecurity: towards a sociology and geography of vulnerability. In: *Climate Change and World Food Security* [Downing, T.E. (ed.)]. Springer, Berlin, Germany, pp. 183-206.
- Dudley**, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith, and N. Sekhran (eds.), 2010: *Natural Solutions: Protected Areas Helping People Cope with Climate Change*. The International Union for Conservation of Nature-World Commission on Protected Areas (IUCN-WCPA), the Nature Conservancy (TNC), the United Nations Development Programme (UNDP), the Wildlife Conservation Society (WCS), The World Bank, and the World Wildlife Fund (WWF), IUCN-WCPA and WWF International, Gland, Switzerland, TNC, Arlington, VA, USA, UNDP, New York, NY, USA, WCS, Bronx, NY, USA, and The World Bank, Washington, DC, USA, 126 pp.
- Eakin**, H. and M.C. Lemos, 2006: Adaptation and the state: Latin America and the challenge of capacity-building under globalization. *Global Environmental Change*, **16(1)**, 7-18.
- Eakin**, H. and A. Luers, 2006: Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources*, **31(1)**, 365-394.
- Eakin**, H., E.L. Tompkins, D.R. Nelson, and J.M. Anderies, 2012: Hidden costs and disparate uncertainties: trade-offs in approaches to climate policy. In: *Adapting to Climate Change: Thresholds, Values, Governance* [Adger, W.N., I. Lorenzoni, and K.L. O'Brien (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 212-226.
- Ebi**, K., 2011: Climate change and health risks: assessing and responding to them through "adaptive management". *Health Affairs*, **30(5)**, 924-930.
- Ebi**, K.L. and I. Burton, 2008: Identifying practical adaptation options: an approach to address climate change-related health risks. *Environmental Science and Policy*, **11(4)**, 359-369.
- ECA**, 2009: *Shaping Climate-Resilient Development: A Framework for Decision-Making*. A Report of the Economics of Climate Adaptation (ECA) Working Group, a partnership of the Climate Works Foundation, Global Environment Facility, European Commission, McKinsey and Company, The Rockefeller Foundation, Standard Chartered Bank, and Swiss Re, 159 pp.
- Edwards**, F., J. Dixon, S. Friel, G. Hall, K. Larsen, S. Lockie, B. Wood, M. Lawrence, I. Hanigan, A. Hogan, and L. Hattersley, 2011: Climate change adaptation at the intersection of food and health. *Asia Pacific Journal of Public Health*, **23(2)**, 91-104.
- Eierdanz**, F., J. Alcamo, L. Acosta-Milchlik, D. Krömker, and D. Tänzler, 2008: Using fuzzy set theory to address the uncertainty of susceptibility of drought. *Regional Environmental Change*, **8(4)**, 197-205.
- Engle**, N.L. and M.C. Lemos, 2010: Unpacking governance: building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change*, **20(1)**, 4-13.

- Eriksen, S.H. and P.M. Kelly, 2007: Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change*, **12**, 495-524.
- Eriksen, S., P. Aldunce, C.S. Bahinipati, R. D'Almeida Martins, J.I. Molefe, C. Nhemachena, K. O'Brien, F. Olorunfemi, J. Park, L. Synge, and K. Ulsrud, 2011: When not every response to climate change is a good one: identifying principles for sustainable adaptation. *Climate and Development*, **3**(1), 7-20.
- European Commission, 2009: *Adapting to Climate Change: Towards a European Framework for Action*. White Paper, Brussels 1.4.2009 COM(2009) 147 final, Publications Office of the European Union, Luxembourg, Luxembourg, 16 pp.
- Fankhauser, S. and I. Burton, 2011: Spending adaptation money wisely. *Climate Policy*, **11**(3), 1037-1049.
- FAO, 2007: *Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities*. Interdepartmental Working Group on Climate Change, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 24 pp.
- FEMA, 2010: *Hazard Mitigation Assistance Unified Guidance*. Federal Emergency Management Agency (FEMA), Department of Homeland Security, FEMA, Washington, DC, USA, 168 pp.
- Ferrara de Giner, G., M.T. Martelo, R. Lairet, A. Villamizar, and J.C. Sánchez, 2012: A proposal for community adaptive capacity on adaptation to climate change: San Pedro community, Caracas, Venezuela. In: *E-Annals from ABES-AIDIS. XXXIII Congreso Interamericano de Engenharia Sanitária e Ambiental (Associação Brasileira de Engenharia Sanitária e Ambiental)*, Theme VIII-024, pp. 1-7.
- Finzi Hart, J.A., P.M. Grifman, S.C. Moser, A. Abeles, M.R. Myers, S.C. Schlosser, and J.A. Ekstrom, 2012: *Rising to the Challenge: Results of the 2011 Coastal California Adaptation Needs Assessment*. Technical Report: USCSG-TR-01-2012, University of Southern California (USC) Sea Grant, USC, Los Angeles, CA, 76 pp.
- Ford, J.D., L. Berrang-Ford, and J. Paterson, 2011: A systematic review of observed climate change adaptation in developed nations. *Climatic Change*, **106**(2), 327-336.
- Fünfgeld, H. and D. McEvoy, 2011: *Framing Climate Change Adaptation in Policy and Practice*. VCCCAR Working Paper 1, VCCCAR Project: Framing Adaptation in the Victorian Context, Victorian Centre for Climate Change Adaptation Research (VCCCAR), Melbourne, Australia, 65 pp.
- Furlow, J., J.B. Smith, G. Anderson, W. Breed, and J. Padgham, 2011: Building resilience to climate change through development assistance: USAID's Climate Adaptation Program. *Climatic Change*, **108**(3), 411-421.
- Füssel, H.-M., 2007: Vulnerability: a generally applicable conceptual framework for climate change research. *Global Environmental Change*, **17**(2), 155-167.
- Füssel, H.-M., 2009: An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. *Climatic Change*, **97**(3-4), 469-482.
- Füssel, H.-M., 2010: How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: a comprehensive indicator-based assessment. *Global Environmental Change*, **20**(4), 597-611.
- Füssel, H.-M. and R.J.T. Klein, 2006: Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change*, **75**(3), 301-329.
- Gagnon-Lebrun, F. and S. Agrawala, 2006: *Progress on Adaptation to Climate Change in Developed Countries: An Analysis of Broad Trends*. Organisation for Economic Co-operation and Development (OECD), OECD Publishing, Paris, France, 61 pp.
- Gardiner, D., M. Anderson, R. Schlesinger, J. Fox Gorte, and D. Zeller, 2007: *Climate Risk Disclosure by the S&P 500*. David Gardiner & Associates report for Ceres and Calvert analyzing the S&P 500 CDP4 responses to the Carbon Disclosure Project information request regarding the risks and opportunities of climate change, Ceres, Boston, MA, USA, 72 pp., www.calvert.com/documents/ceres_calvert_sandp_500.pdf.
- Garg, A., R.C. Dhiman, S. Bhattacharya, and P.R. Shukla, 2009: Development, malaria and adaptation to climate change: a case study from India. *Environmental Management*, **43**(5), 779-789.
- GEF, 2002: *Note on GEF Support for National Adaptation Plans of Action (NAPA)*. GEF/C.19/Inf.7, May 8, 2002, Global Environment Facility (GEF), GEF Secretariat, Washington, DC, USA, 28 pp.
- Gething, P.W., D.L. Smith, A.P. Patil, A.J. Tatem, R.W. Snow, and S.I. Hay, 2010: Climate change and the global malaria recession. *Nature*, **465**(7296), 342-345.
- Ghimire, Y.N., G.P. Shivakoti, and S.R. Perret, 2010: Household-level vulnerability to drought in hill agriculture of Nepal: implications for adaptation planning. *International Journal of Sustainable Development and World Ecology*, **17**(3), 225-230.
- GIZ, 2011: *Making Adaptation Count: Concepts and Options for Monitoring and Evaluation of Climate Change Adaptation*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, on behalf of Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), and The World Resources Institute (WRI), GIZ, Eschborn, Germany, 92 pp.
- Glatzel, K., H. Wright, and Z. Makuch, 2012: Technology innovation and the law - the example of climate adaptation technologies. In: *Environmental and Energy Law* [Makuch, K.E. and R. Pereira (eds.)]. Wiley-Blackwell, Chichester, UK, pp. 92-116.
- Goldman, R.L., H. Tallis, P. Kareiva, and G.C. Daily, 2008: Field evidence that ecosystem service projects support biodiversity and diversify options. *Proceedings of the National Academy of Sciences of the United States of America*, **105**(27), 9445-9448.
- Goldstein, J.H., G. Caldarone, T.K. Duarte, D. Ennaanay, N. Hannahs, G. Mendoza, S. Polasky, S. Wolny, and G.C. Daily, 2012: Integrating ecosystem-service tradeoffs into land-use decisions. *Proceedings of the National Academy of Sciences of the United States of America*, **109**(19), 7565-7570.
- Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek, 2010: Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography*, **19**(6), 755-768.
- Government of Nepal, 2011: *National Framework on Local Adaptation Plan for Action (LAPA)*, Kathmandu, Nepal, 56 pp.
- Green Climate Fund, 2013a: *Governing Instrument for the Green Climate Fund*, Green Climate Fund, Interim Secretariat of the Green Climate Fund, Bonn, Germany, 16 pp., gcfund.net/fileadmin/00_customer/documents/pdf/GCF-governing_instrument-120521-block-LY.pdf.
- Green Climate Fund, 2013b: *Business Model Framework: Objectives, Results and Performance Indicators*. GCF/B.04/03, Green Climate Fund, Meeting of the Board, 26-28 June 2013, Songdo, Republic of Korea, 27 pp., www.gcfund.net/fileadmin/00_customer/documents/pdf/B-04_03_BMF_Objectives_Results_PerformanceIndicators_10Jun13.pdf.
- Grothmann, T. and A. Patt, 2005: Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Global Environmental Change*, **15**(3), 199-213.
- GTZ, 2008: *Adaptation and Refinement of the World Bank's "Country Policy and Institutional Assessment" (CPIA)*. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, on behalf of Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), and the Global Public Policy Institute (GPPI), GTZ, Eschborn, Germany, 90 pp.
- Guariguata, M., 2009: El manejo forestal en el contexto de la adaptación al cambio climático. *Revista de Estudios Sociales*, **32**, 98-112.
- Gupta, J., C. Termeer, J. Klostermann, S. Meijerink, M. van den Brink, P. Jong, S. Nootboom, and E. Bergsma, 2010: The adaptive capacity wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science and Policy*, **13**(6), 459-471.
- Haines, A., R.S. Kovats, D. Campbell-Lendrum, and C. Corvalan, 2006: Climate change and human health: impacts, vulnerability, and mitigation. *Lancet*, **367**(9528), 2101-2109.
- Hallegatte, S., 2009: Strategies to adapt to an uncertain climate change. *Global Environmental Change*, **19**(2), 240-247.
- Hallegatte, S., 2011: How economic growth and rational decisions can make disaster losses grow faster than wealth. Policy Research Working Paper 5617, Office of the Chief Economist, Sustainable Development Network, The International Bank for Reconstruction and Development / The World Bank, Washington, DC, 21 pp.
- Hamin, E.M. and N. Gurran, 2009: Urban form and climate change: balancing adaptation and mitigation in the U.S. and Australia. *Habitat International*, **33**(3), 238-245.
- Hardoy, J. and P. Romero Lankao, 2011: Latin American cities and climate change: challenges and options to mitigation and adaptation responses. *Current Opinion in Environmental Sustainability*, **3**(3), 158-163.
- Harlan, S.L. and D.M. Ruddle, 2011: Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinion in Environmental Sustainability*, **3**(3), 126-134.
- Harsdorff, M., M. Lieu-Kie-Song, and M. Tsukamoto, 2011: *Towards an ILO Approach to Climate Change Adaptation*. ILO Employment Working Paper No. 104, International Labour Organization (ILO), Geneva, Switzerland, 85 pp.
- Heffernan, O., 2012: No going back. *Nature*, **491**, 659-661.
- 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.

- Hinkel, J., 2011: Indicators of vulnerability and adaptive capacity: towards a clarification of the science-policy interface. *Global Environmental Change*, **21(1)**, 198-208.
- Hochrainer, S., R. Mechler, and G. Pflug, 2007: Climate change and weather insurance in Malawi: assessing the impact. In: *Feasibility of Risk Financing Schemes for Climate Adaptation: The Case of Malawi* [Suarez, P., J. Linnerooth-Bayer, and R. Mechler (eds.)]. International Institute for Applied Systems Analysis (IIASA) Report to the World Bank Development Economics Research Group, IIASA, Laxenburg, Austria, pp. 53-86.
- Hoddinott, J., J.A. Maluccio, J.R. Behrman, R. Flores, and R. Martorell, 2008: Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. *Lancet*, **371(9610)**, 411-416.
- Hoegh-Guldberg, O., 2011: Coral reef ecosystems and anthropogenic climate change. *Regional Environmental Change*, **11(Suppl. 1)**, 215-227.
- Hoeppe, P. and E.N. Gurenko, 2006: Scientific and economic rationales for innovative climate insurance solutions. *Climate Policy*, **6(6)**, 607-620.
- Huang, C., P. Vaneckova, X. Wang, G. Fitzgerald, Y. Gro, and S. Tong, 2011: Constraints and barriers to public health adaptation to climate change: a review of the literature. *American Journal of Preventive Medicine*, **40(2)**, 183-190.
- Hulme, M., 2009: *Why We Disagree about Climate Change: Understanding Controversy, Inaction and Opportunity*. Cambridge University Press, Cambridge, UK and New York, NY, USA, 392 pp.
- Huntjens, P., C. Pahl-Wostl, and J. Grin, 2010: Climate change adaptation in European river basins. *Regional Environmental Change*, **10(4)**, 263-284.
- Huq, S. and M.R. Khan, 2006: Equity in National Adaptation Programs of Action (NAPAs): the case of Bangladesh. In: *Fairness in Adaptation to Climate Change* [Adger, W.N., J. Paavola, S. Huq, and M.J. Mace (eds.)]. MIT Press, Cambridge, MA, USA, pp. 131-153.
- Huq, S., S. Kovats, H. Reid, and D. Satterthwaite, 2007: Editorial: reducing risks to cities from disasters and climate change. *Environment and Urbanization*, **19(1)**, 3-15.
- Hussey, K. and S. Dovers, 2006: Trajectories in Australian water policy. *Journal of Contemporary Water Research and Education*, **135(1)**, 36-60.
- IEG, 2009: *The World Bank's Country Policy and Institutional Assessment: An Evaluation*. Independent Evaluation Group (IEG), The World Bank Group, Washington, DC, USA, 142 pp.
- IFC, 2010: *Climate Risk and Financial Institutions: Challenges and Opportunities*. International Finance Corporation (IFC), Washington, DC, USA, 120 pp.
- IPCC, 2001: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 1032 pp.
- IPCC, 2007a: *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K. and A. Reisinger (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
- IPCC, 2007b: *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 Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 976 pp.
- IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* [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.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 582 pp.
- Irfanullah, H.M., 2009: Floating gardening in Bangladesh: already affected by climate variability? In: *Biodiversity Conservation and Response to Climate Variability at Community Level* [Irfanullah, H.M., R. Amin, and A. Nishat (eds.)]. International Union for Conservation of Nature (IUCN), United Nations Environment Programme (UNEP), and United Nations University (UNU), IUCN, Dhaka, Bangladesh, pp. 7-14.
- Irfanullah, H.M., 2013. Floating gardening: a local lad becoming a climate celebrity? *Clean Slate*, **88**, 26-27.
- Irfanullah, H.M., A. Adrika, A. Ghani, Z.A. Khan, and M.A. Rashid, 2011a: Introduction of floating gardening in the north-eastern wetlands of Bangladesh for nutritional security and sustainable livelihoods. *Renewable Agriculture and Flood Systems*, **23(2)**, 89-96.
- Irfanullah, H.M., M.A.K. Azad, A.K.M. Kamruzzaman, and M.A. Wahed, 2011b: Floating gardening in Bangladesh: a means to rebuild lives after devastating flood. *Indian Journal of Traditional Knowledge*, **10(1)**, 31-38.
- Jentsch, A. and C. Beierkuhnlein, 2008: Research frontiers in climate change: effects of extreme meteorological events on ecosystems. *Comptes Rendus Geoscience*, **340(9-10)**, 621-628.
- Jones, H.P., D.G. Hole, and E.S. Zavaleta, 2012: Harnessing nature to help people adapt to climate change. *Nature Climate Change*, **2**, 504-509.
- Kalame, F.B., D. Kudejira, and J. Nkem, 2011: Assessing the process and options for implementing National Adaptation Programmes of Action (NAPA): a case study from Burkina Faso. *Mitigation and Adaptation Strategies for Global Change*, **16(5)**, 535-553.
- Kasperson, J.X. and R.E. Kasperson, 2001: *Global Environmental Risk*. United National University Press, Tokyo, Japan and New York, NY, USA, 574 pp.
- Kates, R.W. and T.J. Wilbanks, 2003: Making the global local: responding to climate change concerns from the ground. *Environment*, **45(3)**, 12-23.
- Kates, R.W., W.R. Travis, and T.J. Wilbanks, 2012: Transformational adaptation when incremental adaptation climate change insufficient. *Proceedings National Academy Sciences of the United States of America*, **109(19)**, 7156-7161.
- Kaufman, R. and F.W. English, 1979: *Needs Assessment: Concept and Application*. Educational Technology Publications, Englewood Cliffs, NJ, USA, 355 pp.
- Khan, M.M.R., S.H. Miah, and H.M. Irfanullah, 2013: Small-scale silage-making technology for the extreme poor on floodplains. *International Journal of Environmental Studies*, **70(2)**, 192-202.
- Khattri, A., D. Parameshwar, and S. Pellech, 2010: *Opportunities for Private Sector Engagement in Urban Climate Change Resilience Building*. Report by Intellectual Capital Advisory Services Pvt. Ltd. (Intellicap) with the support of the Asian Cities Climate Change Resilience Network (ACCCRN) and the Rockefeller Foundation, Intellicap, Hyderabad, India and the Rockefeller Foundation, Bangkok, Thailand, 90 pp.
- Kiparsky, M., A. Milman, and S. Vicuña, 2012: Climate and water: knowledge of impacts to action on adaptation. *Annual Review of Environment and Resources*, **37(1)**, 163-194.
- Klein, R.J.T., 2010: Mainstreaming climate adaptation in development: a policy dilemma. In: *Climate Governance and Development* [Ansohn, A. and B. Pleskovic (eds.)]. Berlin Workshop Series 2010, The International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA, pp. 35-52.
- Klein, R.J.T. and A. Möhner, 2011: The political dimension of vulnerability: implications for the Green Climate Fund. *IDS Bulletin*, **42(3)**, 15-22.
- Klein, R.J.T., R.J. Nicholls, and F. Thomalla, 2003: Resilience to natural hazards: how useful is this concept? *Global Environmental Change Part B: Environmental Hazards*, **5(1-2)**, 35-45.
- Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, and F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contributions 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 Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 745-777.
- Koetse, M.J. and P. Rietveld, 2012: Adaptation to climate change in the transport sector. *Transport Reviews*, **32(3)**, 267-286.
- Kovats, S. and R. Akhtar, 2008: Climate, climate change and human health in Asian cities. *Environment and Urbanization*, **20(1)**, 165-175.
- KPMG International, 2008: *Climate Changes Your Business: KPMG's Review of the Business Risks and Economic Impacts at Sector Level*. KPMG International, Amstelveen, Netherlands, 76 pp.
- Krasny, M.E., C. Lundholm, and R. Plummer, 2010: Resilience in social-ecological systems: the roles of learning and education. *Environmental Education Research*, **16(5-6)**, 463-474.
- Kumamoto, M. and A. Mills, 2012: What African countries perceive to be adaptation priorities: results from 20 countries in the Africa Adaptation Programme. *Climate and Development*, **4(4)**, 265-274.
- Lamhauge, N., E. Lanzi, and S. Agrawala, 2011: *Monitoring and Evaluation for Adaptation: Lessons from Development Co-operation Agencies*. OECD Environment Working Paper No. 38, Organization for Economic Co-operation and Development (OECD) Publishing, Paris, France, 49 pp.
- Laukkonen, J., P.K. Blanco, J. Lenhart, M. Keiner, B. Cavric, and C. Kinuthia-Njenga, 2009: Combining climate change adaptation and mitigation measures at the local level. *Habitat International*, **33(3)**, 287-292.

- LDC Expert Group**, 2009: *The Least Developed Countries National Adaptation Programmes of Action: Overview of Preparation, Design of Implementation Strategies and Submission of Revised Project Lists and Profiles*. United Nations Framework Convention on Climate Change (UNFCCC), UNFCCC Secretariat, Bonn, Germany, 32 pp.
- LDC Expert Group**, 2012: *National Adaptation Plans: Technical Guidelines for the National Adaptation Plan Process*. LDC Expert Group, United Nations Framework Convention on Climate Change (UNFCCC), UNFCCC Secretariat, Bonn, Germany, 148 pp.
- Learmonth, G., D.E. Smith, W.H. Sherman, M.A. White, and J. Plank**, 2011: A practical approach to the complex problem of environmental sustainability: the UVa Bay Game. *The Innovation Journal*, **16**(1), 2-8.
- Lee, K.S. and E.S. Chung**, 2007: Hydrological effects of climate change, groundwater withdrawal, and land use in a small Korean watershed. *Hydrological Processes*, **21**(22), 3046-3056.
- Lempert, R.J. and M.E. Schlesinger**, 2000: Robust strategies for abating climate change. *Climatic Change*, **45**(3-4), 387-401.
- Levina, E.**, 2007: *Adaptation to Climate Change: International Agreements for Local Needs*. COM/ENV/EPOC/IEA/SLT(2007)6, Organization for Economic Co-Operation and Development (OECD) and the International Energy Agency (IEA), OECD and IEA, Paris, France, 60 pp.
- Loneragan, S., K. Gustavson, and M. Harrower**, 1999: Mapping human insecurity. In: *Environmental Change, Adaptation, and Security* [Loneragan, S.C. (ed.)]. NATO/Kluwer, Dordrecht, Netherlands, pp. 397-413.
- MacLean, D.**, 2008: *ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges*. IISD Commentary, International Institute for Sustainable Development (IISD), Winnipeg, MB, Canada, 5 pp.
- Mallawaarachchi, T. and A. Foster**, 2009: *Dealing with Irrigation Drought: The Role of Water Trading in Adapting to Water Shortages in 2007-08 in the Southern Murray-Darling Basin*. ABARE Research Report 09.6 to the Department of the Environment, Water, Heritage, and the Arts, Australian Bureau of Agriculture and Resource Economics (ABARE), Canberra, Australia, 32 pp.
- Martens, P., D. McEvoy, and C. Chang**, 2009: The climate change challenge: linking vulnerability, adaptation, and mitigation. *Current Opinion in Environmental Sustainability*, **1**(1), 14-18.
- Masofera, M., M. Bailey, and C. Kerchner**, 2007: Distribution of impacts of natural disasters across income groups: a case study of New Orleans. *Ecological Economics* **63**(2-3), 299-306
- Mawdsley, J.R., R. O'Malley, and D.S. Ojima**, 2009: A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conservation Biology*, **23**(5), 1080-1089.
- McDowell, J.Z. and J.J. Hess**, 2012: Accessing adaptation: multiple stressors on livelihoods in the Bolivian Highlands under a changing climate. *Global Environmental Change*, **22**(2), 342-352.
- McEvoy, D., S. Lindley, and J. Handley**, 2006: Adaptation and mitigation in urban areas: synergies and conflicts. *Proceedings of the Institution of Civil Engineers: Municipal Engineer*, **159**(4), 185-191.
- McGray, H., R. Bradley, A. Hammill, E.L. Schipper, and J. Parry**, 2007: *Weathering the Storm: Options for Framing Adaptation and Development*. World Resources Institute, Washington, DC, USA, 57 pp.
- McKenzie Hedger, M., R. Connell, and P. Bramwell**, 2006: Bridging the gap: empowering adaptation decision-making through the UK Climate Impacts Programme. *Climate Policy*, **6**, 201-215.
- McKenzie Hedger, M., T. Mitchell, J. Leavy, M. Greenly, A. Downie, and L. Horrocks**, 2008: *Desk Review: Evaluation of Adaptation to Climate Change from a Development Perspective*. Report commissioned by the GEF Evaluation Office (EO) and financed by DFID, as part of the GEF Evaluation Office International Conference on Evaluating Climate Change and Development (Alexandria, May 10th to 13th, 2008), Institute of Development Studies (IDS), London, UK, 60 pp.
- McKillip, J.**, 1987: *Need Analysis: Tools for the Human Services and Education*. Sage Publications, Thousand Oaks, CA, USA, 143 pp.
- McMichael, A.J. and E. Lindgren**, 2011: Climate change: present and future risks to health, and necessary responses. *Journal of Internal Medicine*, **270**(5), 401-413.
- Mechler, R., S. Hochrainer, G. Pflug, A. Lotsch, and K. Williges**, 2010: *Assessing the Financial Vulnerability to Climate-Related Natural Hazards*. World Bank Policy Research Paper No. 5232, Background Paper to the 2010 World Development Report, The International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA, 30 pp.
- Mertz, O., K. Halsnaes, J.E. Olsen, and K. Rasmussen**, 2009: Adaptation to climate change in developing countries. *Environmental Management*, **43**(5), 743-752.
- Meze-Hausken, E., A. Patt, and S. Fritz**, 2009: Reducing climate risk for micro-insurance providers in Africa: a case study of Ethiopia. *Global Environmental Change*, **19**(1), 66-73.
- Moench, M., E. Fajber, A. Dixit, E. Caspari, and A. Pokhrel**, 2009: *Catalyzing Climate and Disaster Resilience. Processes for Identifying Tangible and Economically Robust Strategies*. Final Report of the Risk to Resilience Study, Institute for Social and Environmental Transition (ISET), ISET-Nepal, Kathmandu, Nepal, 324 pp.
- Moody, P. and C. Brown**, 2012: Modeling stakeholder-defined climate risk on the Upper Great Lakes. *Water Resources Research*, **48**(10), doi:10.1029/2012WR012497.
- Mooney, H., A. Larigauderie, M. Cesario, T. Elmquist, O. Hoegh-Guldberg, S. Lavorel, G. Mace, M. Palmer, R. Scholes, and T. Yahara**, 2009: Biodiversity, climate change, and ecosystem services. *Current Opinion in Environmental Sustainability*, **1**, 46-54.
- Morecroft, M.D. and C. E. Cowan**, 2010: Responding to climate change: an essential component of sustainable development in the 21st century. *Local Economy*, **25**(3), 170-175.
- Morris, J.**, 2007: Ecological engineering in intertidal saltmarshes. *Hydrobiologia*, **192**, 161-168.
- Moser, S.C.**, 2006: *Asset-Based Approaches to Poverty Reduction in a Globalized Context: An Introduction to Asset Accumulation Policy and Summary of Workshop Findings*. Global Economy and Development Working Paper, Brookings Institution, Washington, DC, USA, 39 pp.
- Moser, S.C.**, 2009: Governance and the art of overcoming barriers to adaptation. *Magazine of the International Human Dimensions Programme on Global Environmental Change*, **3**, 31-36.
- Moser, S.C. and J.A. Ekstrom**, 2011: Taking ownership of climate change: participatory adaptation planning in two local case studies from California. *Journal of Environmental Studies and Sciences*, **1**(1), 63-74.
- Moser, S.C. and D. Satterthwaite**, 2010: Toward pro-poor adaptation to climate change in the urban centers of low- and middle-income countries. In: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World* [Mearns, R. and A. Norton (eds.)]. The International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA, pp. 231-258.
- Moss, R.H., A.L. Brenkert, and E.L. Malone**, 2001: *Vulnerability to Climate Change: A Quantitative Approach*. Technical Report PNNL-SA-33642, Prepared by the Pacific Northwest National Laboratory for the Department of Energy, Office of Scientific and Technical Information, Oak Ridge, TN, USA and U.S. Department of Commerce, Springfield, VA, USA, 70 pp.
- Moss, R.H., E.L. Malone, N.L. Engle, A. de Bremond, and A. Delgado**, 2012: *Ready or Not: Towards a Resilience Framework for Making Climate-Change Adaptation Decisions*. Report prepared for the World Bank by the Joint Global Change Research Institute.
- National Research Council**, 2011: *Adapting to the Impacts of Climate Change*. America's Climate Choices: Panel on Adapting to the Impacts of Climate Change, National Research Council, The National Academies Press, Washington, DC, USA, 292 pp.
- NCCARF**, 2012: *Climate Change Adaptation Research in Australia: An Overview of Research Funded by the National Climate Change Adaptation Research Facility*. National Climate Change Adaptation Research Facility (NCCARF), Griffith University Gold Coast, Queensland, Australia, 27 pp.
- Nelson, D.R., W.N. Adger, and K. Brown**, 2007: Adaptation to environmental change: contributions of a resilience framework. *Annual Review of Environment and Resources*, **32**, 395-419.
- Nicholls, N., C.D. Butler, and I. Hanigan**, 2006: Inter-annual rainfall variations and suicide in New South Wales, Australia, 1964-2001. *International Journal of Biometeorology*, **50**(3), 139-143.
- Niemeyer, S., J. Petts, and K. Hobson**, 2005: Rapid climate change and society: assessing responses and thresholds. *Risk Analysis*, **25**(6), 1443-1456.
- O'Brien, K.L.**, 2012: Global environmental change II: from adaptation to deliberate transformation. *Progress in Human Geography*, **36**(5), 667-676.
- O'Brien, K.L., S. Eriksen, L.P. Nygaard, and A. Schjolden**, 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, **7**(1), 73-88.
- O'Neill, M.S. and K.L. Ebi**, 2009: Temperature extremes and health: impacts of climate variability and change in the United States. *Journal of Occupational and Environmental Medicine*, **51**(1), 13-25.

- OECD, 2009: *Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance*. Organization for Economic Co-operation and Development (OECD), OECD Publishing, Paris, France, 193 pp.
- OECD, 2011: *Financing Climate Change Action and Boosting Technology Change: Key Messages and Recommendations from Current OECD Work*. Organisation for Economic Co-operation and Development (OECD), OECD Publishing, Paris, France, 15 pp.
- Ogden, A.E. and J. L. Innes, 2009: Adapting to climate change in the southwest Yukon: locally identified research and monitoring needs to support decision making on sustainable forest management. *Arctic*, **62(2)**, 159-174.
- Ormerod, S.J., M. Dobson, A.G. Hildrew, and C.R. Townsend, 2010: Multiple stressors in freshwater ecosystems. *Freshwater Biology*, **55(Suppl. 1)**, 1-4.
- Osman-Elasha, B., N. Goutbi, E. Spanger-Siegrfried, B. Dougherty, A. Hanafi, S. Zakielden, E-A. Sanjak, H.A. Atti, and H.M. Elhassan, 2009: Community development and coping with drought in rural Sudan. In: *Climate Change and Adaptation* [Leary, N., J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, and R. Lasco (eds.)]. Earthscan, London, UK, pp. 90-108.
- Paavola, J., 2008: Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy*, **11(7)**, 642-654.
- Pant, L.P. and R. Heeks, 2011: *ICT-Enabled Development of Capacity for Climate Change Adaptation Centre for Development Informatics Institute for Development Policy and Management*. Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK, 26 pp.
- Park, S.E., N.A. Marshall, E. Jakku, A.M. Dowd, S.M. Howden, E. Mendham, and A. Fleming, 2012: Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change*, **22(1)**, 115-126.
- Parry, M. and T. Carter, 1998: *Climate Impact and Adaptation Assessment: A Guide to the IPCC Approach*. Earthscan, London, UK, 166 pp.
- Parry, M., N. Arnell, P. Berry, D. Dodman, S. Fankhauser, C. Hope, S. Kovats, R. Nicholls, D. Satterthwaite, R. Tiffin, and T. 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 (IIED) and Grantham Institute for Climate Change, London, UK, 113 pp.
- Patz, J.A., S.H. Olson, C.K. Uejio, and H.K. Gibbs, 2008: Disease emergence from global climate and land use change. *Medical Clinics of North America*, **92(6)**, 1473-1491.
- Pelling, M., 2010: *Adaptation to Climate Change: From Resilience to Transformation*. Routledge, Abingdon, UK and New York, NY, USA, 224 pp.
- Perch-Nielsen, S., 2010: The vulnerability of beach tourism to climate change - an index approach. *Climatic Change*, **100(3-4)**, 579-606.
- Perkins, W., D., Ojima, and R., Corell, 2007: A survey of climate change adaptation planning. The Heinz Center, Washington, DC, USA, 52 pp.
- Persson, A., R.J.T Klein, C.K. Siebert, A. Atteridge, B. Mueller, J. Hoffmaister, M. Lazarus, and T. Takama, 2009: *Adaptation Finance under a Copenhagen Agreed Outcome*. Stockholm Environment Institute (SEI), Stockholm, Sweden, 187 pp.
- Peskett, L., N. Grist, M. Hedger, T. Lennartz-Walker, and I. Scholz, 2009: *Climate Change Challenges for EU Development Co-operation: Emerging Issues*. European Development Co-operation to 2020 Working Paper No. 3, European Association of Development Research and Training Institutes (EADI), Bonn, Germany, 23 pp.
- Pittock, J., 2011: National climate change policies and sustainable water management: conflicts and synergies. *Ecology and Society*, **16(2)**, 25, www.ecologyandsociety.org/vol16/iss2/art25/.
- Polsky, C., R. Neff, and B. Yarnal, 2007: Building comparable global change vulnerability assessments: the vulnerability scoping diagram. *Global Environmental Change*, **17(3-4)**, 472-485.
- Porio, E., 2011: Vulnerability, adaptation, and resilience to floods and climate change-related risks among marginal, riverine communities in Metro Manila. *Asian Journal of Social Science*, **39(4)**, 425-445.
- Porter, M.G., 2013: *A Tale of Two Cities: Desalination and Drought in Perth and Melbourne*. A report prepared for NCEDA under: 'Desalination for Australian Economic Development,' National Centre of Excellence in Desalination Australia (NCEDA), Alfred Deakin Research Institute, Deakin University, Melbourne, Australia, 43 pp.
- Pouliotte, J., B. Smit, and L. Westerhoff, 2009: Adaptation and development: livelihoods and climate change in Subarnabad, Bangladesh. *Climate and Development*, **1(1)**, 31-46.
- Prabhakar, S.V.R.K. and A. Srinivasan, 2011: Metrics for mainstreaming adaptation in agriculture sector. *Climate Change and Food Security in South Asia*, **8**, 551-567.
- Pramova E., B. Locatelli, M. Brockhaus, and S. Fohlmeister, 2012: Ecosystem services in the National Adaptation Programmes of Action. *Climate Policy*, **12(4)**, 393-409.
- Preston, B. and M. Stafford-Smith, 2009: *Framing Vulnerability and Adaptive Capacity Assessment: Discussion Paper*. CSIRO Climate Adaptation National Research Flagship Working Paper No. 2, CSIRO Marine and Atmospheric Research, Aspendale, Victoria, Australia, 52 pp.
- Preston, B.L., R.M. Westaway, S. Dessai, and T. Smith, 2009: *Are We Adapting to Climate Change? Research and Methods for Evaluating Progress*. In: 89th American Meteorological Society Annual Meeting: Fourth Symposium on Policy and Socio-Economic Research, Phoenix, AZ, 15 pp.
- Preston, B.L., R.M. Westaway, and E.J. Yuen, 2011a: 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.
- Preston, B.L., E.J. Yuan, and R.M. Westaway, 2011b: Putting vulnerability to climate change on the map: a review of approaches, benefits and risks. *Sustainability Science*, **6**, 177-202.
- Pulwarty, R.S., C. Simpson, and C.R. Nierenberg, 2009: The Regional Integrated Sciences and Assessments (RISA) Program: Crafting effective assessments for the long haul. In: *Integrated Regional Assessment of Global Climate Change* [Knight, C.G. and J. Jäger (eds.)]. Cambridge University Press, Cambridge, UK, pp. 367-393.
- Ranger, N. and S.-L. Garbett-Shiels, 2012: Accounting for a changing and uncertain climate in planning and policymaking today: lessons for developing countries. *Climate and Development*, **4(4)**, 288-300.
- Reid, H. and S. Huq, 2005: Climate change- biodiversity and livelihood impacts. In: *Tropical Forests and Adaptation to Climate Change: In Search of Synergies* [Robledo, C., M. Kanninen, and L. Pedroni (eds.)]. Center for International Forestry Research, Bogor Barat, Indonesia, pp. 57-70.
- Repetto, R., 2008: *The Climate Crisis and the Adaptation Myth*. Yale School of Forestry and Environmental Studies Working Paper 13, Yale School of Forestry and Environmental Studies, New Haven, CT, USA, 21 pp.
- Reser, J.P. and J.K. Swim, 2011: Adapting to and coping with the threat and impacts of climate change. *American Psychologist*, **66(4)**, 277-289.
- Reser, J.P., G. Bradley, and M. Ellul, 2012: Coping with climate change: bringing psychological adaptation in from the cold. In: *Handbook of the Psychology of Coping: New Research* [Molinelli B. and V. Grimaldo (eds.)]. Nova Science Publishers, Hauppauge, NY, USA, pp. 1-34.
- Revi, A., 2008: Climate change risk: an adaptation and mitigation agenda for Indian cities. *Environment and Urbanization*, **20(1)**, 207-229.
- Reyer, C., M. Guericke, and P.L. Ibsch, 2009: Climate change mitigation via afforestation, reforestation and deforestation avoidance: and what about adaptation to environmental change? *New Forests*, **38(1)**, 15-34.
- Ribot, J., 2010: Vulnerability does not fall from the sky: toward multiscale, pro-poor climate policy. In: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World* [Mearns, R. and A. Norton (eds.)]. The International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA, pp. 47-74.
- Roberts, D., 2008: Thinking globally, acting locally – institutionalizing climate change at the local government level in Durban, South Africa. *Environment and Urbanization*, **20(2)**, 521-537.
- Roberts, D., 2010: Prioritizing climate change adaptation and local level resilience in Durban, South Africa. *Environment and Urbanization*, **22(2)**, 397-413.
- Rosenzweig, C., W. Solecki, S.A. Hammer, and S. Mehrotra, 2010: Cities lead the way in climate-change action. *Nature*, **467**, 909-911.
- Rosenzweig, C., W.D. Solecki, R. Blake, M. Bowman, C. Faris, V. Gornitz, R. Horton, K. Jacob, A. LeBlanc, R. Leichenko, M. Linkin, D. Major, M. O'Grady, L. Patrick, E. Sussman, G. Yohe, and R. Zimmerman, 2011: Developing coastal adaptation to climate change in the New York City infrastructure-shed: process, approach, tools, and strategies. *Climatic Change*, **106(1)**, 93-127.
- Rygel, L., D. O'Sullivan, and B. Yarnal, 2006: A method for constructing a social vulnerability index: an application to hurricane storm surges in a developed country. *Mitigation and Adaptation Strategies for Global Change*, **11**, 741-764.
- Satterthwaite, D. and D. Dodman, 2009: The costs of adapting infrastructure to climate change. In: *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates* [Parry, M., N. Arnell, P. Berry, D. Dodman, S. Fankhauser, C. Hope, S. Kovats, R. Nicholls, D. Satterthwaite, R. Tiffin, and T. Wheeler (eds.)]. International Institute for Environment and

- Development (IIED) and the Grantham Institute for Climate Change, IIED, London, UK, pp. 73-89.
- Satterthwaite, D., S. Huq, H. Reid, M. Pelling, and P. Romero Lankao, 2009:** Adapting to climate change in urban areas: the possibilities and constraints in low- and middle-income nations. In: *Adapting Cities to Climate Change* [Bicknell, J., D. Dodman, and D. Satterthwaite (eds.)]. Earthscan, London, UK, pp. 3-47.
- Scheraga, J.D., K.L. Ebi, J. Furlow, and A.R. Moreno, 2003:** From science to policy: developing responses to climate change. In: *Climate Change and Human Health: Risks and Responses* [McMichael, A.J., D. Lendrum, C.F. Corvalan, K.L. Ebi, A. Githeko, and J.D. Scheraga (eds.)]. World Health Organization (WHO), World Meteorological Organization (WMO), United Nations Environment Programme (UNEP), World Health Organization, Geneva, Switzerland, pp. 237-266.
- Schipper, L., 2009:** Meeting the crossroads? Exploring the linkages between climate change adaptation and disaster risk reduction. *Climate and Development*, **1**(1), 16-30.
- Schröter, D., C. Polsky, and A. Patt, 2005:** Assessing vulnerabilities to the effects of global change: an eight step approach. *Mitigation and Adaptation Strategies for Global Change*, **10**(4), 573-595.
- Semenov, M.A., 2006:** Using weather generators in crop modeling. *Acta Horticulturae*, **707**, 93-100.
- Semenov, M.A., 2008:** Simulation of extreme weather events by a stochastic weather generator. *Climate Research*, **35**(3), 203-212.
- Semenza, J.C., S. Herbst, A. Rechenburg, J.E. Suk, C. Hoser, C. Schreiber, and T. Kistemann, 2012:** Climate change impact assessment of food- and waterborne diseases. *Critical Reviews in Environmental Science and Technology*, **42**(8), 857-890.
- Shikanga, O-T., D. Mutonga, M. Abade, S. Amwayi, M. Ope, H. Limo, E.D. Mintz, R.E. Quick, R.F. Breiman, and D.R. Feikin, 2009:** High mortality in cholera outbreak in western Kenya after post-election violence in 2008. *The American Journal of Tropical Medicine and Hygiene*, **81**(6), 1085-1090.
- Sietz, D., M. Boschütz, and R.J.T. Klein, 2011a:** Mainstreaming climate adaptation into development assistance: rationale, institutional barriers and opportunities in Mozambique. *Environmental Science and Policy*, **14**(4), 493-502.
- Sietz, D., M.K.B. Lüdeke, and C. Walther, 2011b:** Categorisation of typical vulnerability patterns in global drylands. *Global Environmental Change*, **21**(2), 431-440.
- Skoufias, E. (ed.), 2012:** *The Poverty and Welfare Impacts of Climate Change: Quantifying the Effects, Identifying the Adaptation Strategies*. World Bank Publications, Washington, DC, USA, 184 pp.
- Smit, B. and O. Pilifosova, 2003:** From adaptation to adaptive capacity and vulnerability reduction. In: *Climate Change, Adaptive Capacity and Development* [Smith, J.B., R.J.T. Klein, and S. Huq (eds.)]. Imperial College Press, London, UK, pp. 9-28.
- Smit, B. and J. Wandel, 2006:** Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, **16**(3), 282-292.
- Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R.J.T. Klein, and G. Yohe, 2001:** Adaptation to climate change in the context of sustainable development and equity. In: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 877-912.
- Smith, J.B., J.M. Vogel, and J.E. Cromwell III, 2009:** An architecture for government action on adaptation to climate change. *Climatic Change*, **95** (1-2), 53-61.
- Sovacool, B.K., 2011:** Hard and soft paths for climate change adaptation. *Climate Policy*, **11**(4), 1177-1183.
- Sovacool, B.K., A.L. D'Agostino, H. Meenawat, and A. Rawlani, 2012:** Expert views of climate change adaptation in least developed Asia. *Journal of Environmental Management*, **97**, 78-88.
- Sowers, J., A. Vengosh, and E. Weinthal, 2011:** Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change*, **104**(3-4), 599-627.
- Srinivasan, A. and S.V.R.K. Prabhakar, 2009:** *Measures of Adaptation to Climatic Change and Variability (Adaptation Metrics)*. Final Report to the World Bank, Contract No. 7145543, Institute for Global Environmental Strategies (IGES) Research Report, IGES, Hayama, Japan and The World Bank, Washington, DC, USA, 108 pp., <http://pub.iges.or.jp/modules/envirolib/view.php?docid=2940>.
- Stafford Smith, M., L. Horrocks, A. Harvey, and C. Hamilton, 2010:** Rethinking adaptation for a 4°C world. *Philosophical Transactions of the Royal Society A*, **369**(1934), 196-216.
- Stern, N., 2006:** *The Economics of Climate Change*. Cambridge University Press, Cambridge, UK, 712 pp.
- Stokes, C. and M. Howden, 2010:** *Adapting Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for the Future*. CSIRO Publishing, Canberra, Australia, 296 pp.
- Suarez, P., F. Ching, G. Ziervogel, I. Lemaire, D. Turnquest, J. Mendler de Suarez, and B. Wisner, 2009:** Video-mediated approaches for community-level climate adaptation. *IDS Bulletin*, **39**(4), 96-104.
- Swart, R. and F. Raes, 2007:** Making integration of adaptation and mitigation work mainstreaming into sustainable development policies? *Climate Policy*, **7**, 288-303.
- Tengö, M. and K. Belfrage, 2004:** Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania. *Ecology and Society*, **9**(3), 4, www.ecologyandsociety.org/vol9/iss3/art4/.
- The Climate Institute, 2011:** *A Climate of Suffering: The Real Cost of Living with Inaction on Climate Change*. The Climate Institute, Melbourne and Sydney, Australia, 28 pp.
- Thomsen, D.C., T.F. Smith, and N. Keys, 2012:** Adaptation or manipulation? Unpacking climate change response strategies. *Ecology and Society*, **17**(3), 20, www.ecologyandsociety.org/vol17/iss3/art20/.
- Tol, R.S.J., T.E. Downing, O.J. Kuik, and J.B. Smith, 2004:** Distributional aspects of climate change impacts. *Global Environmental Change*, **14**(3), 259-272.
- Tonnang, H.E.Z., R.Y.M. Kangelawe, and P.Z. Yanda, 2010:** Predicting and mapping malaria under climate change scenarios: the potential redistribution of malaria vectors in Africa. *Malaria Journal*, **9**, 111-120.
- 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**(4), 627-635.
- Turner, W.R., B.A. Bradley, L.D. Estes, D.G. Hole, M. Oppenheimer, and D.S. Wilcove, 2010:** Climate change: helping nature survive the human response. *Conservation Letters*, **3**(5), 304-312.
- UKCIP, 2011:** *Making Progress: UKCIP & Adaptation in the UK*. UK Climate Impacts Programme (UKCIP), School of Geography and the Environment, at the University of Oxford, Oxford, UK, 99 pp.
- UNDP, 2004:** *Reducing Disaster Risk: A Challenge for Development*. United Nations Development Programme (UNDP), Bureau for Crisis Prevention and Recovery, New York, NY, USA, 146 pp.
- UNDP, 2005:** *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge University Press, New York, NY, USA, 258 pp.
- UNDP, 2008:** *Human Development Report 2007/8. Fighting Climate Change: Human Solidarity in a Divided World*. United Nations Development Programme (UNDP), Palgrave Macmillan, Houndmills, Basingstoke, Hampshire, UK and New York, NY, USA, 384 pp.
- UNDP, 2010:** *Gender, Climate Change and Community-Based Adaptation*. A Guidebook for Designing and Implementing Gender-Sensitive Community-Based Adaptation Programmes and Projects, United Nations Development Programme (UNDP), New York, NY, USA, 69 pp.
- UNFCCC, 2006:** *Technologies for Adaptation to Climate Change*. The United Nations Framework Convention on Climate Change (UNFCCC), UNFCCC Secretariat, Bonn, Germany, 38 pp.
- UNFCCC, 2007:** *Investment and Financial Flows to Address Climate Change*. The United Nations Framework Convention on Climate Change (UNFCCC), UNFCCC Secretariat, Bonn, Germany, 272 pp.
- UNFCCC, 2010:** *Synthesis Report on Efforts Undertaken to Assess the Costs and Benefit of Adaptation Options, and Views on Lessons Learned, Good Practices, Gaps and Needs*. UNFCCC Secretariat, Bonn, Germany, 13 pp.
- UNFCCC, 2011:** *Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches*. The Nairobi Work Programme and United Nations Framework Convention on Climate Change (UNFCCC), UNFCCC Secretariat, Bonn, Germany, 48 pp.
- 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 Aalst, M.K., T. Cannon, and I. Burton, 2008:** Community level adaptation to climate change: the potential role of participatory risk assessment. *Global Environmental Change*, **18**(1), 165-179.

- Verner, D.**, 2012: Gender-responsive climate change adaptation: ensuring effectiveness and sustainability. In: *Adaptation to a Changing Climate in the Arab Countries: A Case for Adaptation Governance and Leadership in Building Climate Resilience* [Verner, D. (ed.)]. The International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA, pp. 277-308.
- Villamizar, A.**, 2011: Adaptación al Cambio Climático y políticas públicas: una deuda de alto riesgo para América Latina? *Mundo Nuevo*, **1(6)**, 301-338.
- Webb, R.** and J. Beh, 2013: *Leading Adaptation Practices and Support Strategies for Australia: An International and Australian Review of Products and Tools*. Synthesis and Integrative Research: Final Report, National Climate Change Adaptation Research Facility (NCCARF) and Australian National University, NCCARF, Griffith University Gold Coast Campus, Southport, Australia, 105 pp.
- West, J.M.** and D. Brereton, 2013: *Climate Change Adaptation in Industry and Business*. Synthesis and Integrative Research Final Report, National Climate Change Adaptation Research Facility (NCCARF), Griffith University Gold Coast Campus, Southport, Australia, 144 pp.
- Westerhoff, L.**, E.C.H. Keskkitalo, and S. Juhola, 2011: Capacities across scales: local to national adaptation policy in four European countries. *Climate Policy*, **11(4)**, 1071-1085.
- Wheeler, D.**, 2011: *Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance*. CGD Working Paper 240, Center for Global Development (CGD), Washington, DC, USA, 49 pp.
- Wolf, J.**, W.N. Adger, I. Lorenzoni, V. Abrahamson, and R. Raine, 2010: Social capital, individual responses to heat waves and climate change adaptation: an empirical study of two UK cities. *Global Environmental Change*, **20(1)**, 44-52.
- World Bank**, 2008: *The Pilot Program for Climate Resilience under the Strategic Climate Fund*. CTF-SCF/7 November 10, 2008, The World Bank, Washington, DC, USA, 7 pp.
- World Bank**, 2010: *World Development Report 2010: Development in a Changing Climate – Concept Note*. The International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA, 43 pp.
- World Economic Forum**, 2002: *2002 Environmental Sustainability Index*. An Initiative of the Global Leaders for Tomorrow Environment Task Force, World Economic Forum (WEF), Annual Meeting 2002, in collaboration with Yale Center for Environmental Law and Policy (YCELP), Yale University and Center for International Earth Science Information Network (CIESIN), Columbia University, YCELP, New Haven, CT, USA, 297 pp.
- World Economic Forum**, 2012: *Global Risks 2012*. 7th edn., An initiative of the Risk Response Network, World Economic Forum (WEF), Geneva, Switzerland, 62 pp.
- WRI**, 2009: *Bellagio Framework for Adaptation Assessment and Prioritization*. WRI Working Paper, World Resources Institute (WRI), Washington, DC, USA, 6 pp.
- Wu, Q.**, G. Cheng, W. Ma, and Y. Liu, 2008: Railway construction techniques adapting to climate warming in permafrost regions. *Advances in Climate Change Research*, **4**, 60-66.
- Yohe, G.** and R.S.J. Tol, 2001: Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity. *Global Environmental Change*, **12(1)**, 25-40.
- Young, H.**, A.M. Osman, A.M. Abusin, M. Asher, and O. Egemi, 2009: *Livelihoods, Power and Choice: The Vulnerability of the Northern Rizaygat, Darfur, Sudan*. Feinstein International Center, Tufts University, Medford, MA, USA, 115 pp.
- Ziervogel, G.** and A. Taylor, 2008: Feeling stressed: integrating climate adaptation with other priorities in South Africa. *Environment*, **50(2)**, 32-41.