Chapter 14. Adaptation Needs and Options

Coordinating Lead Authors
Saleemul Huq (Bangladesh), Ian Noble (Australia)

Lead Authors
Yury Anokhin (Russian Federation), JoAnn Carmin (USA), Dieudonne Goudou (Niger), Felino Lansigan (Philippines), Balgis Osman-Elasha (Sudan), Alicia Villamizar (Venezuela)

Contributing Authors
Frans Berkhout (Netherlands), Kirsten Dow (USA), Hans-Martin Füssel (Germany)

Review Editors
Anthony Patt (Austria), Kuniyoshi Takeuchi (Japan)

Volunteer Chapter Scientist
Eric Chu (USA)

Contents

Executive Summary

The most commonly used definitions of adaptation remain based on the IPCC AR3 definition ("adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"), but with some important elaborations being proposed. The IPCC SREX modified the definition and included an element of purposefulness in human adaptation actions (i.e. "in order to moderate..."). Others have sought to place adaptation into a wider context of interacting non-climatic changes and to include adaptation actions that may not succeed in moderating harm. Increasing focus on the costs of adaptation and on evaluating adaptation practices has led to more attention to what constitutes successful adaptation. Some definitions of success emphasize reducing risks to a predetermined level while other focus on achieving predetermined levels of social and or economic well being. [14.2.1]

Since AR4 the framing of adaptation has moved further from a focus on biophysical vulnerability to the wider social and economic drivers of vulnerability. [14.2.1.1] These include the gender, age, health, social status and ethnicity of individuals and groups and the political system in place within a region and country. [14.2.1.1.2, 14.2.1.1.3]

Adaptation activity is increasing and becoming more integrated within wider policy frameworks. Integration streamlines the planning and decision making process and embeds climate sensitive thinking in existing institutions and organizations. Integration helps avoid mismatches with development planning, facilitates the blending of multiple funding streams and reduces the possibility of maladaptive actions. There are many synergies between adaptation and disaster risk reduction and step are being taken to achieve better integration. [14.2.2] However, barriers remain arising from different terminologies, areas of focus and pre-existing institutional structures. [14.2.2.3]

Experience in adaptation practice is increasing rapidly, which serves to clarify the most significant barriers and opportunities for adaptation. Most governments, developed and developing, are seeking to integrate adaptation planning and implementation within wider national and sectoral planning. More local and community based efforts are still challenged by the need to scale up effective practices. [14.2.2.4] Access to finance and the means of access remain impediments to greater action. [14.2.3.3, 14.3.1.4]

Most of the assessments done so far have been restricted to impacts, vulnerability and adaptation planning. Very few assessments have yet been done on the processes of implementation and evaluation of actual adaptation actions. [14.5]

Evaluation of adaptation effectiveness is still in its infancy. Experience in selecting metrics to identify adaptation needs and to measure effectiveness is increasing. [14.6.3, 14.6.4] But the search for metrics for adaptation will remain contentious with multiple alternatives competing for attention as institutions, communities and individuals value needs and outcomes differently and many of those values cannot be captured in a comparable way by metrics. [14.6.2]

14.1. Introduction

Adaptation entails preparing for the impacts of climate change. As such, it is relevant to national, regional, and local governments as well as to the private and nonprofit sectors. Failure to adapt in a timely manner to anticipated climate change will increase the likelihood of human suffering and economic losses and may undermine the ecosystem and societal services upon which we all depend.

Adaptation has a long history, but one where practice is outpacing policy and, while adaptation related research is growing, it has not yet been able to deliver strong frameworks and guidance. In this chapter, we review overarching issues related to adaptation, with an emphasis on key considerations, actors, and processes that have been understood about adaptation efforts. This chapter establishes a foundation for understanding adaptation, and, at the same time, provides a basis for successive chapters in this section to explore adaptation in greater depth. In order to frame these discussions, it is important to clarify what is meant by needs and options and to review how these concepts fit with other terms and views advanced across the adaptation chapters. In this discussion, needs refers to risks posed to valued attributes that exceed acceptable and desired levels. These needs typically should be identified through assessment processes. Options are the array of strategies used to address the needs that have been identified. There is a broad array of needs that emerge from assessments as well as a plethora of options that can be advanced. Rather than delve into and chronicle specifics, which would result in a massive catalog, we review fundamental aspects and cross-cutting issues shaping needs and map out the broad categories under which options are situated.

14.1.1. Summary of Key Findings from AR4

The Fourth Assessment Report (AR4) defined 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 poses novel risks often outside the range of experience.

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. These adaptation measures 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 heatwaves and cyclones often embedded within broader sectoral initiatives such as water resource planning, coastal defence and disaster management planning.

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. But, high adaptive capacity does not necessarily translate into actions that reduce vulnerability.

New planning processes were being implemented to attempt to overcome these barriers at local, regional and national levels in both developing and developed countries. 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 AR4 relating the implementation of adaptation policies and measures, barriers to adaptation and the economic costs of adaptation are summarized in Chapters 15, 16 and 17.

14.1.2. Structure of the Chapter and its Relationship with Other Chapters

As stated in the introductory section, this chapter serves as an entry to the following three chapters, which deal with the planning and implementation of adaptation (Chapter 15); the opportunities and constraints to adaptation (Chapter 16); and the economic costs and benefits of adaptation (Chapter 17). It revisits the core definitions and concepts of adaptation and maladaptation. It discusses the factors determining vulnerability to climate change in relation other stressors and societal trends and examines the need for adaptation across all sectors of society and in all parts of the world. It then outlines the options that exist to address adaptation needs. An ongoing theme throughout the chapter is the concept of mainstreaming or the integration of adaptation to climate change with other areas of government action and responsibility. This chapter also serves to set the basis of some important tools in 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.

14.2. Foundations of Adaptation

14.2.1. Understanding Adaptation

Given historical and current levels of emissions stemming from human activities, it is expected that the climate will continue to change (IPCC, 2007a; Stott *et al.*, 2010). These changes are predicted to be accompanied by greater variability in temperatures, precipitation, and extreme weather events that, in turn, will impact a wide range of critical functions and areas, including food production, water availability and quality, coastal and marine systems, disease vectors, and housing and building stability (IPCC, 2007b; Füssel, 2009). Given that these changes will affect

the functions and well-being of natural systems, human societies, and the built environment, it is essential for countries and subnational areas to be prepared by taking action to adapt (IPCC, 2007b).

Climate adaptation is defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007b: 869). While this definition is widely accepted[1], there is still a great deal of variability in views about the objectives of adaptation. As a result, our understanding of what constitutes successful adaptation span from maintaining present levels of risk, to reducing current risks, to minimizing the exposure of vulnerable populations (Doria *et al*., 2009). Based on Delphi methodology, Doria *et al*., (2009) were able to identify shared views of adaptation. Their findings suggest that it is generally regarded as any type of adjustment that reduces climate risks or vulnerability to climate impacts to levels set by affected actors or decision makers and that promotes efforts to achieve economic, social, and environmental sustainability (Doria, *et al*., 2009).

[FOOTNOTE 1: In the SREX (IPCC 2012) the definition was altered to "In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate." This is essentially the same, but with the addition of purposefulness ("in order to") of adaptation in human versus natural systems in the SREX.]

In this chapter, adaptation needs are defined as risks and other circumstances requiring action to ensure safety of populations and security of assets in response to climate impacts. Given this perspective, adaptation options are the array of strategies and measures available and appropriate to a given context for addressing adaptation needs that have been identified. Adaptation engages people, organizations, and governments at all levels in meeting goals ranging from continuing current activities to assuring acceptable levels of risk and sustainable development. From the perspective of those pursuing adaptation, the existence of adaptation options does not necessarily mean that these options can be implemented when the need arises. As elaborated in Chapter 15, opportunities, or those sets of circumstances that make successful adaptation possible or easier to achieve, may be missed. In addition, there often are socio-economic or biophysical constraints that restrict the number of adaptation options make them more difficult to implement as well as limits that make it impossible for an actor to achieve some adaptation objectives. Some of these limits are mutable and can be overcome eventually, while others are absolute and cannot be changed.

14.2.1.1. Perspectives on Vulnerabilities

The approach to adaptation needs and options adopted in this chapter reflects the emphasis most definitions of adaptation place on reducing vulnerability or the potential to be harmed. According to AR4 (IPCC, 2007a), vulnerability is the degree to which a system is "susceptible to, and unable to cope with, adverse effects of climate change." The concept of vulnerability traditionally is viewed as being comprised of three elements: exposure, sensitivity and adaptive capacity (IPCC, 2007a). In other words, the stress faced by a system or individual, the extent to which the system will be affected, and the degree to which the system is able to cope with or respond to these stresses (Cutter, 1996; Cutter *et al*., 2003; O'Brien *et al*., 2004; Adger, 2006). From an adaptation standpoint, this concept is used to explicate contextual factors associated with exposure (Leichenko and O'Brien, 2008). For instance, vulnerability at the national and sub-national levels is affected by geographic location, biophysical conditions, institutional and governance arrangements, and resource availability, including access to technology and economic stability. At the individual level it is shaped by personal characteristics such as gender and health as well as by social status and networks (Ionescu *et al.,* 2009). At the same time, vulnerability is used to identify and understand the ability of different systems and groups to cope with climate impacts (Leichenko and O'Brien, 2008).

Multiple sources of stress, some from climate impacts and some from other sources, combine to increase vulnerability. For instance, existing coastal erosion, deforestation and habitat fragmentation become even more serious problems when coupled with the projected impacts of climate change (Ayache *et al*.2009; Werner and Simmons, 2009; Sánchez-Arcilla *et al*., 2008). Multiple stressors also increase the risks to human populations. Numerous countries within Africa, for instance, face a critical convergence of deleterious multiple stressors, including the spread of HIV/AIDS, poverty, scarcity of basic resources and services, and armed conflict. In

combination, these and other stressors are leading to greater vulnerability across the continent (Fields, 2005). As these examples suggest, multiple stressors can be additive or cumulative, resulting in impacts that are greater than any single stressor would produce.

14.2.1.1.1. Biophysical perspectives

Early views of climate impacts emphasized the magnitude of biophysical threats arising from climate change to define vulnerability and the need for adaptive actions (Adger, 1999; Brooks, 2003; Brooks *et al*., 2005). This view continues to be widely used to understand climate impacts. For instance, Hanson *et al*. (2011) offer a global ranking of the vulnerability of port cities using biophysical indicators. While this orientation persists, a variety of views of vulnerability have emerged, many combining biophysical and social perspectives of vulnerability (Adger *et al*., 2003; Füssel and Klein, 2006). This refinement has contributed to a more operational concept of vulnerability that focuses on its underlying causes and on actions to reduce vulnerability without waiting for ongoing refinements in estimates of the size and location of climate hazards.

14.2.1.1.2. Social perspectives

From a social perspective, vulnerability varies as a consequence of the capacity of groups and individuals to cope with the impacts of climate change. Among the key factors associated with vulnerability are gender, age, health, social status, ethnicity, and class (Adger *et al*., 2009; Smit *et al*., 2001). For instance, the elderly and infirmed may not have the financial resources or social capital necessary to relocate or the physical capacity to evacuate when natural disasters strike. Those who are socially isolated may have difficulty adjusting to the changes taking place around them while those who do not speak the national language, such as immigrants and foreigners, may be unable to learn about impending issues. Ethnic minorities have a long history of unequal treatment in many parts of the world and these disparities often become acute in the aftermath of natural disasters.

Climate change is expected to have a significant impact on the poor as a consequence of their lack of financial resources, poor quality of shelter, exposure to the elements, and limited provision of basic services, (Patz *et al.,* 2008; Moser and Satterthwaite, 2010; Huq *et al.,* 2007; Shikanga *et al*., 2009; Kovats and Akhtar, 2008; Revi, 2008; Tol *et al*., 2004; Gething *et al*., 2010; Rosenzweig *et al*., 2010). There are numerous instances where the poor have been able to adapt to changes. However, in addition to limited financial resources, the health and nutritional status of poor populations often is compromised. As a result, along with the sick and elderly, they are at increased risk from 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; O'Neill and Ebi, 2009; Tonnang *et al*., 2010; Costello *et al*., 2011; Ebi, 2011; Harlan and Ruddell, 2011; Huang *et al*., 2011; McMichael and Lindgren, 2011; Semenza *et al*., 2012). In a survey of recovery from shocks in Pakistan, Heltberg and Lund (2009) found that when faced with health and economic challenges, poor households often do not have sufficient coping mechanisms to rebuild their assets. This leaves them more prone to destitution and associated problems of food insecurity and landlessness (Heltberg and Lund, 2009). A further consideration is that many poor, as well as indigenous, populations maintain subsistence lifestyles. Climate-induced changes in temperature, weather, and pollution will affect habitats and result in an inability to obtain or grow food supplies thereby posing challenges to their food security (Huq *et al.,* 2007; Sivakumar and Hansen, 2007; Ford *et al*., 2008; Gero *et al*., 2011).

14.2.1.1.3. Political perspectives

Political systems and politics are important in shaping and understanding national and sub-national vulnerability. Different types of regimes rely on different types of policy instruments. For instance, drawing on case studies of water systems in the Middle East and North Africa, Sower *et al*. (2011) maintain that these largely centralized systems of planning, taxation, and revenue distribution render these governments more vulnerable since they are limited in their ability to adapt to climate change. Further, while there are jurisdictional, institutional, economic, and

technical issues that come into play, there also are a number of ongoing political issues that shape the relationships local governments have to managing climate risks (Corfee-Morlot *et al.* 2011). For instance, short-term election cycles, 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. Collectively, these situations have the potential to both foster as well as address vulnerabilities (Corfee-Morlot *et al.* 2011).

Rapid onset events, such as floods, and slow onset events including water shortages, famine, and desertification can serve as triggers for human migration, both within a given country as well as across borders. Based on case studies conducted in areas of Vietnam and Mozambique that are prone to rapid-onset flooding and in Egypt where they are facing slow-onset hazards of desertification as well as the potential of sea level rise, Warner *et al.* (2010) found patterns similar to those associated with conflict. Specifically, they suggest that economic and social factors are the major drivers of migration at the present time, but environmental forces associated with natural hazards contributed to the relocation process (Warner *et al.*, 2010). Further, stresses such as poverty, high population growth and density, and low levels of economic development can exacerbate the situation even further since they are intertwined with access to resources and the ability to cope with stressors associated with climate change (Gemenne, 2011; Warner *et al.,* 2010).

14.2.1.1.4. Economic perspectives

In assessing vulnerability in relation to adaptation, economic and social elements are often combined in a socioeconomic perspective. However, in some circumstances the emphasis is much more directly on the economic component. This is particularly true in disaster risk assessment and in comparing the needs of different countries, regions or sectors. Here the assessment typically uses the building blocks of probabilistic risk analysis to deliver for a particular scenario a quantitative estimate of the magnitudes of the hazard, exposure, vulnerability, and losses expressed in economic terms. Often the analysis is extended via randomized evaluations of the model to calculate the probability that a certain level of loss will be exceeded leading to a "loss exceedance curve", which then can be used to calculate other useful planning variables such average annual loss or probable maximum loss (Ghesquiere and Mahul, 2010; Anon 2010; IPCC, 2012).

Recently there have been efforts to estimate the economic costs of adaptation both at global (see Chpt 17) and national level (Brander, 2010; Galindo and Samaniego, 2010; Tonnang *et al.*, 2010; Conway and Schipper, 2011). One challenge has been to define and operationalize the concept of adaptation costs (Martens *et al.*, 2009; van Ierland *et al.*, 2007). The IPCC defines adaptation costs as the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transaction costs (AR4 Glossary). But this is still difficult to operationalize and does not include losses avoided. In a multi-country comparison, the World Bank (2010) established a baseline development path for each country with no climate change using standard economic forecasts and assuming that countries grow along reasonable development path. Then the calculations were repeated, sector by sector, assuming an appropriate level of adaptation. But there are many options as to that level. One option is to adapt completely, so that society is at least as well off as it was before climate change, but this may be prohibitively expensive. At the other extreme, countries could choose to do nothing, experiencing the full impact and losses from climate change. In the intermediate cases, countries invest in adaptation using the same criteria as for other development projects—until the marginal benefits of the adaptation measure exceed the costs. This method still had serious limitations. For example it was not able to deal with non-monetary losses such as those associated with ecosystems services, or costs of "soft adaptation options" such as institutional reform and strengthening.

Another approach (Economics of Climate Adaptation Working Group, 2011) sought to estimate the potential climate change losses over coming decades (20 years), how much could be averted, with what measures, what investments would be needed, and where benefits outweigh losses. It provides a systematic presentation of the costs of adaptation actions against the losses avoided, to assist decision makers to visualize the range of adaptation options available.

14.2.1.2. Adaptive Capacity

All regions and all countries of the world are vulnerable to the impacts of climate change. Attending to these impacts requires that countries and sub-national bodies have sufficient capacity to adapt. Adaptive capacity refers to the ability to recover, adjust, or cope with the impacts of climate change (Smit and Pilifosova, 2001; Smit and Wandel, 2006; IPCC 2007a; Nelson *et al.*, 2007; Jernek and Olsson, 2008). This can take place through advance preparation or through response at the time an event takes place (Smit *et al.*, 2001). Adaptive capacity is not limited to the ability to maintain an existing state, but reflects flexibility to transition to one that is more desirable (Engle and Lemos, 2009). What constitutes adaptive capacity varies in light of specific challenges and contexts (Adger *et al.*, 2007), but it is closely tied to the availability of tangible resources, including money, political power, and access to information and technology (Yohe and Tol, 2001; Smit and Wandel, 2006). While tangible resources are important, those associated with strong governance measures, such as institutions, networks, and civil and political rights, also contribute to the adaptive capacity of nations, regions, cities, and communities (Engle, 2011; Adger, 2006; Eakin and Lemos, 2006; Brooks *et al.*, 2005).

Fostering adaptive capacity typically is associated with preparing for climate change in both national and sub-national contexts and in biophysical, social and political domains. Because of their limited resources, developing countries, small island developing states, and poor populations have limited adaptive capacity and therefore, are among the least able to cope with climate impacts (Adger *et al.*, 2003; Dow *et al.*, 2006). As a result, adaptive capacity is closely tied to the development path that is pursued by national and by sub-national bodies. Achieving widespread commitment in both developed and developing country contexts may require that adaptation is aligned with and integrated into ongoing economic and sustainable development efforts (Ayers and Dodman, 2010; Conway and Schipper, 2011; Eriksen and Brown, 2011; Tanner and Allouche, 2011).

14.2.2. Mainstreaming Adaptation

Adaptation complements and has the potential to achieve co-benefits with and produce new opportunities in many policy and planning arenas. As an alternative to pursuing isolated action, a mainstreaming approach focuses on linking adaptation to national and local goals and priorities. The rationale behind mainstreaming is that integrated interventions can have effects surpassing those of disaggregated, fragmented, or differentiated initiatives (Chuku, 2010). Mainstreaming emphasizes synergies between adaptation and ongoing activities of government ministries and departments as well as practical activities taking place at the community and household levels (Smit and Wandel, 2006; Agrawala, 2005; Willbanks and Kates, 2010).

By developing an integrated plan of action, mainstreaming enhances the ability to streamline decision-making processes and accommodate an adaptation agenda without reinventing institutions and organizations (Smit and Wandel, 2006). It also can promote long-term sustainability of adaptation activities (Warner *et al.*, 2010), and reduce future remedial costs (Agrawala and van Aalst, 2008), such as those that could emerge from maladaptation, poor decision-making tools, and mismatches in development trajectories.

While adaptation offers complementarities and co-benefits with a variety of policy and planning arenas, this section focuses on linkages to and mainstreaming with climate change mitigation, development planning, and disaster management and hazard risk reduction.

14.2.2.1. Integrating with Mitigation

For many years, mitigation and adaptation have been viewed as relatively separate issues (Martens *et al.*, 2009), with mitigation seen more as a more pressing issue for developed countries and adaptation a priority for developing nations (Ayers and Huq, 2009). However, there is growing recognition that both are integral aspects of managing climate change (Willbanks *et al.*, 2003; Dowlatabadi, 2007; Klein *et al.*, 2007; Swart and Raes, 2007; Venema and Rehman, 2007; Ayers and Huq, 2009; Larsen and Gunnarsson-Ostling, 2009; Neufeldt *et al.,* 2010; VijayaVenkataRaman *et al.*, 2012). Mitigation priorities and adaptation measures are complementary and can offer

co-benefits if they are addressed simultaneously (McEvoy *et al*., 2006; Wilbanks and Sathaye, 2007; Klein *et al*., 2007; Ayers and Huq, 2009; Laukkonen *et al*., 2009; Neufeldt *et al*., 2009; Preston *et al*., 2011).

A variety of efforts around the world demonstrate the potential for integrating mitigation and adaptation. For example, Tokyo's urban greening policies promote the development of green roofs and urban gardens in order to address urban heat islands by acting as carbon sinks and urban flooding by reducing stormwater runoff and moderating building temperatures (Laukkonen *et al*., 2009). Similarly, Hamin and Gurran (2009) note how the development of renewable energy resources in Cornwall UK and Aspen/Pitkin County, USA not only reduce greenhouse gas emissions, but reduce vulnerability to storm events and peak demand during periods of extreme temperature by generating power through smaller and more decentralized means (Hamin and Gurran, 2009). Despite complementarity, it is essential to consider the full range of alternatives and impacts as mitigation and adaptation measures also can be in conflict with each other. For instance, in the case of city center redevelopment in Byron Shire, Australia, mitigation policies recommended high density development to achieve energy efficiency while adaptation policies recommended more open spaces to buffer stormwater runoff and protect ecosystems and conserve biodiversity (Hamin and Gurran, 2009).

Integrating adaptation and mitigation can produce important co-benefits with biodiversity conservation (Berry, 2009; Mawdsley *et al*., 2009; Vignola *et al.,* 2009; Bradley *et al*., 2012). For example, one adaptation strategy is to link isolated habitats together to form new suitable climate zones that can subsequently be linked to form climate resilient ecosystem networks (Lovejoy, 2005; Vos *et al*., 2008). This strategy allows for species to cope with and adapt to a changing climate while unifying disparate parcels into larger areas that can better facilitate carbon sequestration. Furthermore, the conservation of forests can aid mitigation by sequestering carbon and promote adaptation by protecting ecosystem services. (Guariguata *et al*., 2008; Paterson *et al*., 2008; Locatelli *et al*., 2011; Wertz-Kanounnikoff *et al*., 2011). A project in the Chinchiná watershed of Colombia was able to promote reforestation while also controlling soil degradation and implementing agroforestry and silvo-pastoral systems that created new income opportunities for local inhabitants (Locatelli *et al*., 2011). Similarly, the Scolel Té project in Chiapas, Mexico, is an example of a locally-supported carbon offset project that had around 60% of the carbon sale price going to the farmer. This revenue then went to cover costs of establishing further agroforestry activities and for supplementing livelihood needs (Nelson and de Jong, 2003; Locatelli *et al.,* 2011)

14.2.2.2. Integrating with Development

Developing countries are striving to improve the quality of life for their populations by taking actions reduce poverty and provide an adequate standard of living. However, climate variability and increases in natural hazards have the potential to undermine these goals (UNEP, 2011; Dupont, 2008; Kuwali, 2008). For instance, increased precipitation can contribute to increases in flooding and exposure to toxins and diseases in areas that lack appropriate drainage and sanitation services. Alternatively, droughts may emerge as increases in temperature lead to increasing rates of glacial melt or as regions experience reductions in precipitation (IPCC, 2012). In these situations, the poor may have difficulty obtaining access to water, as supplies become scarce (Kovats and Akhtar, 2008). Mainstreaming adaptation into national and regional development policies offers a means to address vulnerability to climate change while still maintaining progress in achieving economic and human development goals (Chuku, 2010). In fact, for many nations, the relationship between adaptation and development is so pressing that a wide variety of existing development issues are being reframed in the context of climate adaptation (Lemos and Dilling, 2007).

Sustainable development is a distinct and holistic approach to development that seeks to balance economic, ecological and social issues. Climate change and sustainable development often are considered to be two separate agendas. However, they too have the potential to be complementary and mutually reinforcing. This complementarity derives from the fact that climate adaptation initiatives can reduce vulnerability while promoting economic, ecological, and social goals and objectives associated with development (Eriksen and O'Brien, 2007; Ayers and Huq, 2009; Ayers and Dodman, 2010). At the same time, the promotion of issues such as food security, environmental quality, and health and sanitation associated with development, can be made more sustainable and

equitable over the long term by accounting for projected climate impacts (Tanner and Allouche, 2011; Mooney *et al*., 2009).

The term sustainable adaptation has been advanced to emphasize the potential co-benefits that can be derived when development and climate adaptation are seen as complementary (O'Brien and Leichenko, 2007). Despite the potential for synergies to exist, adaptation efforts do not always attend to the environmental, social, and economic consequences of action. For example, in some situations adaptation has inadvertently reinforced traditional gender roles (Carr, 2008) and inequalities (Eriksen and Lind, 2009). In addition, according to Turner et al (2010), adaptations such as building dams, migrating from water stressed to less developed areas, and exploiting natural resources in times of stress will have negative impacts on biodiversity conservation. By linking adaptation and sustainability, there will be greater sensitivity to equity, environment, and economic issues such as livelihoods when seeking to advance climate adaptation.

The relationship between economic development and adaptation tends to be articulated somewhat differently in developed and developing countries. In developed countries, adaptation plans and strategies often focus more on infrastructure, particularly in relationship to transportation and utilities (Ford *et al*., 2011), and rely on large-scale, complex, and capital intensive engineering and technological solutions (Sovacool, 2011). Developing countries, on the other hand, tend to be more concerned with integrating adaptation strategies with poverty and vulnerability reduction (Eriksen and O'Brien, 2007; Mertz *et al*., 2009; Hertel and Rosch, 2010), including those that promote basic service provision and delivery (Satterthwaite *et al*., 2009; Bauer and Scholz, 2010), food and water security (Nath and Behera, 2011), and education and health care (Smit and Wandel, 2006; Eriksen and O'Brien, 2007; Brauch, 2008; Perch-Nielsen *et al*., 2008; Halsnaes and Traerup, 2009; Scott and Becken, 2010). Given this North-South difference, while adaptation planning must ensure that development plans are robust against climate hazards and disasters in all socioeconomic and development contexts, this nexus is especially critical in the most vulnerable countries and least developed locations (ADB and IFPRI, 2009).

14.2.2.3. Integrating with Disaster Risk Reduction

Climate adaptation and disaster risk reduction (DRR) share the common goals of reducing vulnerability of areas and populations to the impacts of extreme events while creating sustainable strategies that limit risks from hazards (Solecki *et al*. 2011; Schipper, 2009; IPCC, 2012). Given that both fields seek to reduce vulnerabilities and build capacity (Solecki *et al*., 2011), integrating adaptation and DRR offers a number of co-benefits. Furthermore, a combination of adaptation and disaster risk reduction strategies can reduce the risk of climate extremes and disasters while also increasing resilience against remaining risks as they change over time (IPCC, 2012). For instance, DRR can become more robust by considering climate change projections and assessments when planning measures to reduce impacts. Further, many rural and subsistence communities are aware of climate change, but do not distinguish between climate impacts and events and stressors that affect their lives and livelihoods. Integrating adaptation and DRR, will ensure that the climate predictions and scenarios are considered when planning for disasters and extreme events (Mercer, 2010).

Given the synergies between adaptation and DRR, some cities and communities have begun to explore the linkages between these two areas. However, integration remains limited, particularly at the national level. Drawing on reviews of plans, as well as expert interviews conducted in Germany, the United Kingdom, and Fiji, Birkmann and Teichman (2010) found that despite having national adaptation plans that noted the importance of linking adaptation and DRR, little action was taken at the national level to establish working relationships. Though effective integration has yet to be substantively promoted at the international or national levels, adaptation and disaster risk reduction may utilize local knowledge to better plan for extreme weather events and to uncover important existing local capacities (IPCC, 2012).

Climate change is one of many stressors that governments and communities must address (Willbanks and Kates, 2010; Mercer, 2010). At the same time, adaptation is increasingly recognized as being linked to the development paths of both developed and developing countries (Agrawala, 2005; Stern, 2006; Nelson *et al*., 2007; Agrawala and van Aalst, 2008; Ayers and Dodman, 2010; Willbanks and Kates, 2010). Since DRR has a long history of being

associated with development, more comprehensive efforts are being called for in order to bridge adaptation, disaster management, sustainability, and economic and social development needs (Willbanks and Kates, 2010; IPCC, 2012). By adopting a broader perspective, countries, states, and communities can address multiple stressors and multiple vulnerabilities while building adaptive capacity (Willbanks and Kates, 2010; Solecki *et al.,* 2011). Moreover, the most effective strategies that simultaneously contribute to adaptation and disaster risk reduction are those that provide short-term developmental gains while helping to build long-term climate resilience (IPCC, 2012).

14.2.2.4. Integrating with National and Local Policy and Planning

Countries have pursued different approaches to integrating adaptation priorities with existing planning processes (see Keskitalo, 2010). Some have chosen to produce stand-alone climate adaptation plans and strategies. These include Finland's National Strategy for Adaptation to Climate Change (Marttila *et al*., 2005; Juhola *et al*., 2011), Germany's Strategy for Adaptation to Climate Change (BMU, 2008), and Burkina Faso's submission to the National Adaptation Programmes of Action (Kalame *et al*., 2011). Although these stand-alone plans are administered through one central ministry or department, they explicitly address integrating adaptation into areas and sectors such as agriculture, water resources, land use, and transportation (Biesbroek *et al*., 2010; Kalame *et al*., 2010). In addition, some countries have begun to integrate adaptation into their sector plans. For example, Australia's National Agriculture and Climate Change Action Plan seeks to promote the development of a sustainable, competitive, and profitable agricultural sector while also recognizing the need to pursue adaptation strategies and build resilience (DAFF, 2006). Despite these examples, incidences of successfully mainstreamed adaptation into national planning lag behind those at local and sub-national levels (Ford *et al.,* 2011).

Local governments are responsible for ensuring the safety, security, and well-being of their residents through efforts including the provision of infrastructure and basic services, preparedness for emergency response, and protection of environment quality and biodiversity. Of particular importance at the local level is addressing adaptation in the context of land use planning. Adaptation can be integrated into these and other activities as well as into local policies and plans (Dodman and Satterthwaite, 2008; Corfee-Morlot *et al*., 2011; Measham *et al.,* 2011) and then be implemented using existing institutional structures and processes (Wheeler, 2008; Kithiia and Dowling, 2010). Many local governments are making strides in advancing an adaptation agenda (Rosenzweig, *et al.,* 2010; Carmin, *et al.,* 2012), but mainstreaming is proving to be a challenge in many locations (Carmin, *et al.,* 2012). In order for local governments to integrate adaptation with their policies, plans, and ongoing activities, there must be adequate political support, capacity, commitment, and resources (Dodman and Satterthwaite, 2008; Seto *et al*., 2010; Amundsen *et al*., 2010; Corfee-Morlot 2011; Carmin *et al.,* 2012), along with reliable local information (Dessai *et al*., 2005; Amundsen *et al*., 2010; Measham *et al*., 2011).

14.2.3. Challenges in Adapting

If adaptation actions are to be effective in reducing and managing the risks associated with a changing climate there are a number of challenges that need to be addressed. The sections that follow summarize the most important challenges and discussed in more detail in Chapters 15 and 16. Among the challenges that must be overcome are scaling up, institutional mismatches, financial resource and capacity limitations, and the availability of information and models that support decisions

14.2.3.1. Scaling Up

An ongoing challenge that nations, regions, cities and communities face is moving from ideas to action. Scaling-up in the context of climate adaptation refers to transitioning from isolated projects and activities to comprehensive initiatives. Top-down and bottom-up approaches to adaptation can both be scaled-up. The former can take advantage of intergovernmental coordination both within and across levels of government and the potential to bring adaptation to existing and new policies. In contrast, the latter can advance projects from one-off activities to programmatic

modes of action, both within a community as well as across communities and regions (Reid *et al.,* 2010; Urwin and Jordan, 2008).

Scaling up of adaptation usually requires integration with other activities. It is more difficult for stand-alone models of adaptation to achieve widespread adoption as governments are rarely willing or able to allocate special resources to them (Huq and Reid, 2004; Handmer *et al*., 1999; Morduch and Sharma, 2002; Huq *et al*., 2003). In contrast adaptation activities that build upon existing programs can be more effective. The Productive Safety Net in Ethiopia combines an existing long-term workfare program that supports 6 million food-insecure households with scalable safety nets that can be rapidly expanded during drought to cover millions of additional households based on the triggering of a rainfall index (Hess *et al*., 2006). Such safety nets can be combined with workfare programs that undertake labour intensive public works, such as water storage, that will reduce vulnerability in the future (del Ninno *et al*., 2009).

Evidence is emerging to suggest that acceptance of a climate agenda and successful preparations for climate impacts takes place when integrated into ongoing government initiatives (Nelson *et al.,* 2007; Agrawala and van Aalst, 2008; Ayers and Dodman, 2010). For example, adaptation can be integrated into land use and water management sectors (Werner *et al.,* 2010), the agriculture sector (Prabhakar and Srinivasan, 2011), urban storm water systems (Gersonius *et al.,* 2012), or particular government plans and policies around infrastructure investment and disaster resilience (Lasco *et al.,* 2009).

14.2.3.2. Institutional Mismatches

Mainstreaming action is contingent on government ministries and departments taking a long term view of changes and challenges, integrating adaptation into their plans and agendas, and then working in a coordinated fashion to realize these ends (Conway and Shipper, 2011). However, this level of coordination can be a challenge since many adaptation issues cut across the jurisdictions and mandates of different government bodies and actors (Schipper, 2009). For instance, despite the importance of integrating adaptation and disaster risk reduction, legislation and programs for disaster and climate management typically span different ministries and departments, each with their own mandates, time horizons, priorities and agendas, all of which hinder coordination (Schipper and Pelling, 2006; Birkmann and Teichman, 2010; Falaleeva *et al*., 2011; IPCC, 2012)

Studies of decision making across levels of government have focused on mitigation and demonstrated how local decisions are both facilitated and constrained by national level regulations, policies and institutions (Hooghe and Marks, 2003; Betsill and Bulkeley, 2004). However, there also is evidence to suggest that the extent to which national governments focus on and support adaptation can influence local level action (Urwin and Jordan, 2008). For example, a survey of Norwegian municipalities (Amundsen *et al*., 2010) found that local governments did not have a clear idea or sense of their role with regard to adaptation policies and measures. The lack of familiarity with, and attention to, adaptation was directly related to the limited focus given to this issue by the national government.

Adaptation assessment and planning requires the engagement of diverse actors (Lu, 2011). Local stakeholder knowledge can complement expert views (Lane and McDonald, 2005; Crabbe and Robin, 2006; Corfee-Morlot *et al*., 2011; Huang *et al.,* 2011; Measham *et al*., 2011) and enhance the design of adaptation strategies and policies by ensuring that they capture local realities (van Aalst *et al*., 2008). Engagement of local stakeholders also can lead to participation in the subsequent implementation of adaptation initiatives (Gero *et al.,* 2011). Local governments often find that there are institutional barriers to implementing participatory adaptation planning, including differences in access by stakeholders to participatory decision making processes (Few *et al*., 2007), lack of adequate and reliable mechanisms for information sharing (Lwasa, 2010), and different knowledge, values, and perspectives shaping the views and preferences of policymakers, experts, and the public (Veraat, 2010; Webb, 2011).

14.2.3.3. Financial and Capacity Limitations

Resources for adaptation have been slower to become available than for mitigation in both developed and developing countries. This has meant that there is less expertise in adaptation assessment and implementation, which is further confused by the lack of clarity about the distinction between adaptation and more common sustainable development and/or poverty reduction planning (Cruce, 2008).

Within developing countries only modest funding has been available for adaptation actions and much of this funding has been directed towards capacity building, standalone projects or pilot programs. Least Developed Countries were supported via the GEF resources to prepare NAPAs (see section 14.5.) prioritizing their immediate and urgent adaptation needs. However, funding to take action on these needs was slow to come and many governments were reluctant to move ahead without external support given the generally accepted responsibility of developed countries to support the incremental costs of adapting to climate change. The NAPAs were, in most countries, excellent opportunities to build technical capacity and institutional links, but with the long delays in moving to an implementation phase many of these skills dissipated (Ciplet *et al.*, in press).

There has been a significant increase in financial flows recently with replenishment of the GEF adaptation funds (LDCF & SCCF), support for the Pilot Program for Climate Resilience, and special purpose adaptation funds for UN Agencies, MDBs and major bi-lateral funds earmarked for adaptation. {Complete citations and a table of amounts nearer completion of the Report – currently LDCF USD224 million; SSCF USD130 million; Adaptation Fund USD 305-408 million; PPCR USD 970 million.} The Adaptation Fund, which is set up under the Kyoto Protocol and funded through a levy on most 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 multi-lateral development agency. This mechanism has again bought home the need to build and maintain capacity, not just in the technical aspects of adaptation assessment and project design but also in financial management and due diligence (Brown *et al.*, 2010).

14.2.3.4. Availability of Information, Data, and Models Needed for Action

Access to appropriate information and modeling tools is frequently identified as a major limitation to adaptation action by practitioners and stakeholders (World Bank, 2010). The Nairobi Work Program, established at COP12 in 2006 with a goal of helping developing countries making "informed decisions on practical adaptation actions and measures to respond to climate change on a sound scientific, technical and socio-economic basis" has made repeated calls for better observation systems, information sharing and modeling capacity (e.g. UNFCCC/SBSTA/2008/3). OECD recognized the need for improved information services if adaptation is to be better integrated into development planning (OECD, 2009). Developed and developing countries have acted upon this priority by establishing institutions to provide information services at national (e.g. UK Climate Impacts Programme in the United Kingdom (UKCIP 2011) and National Climate Change Adaptation Research Facility in Australia (NCCARF, 2012), regional (e.g. Caribbean Community Climate Change Centre in the Caribbean (CCCCC, 2011) and the EU xxx), and global scales (e.g. World Meteorological Organization (WMO, 2011) and World Bank Climate Knowledge Portal (World Bank, 2010)). The scientific community has supported these calls (e.g. Füssel & Klein, 2006, Wilby et al 2009).

The types of information can be classified broadly as past, current and projected biophysical and socio-economic information (Moss, to appear); information on adaptation options (de Bruin *et al.*, 2009; Patt *et al.*, 2010) including technologies and costs (UNFCCC, 2006; World Bank, 2010, 2011); and sharing of experience (UNDP, 2012). A lack of information and tools to support decision-making is often a costly and time consuming, early step in many assessments and project design processes particularly in developing countries (World Bank, 2010). In some cases a supposed lack of information may be used as a rationale for inaction on adaptation (Moser, 2010).

A challenge is to balance the quantity and complexity of information made available and the need to communicate clear guidance that best serves the purposes of stakeholders (UKCIP, 2011). This has been particularly the case in providing access more precise estimates of changes in climate and weather patterns at given location and times

(Wilby, 2009). Christensen *et al*. (2012) have explored this issue across the Arab countries, a region usually understood to be lacking such information. A thorough review shows that observational hydro-meteorological data are sparse compared to world standards, but the shortfall is made worse by recording stations not being entered into global databases and by restrictions on access arising from security concerns. They also found good coverage of downscaled climate information but point to the need to work closely with end users to assist them in interpreting these data and incorporating them in impact modeling and decision processes.

14.3. Synthesis of Adaptation Needs and Options

The recommended adaptation process is based on identifying needs that stem from climate risks and vulnerabilities, selecting options that promote adaptive capacity, and then implementing the chosen actions. The driver for adaptation stems from the threats that different systems face while action is predicated on the extent to which they are vulnerable or able to adapt. Often, identification of needs is rooted in assessments of different systems that, in turn, make it possible to generate options and determine appropriate actions.

14.3.1. Identification of Adaptation Needs

Adaptation involves building the capacity of nations, regions, cities, communities and individuals, groups to cope with climate impacts as well as mobilizing that capacity by implementing decisions and actions (Tompkins *et al.,* 2010). Adaptation requires that there is adequate information on what and how to adapt (Füssel and Klein, 2006). Consequently, the foundation for generating adaptation options and building capacity is the identification of adaptation needs. More often than not, this process of identifying needs is rooted in a formal assessment.

A number of different methods are used to assess climate risks and vulnerabilities, each having different orientations and strengths and weaknesses (See 14.2.1.1. and Füssel and Klein, 2006). One approach is the risk-hazard framework. Drawn primarily from risk and disaster management, this approach 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). A second approach, which is rooted in a political economy perspective, examines the ways in which individuals, groups and communities are vulnerable to climate impacts. Here, the focus is on social vulnerability, with an emphasis on how structural factors such as institutions shape socioeconomic conditions that place human populations at risk (Blaikie *et al*., 1994; Adger and Kelly, 1999).

Adaptation policy has to be responsive to a wide variety of economic, social, political, and environmental circumstances (Burton *et al*., 2002). Institutions with responsibility for progressing adaptation agendas will usually also have responsibilities for other non-climate related agendas (O'Brien & Leichenko, 2006) Therefore, a more integrated approach that has emerged that joins major elements associated with the risk-hazard and political economy perspectives (Füssel and Klein, 2006). This combination considers a range of climate impacts while placing an emphasis on the adaptive capacity of systems and populations (Heltberg *et al*., 2009). By integrating these approaches, it becomes possible to identify a broad spectrum of adaptation needs and then to draw on this information to select appropriate options.

Assessments are becoming more holistic in their consideration of risks and socio-economic systems, but they still tend to focus on specific levels government and specific sectors (Fekete *et al*., 2010), even though adaptation needs and options should account for the cross-cutting nature of climate impacts. Cross-level and cross-sector analyses offer important vantage points, but also come with some important tradeoffs. For instance, local level assessments offer detailed and often high quality information that captures complexity, but typically it is highly specific and limited in transferability. Sub-national data provides insight into large-scale patterns as well as offers insight into intermediate levels of analyses and processes. However, this level of aggregation makes it impossible to identify many vulnerabilities and validation is a challenge. Finally, national assessments are useful for allocating global funds, particularly in hazard prone regions, but there is little sensitivity to root causes (Fekete *et al*., 2010). In

addition to up and down-scaling information within a given domain, moving across levels can be difficult translate when spanning natural systems, social dynamics, and institutional processes.

14.3.1.1. Institutional Needs

Institutions and institutional actors are integral to reducing vulnerability as they 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 14.2.3.2 and Agrawal, 2010). At the international level, institutions and institutional actors offer adaptation resources and capacity support to developing countries. 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; Corfee-Morlot *et al*., 2009; Bulkeley and Betsill, 2005). However, local governments have the potential to directly enhance the adaptive capacity of vulnerable areas and populations by developing regulations including those related zoning, stormwater 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*., 2003; Nelson *et al*., 2007; Brooks *et al*., 2005). In the course of specific actions, local governments influence vulnerability and capacity by shaping access to resources and structuring individual and collective responses to climate impacts (Agrawal, 2010).

While some approaches to assessment identify institutional needs, there are four general design challenges that typically need to be addressed: adjusting to changing conditions, adopting a climate lens in ongoing activities, facilitating intergovernmental coordination, and attending to the needs of diverse stakeholders (Gupta *et al*., 2010; Agrawal**,** 2010). First, institutions should be designed so that they are flexible. The uncertainty associated with climate change and the availability of changing information and conditions, along with emerging ideas on how best to foster adaptation, requires experimentation, a willingness of governmental and nongovernmental actors to learn from both successes and mistakes, and to integrate this information into regulations, policies, plans, and ongoing activities.

Second, in keeping with the notion of mainstreaming, adaptation would need to become an integral aspect of policymaking, planning, and program development. Existing policies and plans may have the potential to support adaptation, but can be constrained in their ability to achieve this end. This may be the case due to misaligned instruments and timeframes within a given policy. Rather than focusing on short-term climate variability and disaster-response, government actors need to adopt a long-term perspective in order to address vulnerability reduction and promote the development of adaptive capacity (Conway and Shipper, 2011). A further issue with regard to mainstreaming adaptation into institutions is that policies that address the same issue, but at different scales, can result in conflicting aims and outcomes. An alternative is to re-calibrate existing policies and to incorporate climate resilience in new policies, plans and programs so that they advance adaptation planning (Urwin and Jordan, 2008).

Even if ministries or departments commit to addressing adaptation in the course of their ongoing activities, this remains a challenging issue for both national and local governments to achieve. In many instances, a single governmental body is not equipped to deal with a given climate impact while in other instances there are both gaps and overlaps in institutional mandates, conflicting time horizons, and multiple actors involved in decisions and actions (Sietz *et al*., 2011; Hulme, 2009; Urwin and Jordan, 2008; Schipper, 2009; Adger *et al*., 2005). As a result, a third challenge is designing institutions so that they facilitate foster coordination, communication, and cooperation (Schipper, 2009; Conway and Shipper, 2011; Agrawal, 2010). This should take place within levels of government, across levels of government, and both within and across sectors. Coordination and communication are central to adaptation since they not only affect efficiency and effectiveness, but also influence the allocation of resources within and across governmental bodies as well as to numerous nongovernmental entities (Agrawal, 2010).

Further, in order to promote adaptive capacity, institutions would need to attend to the needs of diverse stakeholders and foster means their engagement in adaptation decisions and actions. Top-down and bottom-up approaches each provide important information and views. The former can adapt existing policies and plans and establish protocols for mainstreaming adaptation into government initiatives (Urwin and Jordan, 2008). However, the latter approach

offers a means for ensuring that diverse viewpoints are heard and integrated into measures in ways that enhance capacity. This not only requires that institutions are designed to encourage participation, but that they foster learning, promote the development of leadership qualities, and support fair governance principles (Gupta *et al.,* 2010).

14.3.1.2. Social Needs

There are numerous barriers to implementing adaptation including natural, structural and institutional factors such as the inability of natural systems to adapt to the rate and magnitude of climate change and constraints associated with technology, finances, and political dynamics (Grothmann and Patt, 2005; Yohe and Tol, 2002). They also include social, cultural, and individual factors, including values, identity, cognitive denial, and behavioral opposition. While adaptation often focuses on "hard" measures, such as those rooted in technology and engineering, fostering resilient settlements and societies means not only attending to basic needs such as the availability of food and water, but also addressing social and psychological needs (Reser and Swim, 2011; Adger *et al*., 2009; O'Brien, 2009; Frank *et al*., 2010).

Climate vulnerability is rooted in the ability of individuals and groups to cope with the impacts of climate change. At the individual level, women, the elderly, those with health challenges and disabilities, low social, minority, and class status are among the least able to cope with threats from climate impacts (Adger *et al*., 2009; Smit *et al*., 2001). These individual factors also are often associated with and compounded by community-level conditions. Many poor and ethnic minorities live in substandard housing, lack access to basic services, have compromised health, and are at threat due to excessive densities, poor access roads, and inadequate drainage (Moser and Satterthwaite, 2010; Huq *et al*., 2007; Shikanga *et al*., 2009; Kovats and Akhtar, 2008; Revi, 2009; Baker, 2011). In rural areas, adaptation needs also are linked to the viability of agricultural activity (Bosello *et al*., 2009).

In addition to social conditions, social psychological factors affect needs and adaptation capacity. For instance, based on a study of coffee farmers, Frank *et al*. (2010) found that social identity, particularly social group differentiation, ethnicity, and marginalization, shapes views of the credibility of information and perceptions of risk. These views and perceptions, in turn, affected the willingness of farmers to adapt their growing practices. Further, in a study of the response of the elderly to heat waves, Wolf *et al*. (2010) found that the bonds forged in social networks shape perceptions of vulnerability through the narratives that were communicated. Their findings suggest that vulnerability can either be reduced or enhanced, depending on the types of information that are disseminated through networks. Overall, these findings demonstrate that individual perceptions and social ties influence adaptation needs and measures.

The causes and solutions of vulnerability take place at different social, geographic, and political scales (Ribot, 2010). Therefore, in order to identify critical needs of populations, and the underlying conditions giving rise to these needs, social assessments are best conducted across institutional domains and by spanning from the local to the national. Local assessments provide a means to identify existing vulnerabilities as well as policies, plans, and natural hazards contributing to these vulnerabilities. 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*., 2008). 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.

People often feel powerless when faced with significant threats such as climate change. New institutions may be needed that address this sense of powerlessness, not only by enabling people to feel connected (O'Brien *et al*., 2009), but also by addressing conditions that are entrenching socioeconomic and political inequities (Lemos and Thompkins, 2008). Technological measures are integral to protecting populations, but institutional strategies need to be pursued in order to ensure that the most vulnerable are able to cope with short and long term climate impacts (Gupta *et al*., 2010). Across levels of government, this means redesigning and implementing regulations, standards, and other institutional protocols that reduce exposure to disasters and other impacts of climate change while at the local level it means attending to basic and infrastructure services associated with development.

14.3.1.3. Ecosystem Services and Environmental Needs

It has been observed that climate change is exacerbating the already existing adverse consequences and impacts of anthropogenic activities on the sustainability of biotic resources (Mooney *et al*., 2009, Vorosmarty *et al*., 2010). The impacts of climate change on biotic resources and their interactions may be looked at in terms of the capacity of ecosystems to deliver essential services. In order to sustain ecosystems services, there is a need for improved methods for tracking and monitoring, and modeling ecosystem changes (Davin and de Noblet-Ducoudre, 2010), better understanding of the biological processes and interactions critical in the delivery of ecosystems services, and the creation of new tools and approaches for maintaining and restoring biological diversity (Scholes *et al*., 2008; Mooney *et al*., 2009).

14.3.1.4. Financial and Capacity Needs

As discussed elsewhere in this Report (Sections 3.2.1.1.4 and 3.2.3.3; Chapter 17) estimating the financial needs to achieve effective and equitable adaptation to climate risks has proven a difficult task. AR4 did not provide estimates of the costs but concluded that most case studies showed high benefit cost ratios for most adaptation activities. Recently, in response to the negotiations of under the UNFCC a series of estimates have emerged. These range from about USD10 billion to USD40 billion per year to climate proof[2] development in developing countries (World Bank, 2006; Stern, 2006), which were revised upwards to USD80 billion and higher under revised assumptions (Oxfam, 2007) and new sectors. Two intensive studies by the UNFCCC and the World Bank came to estimates within the same range for developing countries (UNFCCC, 2007; World Bank, 2010), however the distribution of those costs across sectors differs significantly. The UNFCC estimate for the costs in developed countries was USD20 billion to USD100 billion. The core conclusion from these studies was that the costs of adaptation are of the same order of magnitude as those for mitigation although the distribution of these costs between the public and private sectors is not clear (IIED, 2009).

[FOOTNOTE 2: The phrase ‘climate-proofing’ is not well defined, but in the context of adaptation may be taken to mean ensuring the sustainability of investments over their entire lifetime by explicitly taking into account a changing climate (Sveiven 2010). Methods for doing this vary greatly (see Section 14.2.1.1.4).]

A challenge at both the international and national levels is to develop financial instruments that are equitable in both their delivery of resources and the sharing of the burden in supporting the instruments. Burden sharing at the national level lies at the core of the negotiations over mitigation actions, but has been less thoroughly examined in the context of adaptation (Chapters 1& 6, Levina, 2007; World Development Report, 2010; Section 17.xxxx). With the exception of the Adaptation Fund (section 14.2.3.3 and 17.xxxx) most financial instruments for adaptation have depended on voluntary contributions at the national level to bilateral or multilateral funds. Financial flows through these funds have fallen well below the sums identified by the above studies (OECD 2012) and are expected to remain so as many of the resources will flow through the private sector (Agrawala *et al*., 2011). Private sector funding will include not just current risk spreading instruments, such as insurance and contingent lending arrangements, but expenditures by the full range of private actors, from multi-national to SMEs (small-to-medium-enterprises) and small farmers, to protect their activities and supply lines from climate risks and to pursue new opportunities arising from a changing climate. Also, financial mechanisms for disaster risk management are also inextricably linked with those for adaptation (Mechler *et al.,* 2010) and mechanisms for adaptation will have to balance immediate needs for essential development and disaster recovery with longer term goals directed to climate resiliency.

The Cancún Agreement calls on developed countries to provide new and additional resources for climate actions with USD30 billion over the 2010-2012 period and a longer-term goal of USD100 billion per year by 2020, but with the share going to adaptation still undetermined. While efforts to integrate climate change adaptation will be led by developing country partners, international donors have a critical role to play in supporting such efforts as well as in integrating consideration of adaptation within their own plans and activities (OECD, 2011).

Payments required in the future for climate change will equal or dwarf those of current development expenditure (Peskett *et al*., 2009). Delivery channels will need to be designed to reach the poor who are also often most vulnerable to the impacts of climate change. For example, for adaptation financing, working at the sub-national level will be important and mechanisms like microfinance merit a closer look (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 this as an isolated priority to the detriment of other equally pressing social, economic, and environmental issues (Ziervogel and Taylor, 2008).

Capacity is not limited to finances alone, but extends to human, technological, informational, and social resources (Yohe and Tol, 2001; Adger, 2006; Eakin and Lemos, 2006; Smit and Wandel, 2006). These issues are critical capacity needs in all countries and regions, but become most pressing in local governments facing challenges at attending to ongoing needs and demands. Experience in Durban, South Africa, for example, shows that local government departments often have differing abilities to respond to climate challenges. As the city began pursuing adaptation, some departments were able to mainstream adaptation-oriented activities into their ongoing work, while others were struggling to cope with existing backlogs and to maintain business as usual and, therefore, did not have the capacity to address climate-related concerns (Roberts, 2010).

Capacity Section – TBC --
1) What are capacity needs; 2) Capacity development to foster bottom-up planning and (3) need have means to maintain capacity. How do you make sure capacity stays – through regional institutional capacity building; south – south practitioners networks. UNEP Report (2011) to appear soon – will build upon this. Also ACCCA 2009.

14.3.2. Options for Adapting to Climate Change

Adaptedness to climate is a normal feature of societies, evident in cultures, norms and activities everywhere. In this sense, adaptation to climate change includes not just tangible actions – such as the building of a higher river levee as a precaution against changed risks of flooding – but also intangible adjustments – such as the changed landscape values as a result of higher levees (Brander, 2011), or the changing sense of security of residents living behind the levee. Options for (and limits to) adaptation therefore have tangible as well as intangible dimensions (O'Brien, 2009). Adaptation goals, and thus options, are always socially contingent, with actors having different sensitivities to climate impacts, different personal goals, and different understanding of and attitudes towards risk (Adger *et al*. 2007; Stafford-Smith *et al*. 2011).

The universe of adaptation options includes adjustments that reduce perceived risks associated with climate change, as well as adjustments that seek to enhance welfare and resilience (Doria *et al*., 2009). Hallegatte (2009) defines five broad strategies for adapting to climate change: (i) selecting 'no-regret' strategies such as climate-proofing buildings and repairing leaks in water pipes produce desired benefits or outcomes whether regardless of whether climate impacts occur; (ii) favoring reversible and flexible options; (iii) buying 'safety margins' in new investments such as building higher sea walls or greater storm water drainage capacity; (iv) promoting soft adaptation strategies such as the use of ecosystems to manage extreme flows; and (v) reducing time horizons over which decisions will apply.

Selecting specific adaptation options can be challenging partly due to the rate, uncertainty, and cumulative impacts of climate change. However, such signals need to be interpreted and weighed against other cultural, economic, political or social signals that may encourage change. Indirect signals from regulators or customers may be a stronger signal to the agents responsible for adapting 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. Thus, 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 (Sietz *et al*., 2011).

While the selection of adaptation measures must account for different stakeholder perceptions in light of the potential to reduce vulnerability, other factors that should be considered are cost effectiveness, equity, co-benefits, environmental impacts, sustainability, potential for scaling up and community acceptance (Martens *et al*, 2009). There will be divergent perceptions and opinions about these options, influenced by the range of attitudes that exist about the goals of adaptation, risk and uncertainty, costs and benefits and so on. One of the main contributions of recent research on adaptation has been to suggest that adaptation options, at least the majority of those that might be expected over the short-term, are often ambiguous, contested and embedded in specific contexts.

The specific measures employed often are referred to as soft and hard. As discussed below, those in the former category include institutional and social measures while those in the latter category tend to be those that rely on technological and engineering solutions. It is important to note, however, that not all technological solutions are 'hard', as for example some of the changes in agricultural practice based on early warning systems and modeling. Ecosystem-based adaptation, such as the maintenance of wetlands that protect against storm surges, or floodways to manage extreme flows are often considered to be 'soft' measures, but are often linked with 'hard' measures such as levies, drainage and silt-trapping structures.

14.3.2.1. Institutional and Social Options

Numerous institutional measures can be used to foster adaptation. These range from financial instruments such as taxes, subsidies and insurance arrangements to social policies, to regulatory instruments such as building codes and land use plans (Hallegatte, 2009; Heltberg *et al.,* 2009; de Bruin *et al*., 2009). Informational strategies such as early warning systems, education programs, and dissemination of climate information are integral to adaptation as are measures designed to protect populations such as relocation and evacuation schemes. Numerous activities designed to account for changing weather and precipitation patterns are taking place in many nations. However, as previously noted, to ensure that that institutions provide an appropriate context for action, efforts must be made to coordinate across agencies and departments (Schipper, 2009; Conway and Shipper, 2011; Agrawal, 2010) and to account for stakeholder views and preferences while fostering widespread commitment and engagement (van Aalst *et al*., 2008; Few *et al*., 2007; Gero *et al.,* 2011).

An institutional measure that provides support to the most vulnerable populations is social safety nets. For example, long-term and child malnutrition have been associated with reduced adult earnings (Hoddinott, *et al*., 2008; Alderman, et al, 2009). Malnutrition often results from extreme weather events, particularly floods and droughts, as both can alter the price or availability of food. While some studies have shown that food programs can be counterproductive to promoting livelihood or may not prevent malnutrition in non-emergency situations (e.g., Bhutta, *et al*., 2008), programs designed to provide support at times of extreme events can provide an important bridge for vulnerable populations (Alderman *et al*., 2010). Responding to disasters is important, but so too are anticipatory initiatives. Pro-poor measures that foster health, nutrition, and education are no-regrets approaches that can promote development while enhancing adaptive capacity (Heltberg *et al.,* 2009).

Effective governance is important for the 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. The basic premise is that robust governance measures can promote adaptation by building adaptive capacity (Adger *et al*., 2009). This argument is reflected in assessment of river-basin planning in Brazil, where Engle and Lemos (2010) found that improving governance mechanisms appears to enhance adaptive capacity. However, they also note that this is not a simple relationship as tradeoffs exist between different aspects of governance that can make some approaches more or less appropriate for given contexts.

14.3.2.2. Technological and Engineered Adaptations

Technological adaptation measures in various sectors are being developed based on available knowledge and recent advances in science and technology. In food and agriculture sector, for example, a suite of adaptation options are developed and applied to reduce the adverse impacts of climate change on crop production. Wassmann *et al*. (2010)

have presented some adaptation measures in rice production. The alternate wetting and drying technology has been shown to significantly improve water use efficiency and has also reduced methane emissions from rice fields. Sub1 rice variety, which is being tested in several regions in Asia, has been demonstrated to be flood-tolerant and can withstand prolonged submergence with no significant yield reduction. Other adaptation measures in this sector include innovations in good agricultural practices (GAPs) in several areas such as adjusting the cropping calendar based on rainfall distribution or on simulated yield probabilities using process-based crop models under a downscaled climate scenarios (Semenov, 2006; Semenov, 2008; Bannayan and Hoogenboom, 2008).

There are repeated calls for technology transfer to and sharing between developing countries in adaptation to match the programs associated with mitigation (UNFCCC, 2006). However, the circumstances are different. 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.

There are some technologies that may become more important in adapting to climate change. Improved water transport and application through irrigation, or through water use efficiencies in industry all have particular technologies that need to be more widely available, as will desalination technologies. Revised building codes are another important opportunity to increase resilience to climate impacts, but again institutional issues such as enforcement are just as important.

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 and challenges to communication management and trust building, both essential to the development of resilience and adaptation to the changing climate. ICT provides opportunities for both top-down dissemination of relevant information such as weather forecasts, hazard warnings, market information, and advisory services. It can also generate essential information through bottom-up processes such as 'crowd sourcing' of useful information such as hazard warnings (e.g. local flood levels), disease outbreaks and the management of disaster responses.[3] 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 above; as a medium for raising awareness; and as an enabler for a 'networked governance' based on networked open organisations.

[FOOTNOTE 3: See web sites of Ushahidi (http://ushahidi.com/about-us) and Ping (http://www.pingsite.org/index.php) for on-going activities.]

Adaptation experiences suggest that vulnerable communities are more prone to act upon information that they can trust, a complex concept that could be linked to factors such as the source of the information and the local perception of it, the language used to convey the message, the role and credibility of 'infomediaries', and community involvement, among others. Ultimately, ICTs could play an important supportive role helping to build and strengthen trust within vulnerable communities.

14.3.2.3. Ecosystem-Based Adaptation

Climate change is altering ecological systems, biodiversity conservation, and resources associated with ecosystem services (Hoegh-Guldberg, 2011; Mooney *et al.,* 2009). These systems not only are important for their own sake, but because they contribute to human welfare on prosperity in the face of a changing climate. For instance, coastal wetlands and coral reefs can help to protect against rising sea level (Hoegh-Guldberg, 2011) while the maintenance of wetlands and green spaces can control run-off and flooding associated with increases in precipitation (Mooney *et al.*, 2009; Jentsch and Beierkuhnlein, 2008). Consequently, there is a need to protect these systems and resources within the changing climate (Carpenter *et al.*2009).

There are a number of options for ecosystem-based adaptation. In addition to policy and planning options, these include integrative adaptive forest management (Bolte *et al.*, 2009; Guariguata, 2009; CBD, 2009), the inclusion of climate change risk management and adaptation in agricultural and rural development activities (Reyer *et al.*, 2009),

land and water protection and management, and direct species management (Mawdsley *et al.*, 2009). Often, an emphasis is placed on technological and engineered approaches to adaptation. However, working with nature's capacity and pursing 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).

Ecosystem-based adaptation may require trade-offs through managing ecosystems to provide particular services at the expense of others. For example, to provide an effective wetland buffer for coastal protection may require emphasis on silt accumulation possibly at the expense of wildlife values and recreation (CBD 2009). Given uncertainties about how ecosystems will develop under multiple stresses and a changing climate an adaptive management approach to ecosystem-based adaptation is expected to produce the best outcomes.

14.4. Actors and Roles in Adaptation

Climate adaptation requires the engagement of governmental, nongovernmental, and private sector actors across levels and sectors. The identification of diverse needs, generation of appropriate options, and successful implementation of adaptation measures is predicated on diverse actors contributing their views, ideas, and expertise.

14.4.1. Local Actors and Roles

14.4.1.1. Local Governments

Local governments are integral and critical actors in advancing adaptation and in shaping the options identified and selected. As institutional actors, they influence the distribution of climate risks, mediate between levels of government as well as between social and political processes, and they establish incentive structures that affect both individual and collective action at all levels (Agrawal and Perrin, 2008). As a result, local governments have the potential to strengthen the capacity of both the urban and rural poor through the acquisition and distribution of finances, knowledge and information, skills, training, and technological support (Agrawal and Perrin, 2008)

Local governments consist of elected officials as well as individuals who work in government agencies and departments, all of whom have the potential to thwart adaptation initiatives as well as to contribute to the formalization and institutionalization of adaptation initiatives. Critical to both caretaker and facilitation roles are the implementation of national mandates and the development of dedicated local policies. In addition to advancing policies, these individuals 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 (Carmin *et al.*, 2012; Anguelovski and Carmin, 2011).

Despite the critical role they play, 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 (Dodman *et al.*, 2009; Hardoy and Romero Lankao, 2011). Attending to each and every one of these issues may be integral to advancing adaptation. However, government representatives may encounter roadblocks both from within their communities as well as from other levels of government in setting priorities, obtaining and allocating resources, and engaging in coordinated action if attention is oriented to adaptation rather than away from stated priorities.

Although they may encounter challenges, Roberts (2008) suggests that there are a number of indicators that demonstrate whether local government has institutionalized and mainstreamed adaptation. Specifically, she suggests that these include the presence of an identifiable champion from within government, climate change being an explicit issue in municipal plans, resources are dedicated to adaptation, and adaptation is incorporated into local political and administrative decision making (Roberts, 2008).

14.4.1.2. Households

As adaptation is local in nature, households play an important role in responding to climate impacts. At the farm level, for example, decision-making on farm activities and operations are made at the household level, and community or group of households. The identification of adaptation measures often involve household members including women and children (Sivakumar and Hansen, 2007; Sivakumar and Motha, 2007). Climate adaptation measures in this context consist of innovations to existing farm practices and operations from land preparation, crop and livestock management, harvesting and marketing. Adjusting the planting date is usually among the first decision to be made based on available knowledge and information (Lansigan *et al.*, 2007).

14.4.1.3. Indigenous Peoples

Indigenous actors can contribute in important ways to adaptation. In most regions of the world, indigenous knowledge exists about how and when to respond to climate change and climate variability. Alexander *et al.* (2011) noted that the complementarities between traditional ecological knowledge and scientific information include an increased ability to translate indigenous narratives to reflect patterns of regional change and the ability to produce expanded and multidimensional pictures of climate change impacts based in the context of human landscapes (Alexander *et al.*, 2011). For example, indigenous knowledge on climate adaptation in farming operations has been transferred from generation to generation and ranges from activities associated with land preparation to those regarding harvesting methods (Sivakumar and Hansen, 2007). Furthermore, in Southeast Asia, the practice of rice terracing in sloping and fragile mountainous ecosystems have been practiced since time immemorial (Sivakumar and Hasen, 2007; Sivakumar and Motha, 2007). The choice of crops to plant during a dry or wet year has been found to be successful in reducing the adverse impacts of climate change and variability (Lansigan *et al.*, 2007). Likewise, climate adaptation measures for smallholder agroforestry based on good practices in Southeast Asia has recently been documented (Lasco *et al.*, 2011).

In addition to drawing on their traditional knowledge of adaptation measures, indigenous actors can be engaged by regional and local governments to support and advance adaptation initiatives. For instance, agro-pastoralists in Makueni District, Kenya are involved in monitoring, assessing, and adapting to the effects of drought through observing local weather and wildlife behavior signs (Speranza *et al.*, 2010). In this case, indigenous peoples assess changes on the land in tandem with projection information from regional and ecosystem level climate models. Indigenous assessments are crucial for adding locally relevant climate impact information. However, because of preexisting poverty-related resource and capacity limitations, many indigenous communities continue to encounter difficulty in successfully implementing adaptation strategies (Speranza *et al.*, 2010).

14.4.1.4. Local Communities

Many communities pursuing adaptation are engaging community-based, civil society, and nongovernmental organizations in planning and implementation. One approach that relies extensively on communities and community organizations is community-based adaptation (CBA). CBA is characterized by the engagement of local residents in exercises designed to identify measures that can reduce vulnerability while building local adaptation capacity. CBA can both engage as well as empower residents to plan for and take action to address the impacts of climate change (Reid *et al.*, 2010; Ebi, 2008), but it relies on participatory processes and not only considers hazard prone areas, issues in service delivery, and gaps in infrastructure, but often attends to local social and cultural norms as a means to take a holistic approach to reducing vulnerability (Ayers and Forsyth, 2009). The outputs of these processes have included numerous recommendations and plans of action, including the design and implementation of early warning systems, infrastructure development, and improvements in service delivery (Ensor and Berger, 2009; Douglas *et al.*, 2008).

Communities have a long history of participating in vulnerability assessments and risk-mapping in the context of disaster risk reduction (Yamin *et al*., 2005; Larsen and Gunnarsson-Östling, 2009). Many of these ideas and methods have carried over into adaptation initiatives as a means to identify climate-related hazards and risks (Van Aalst *et al*., 2008). For instance, CBA has been adopted in the Philippines and Bangladesh to plan for flood reduction and disaster management (Ensor and Berger, 2009) as well as in cities such as Durban where local communities are engaged in climate risk assessments and adaptation planning (Carmin *et al*., 2012). These activities are designed to foster the transition from assessment to planning to implementation and, in the process, to sensitize communities to climate-related issues while promoting wide-spread adaptation action.

Community members also can contribute to local knowledge in support of government initiatives. For instance, in efforts to address climate adaptation and sustainable resource management needs, local residents from the southwest Yukon in Canada supported forest management plans by providing input on strategic benchmarks and design of appropriate harvest activities (Ogden and Innes, 2009). Community engagement also has been used by governments to ensure that local needs are. One example is the Government of Fiji which introduced a provision for including disaster-affected communities in disaster assessments. Responsibility for surveying and assessing damage was delegated to the affected communities. The information that was collected was then used to inform the design of disaster response and recovery programs (Meheux *et al*., 2010).

14.4.1.5. Local Civil Society and Nongovernmental Organizations

Civil society actors, including NGOs and community-based organizations, also contribute to adaptation, both through dedicated initiatives as well as in the course of their ongoing work. NGOs have the potential to support government action as well as to take independent action that facilitates adaptation beyond government programs. Some programs are initiated by governments. For instance, in Quito, local NGOs receive funding from the government to train indigenous farmers to improve water resource management, particularly in the context of urban agriculture, diversify crops and privilege those that are native, and replant native tree species in hillside areas. The NGOs also work with indigenous communities, teaching them to monitor variations in rainfall and flows from local rivers and then sharing that data with municipal staff so that tracking of water levels is up-to-date (Carmin *et al*., 2012; Anguelovski and Carmin, 2011).

Some programs are initiated by governments, while others originate from NGOs and CBOs. Cameroon, for example, has low adaptive capacity with limited ties within and across levels of government. While many government departments had limited awareness and were taking little to no action on climate change, Brown *et al*. (2010), found that NGOs and other civil society organizations contributed to government capacity. In particular, they found that while many NGOs working at the local level focus on sustainable development rather than climate change, organizational representatives took advantage of the synergies in these two areas and were helping local residents prepare for climate impacts (Brown *et al*., 2010). As this example suggests, civil society actors can contribute to the capacity of local governments and foster mainstreaming by supporting and promoting adaptation activities (Brown, 2010; Carmin *et al*., 2012).

14.4.2. District, State, and National Actors and Roles

14.4.2.1. District, State, and National Governments

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 can develop regulations and provide policy direction to district, state, and local governments. Drawing on an analysis of published articles, Berrang-Ford *et al*. (2011) found that upper levels of government, particularly national governments often used institutional mechanisms such as laws and policies to foster adaptation. In some instance financial support was made available, particularly where adaptation was taking place at the national level. In addition, 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). Although there are general trends in the impact that national actors have on adaptation efforts, there also are differences in developed and developing countries. Among the key differences noted are that higher income countries are more often include governmental engagement in planning and implementation, focus on non-resource-based sectors, pursue long-term planning processes that include activities such as building partnerships and research, and rely on institutional, governmental, and guideline-based protocols (Berrang-Ford *et al*., 2011).

14.4.2.2. National Civil Society and Nongovernmental Organizations

Civil society and nongovernmental organizations play critical roles in the climate adaptation agenda at different levels of social hierarchy. CSOs and NGOs can fill roles associated with monitoring and evaluation, be instrumental in information dissemination and awareness-raising, and stimulate individual and collective climate adaptation actions (Martens *et al*., 2009). They also can serve as catalysts and facilitators. For instance, while many government departments in Cameroon had limited awareness and were taking little to no action on climate change, Brown *et al*. (2010) found that NGOs and other CSOs contributed to national government capacity by enhancing the ability to respond to new international policies, particularly with respect to climate change and forests.

14.4.2.3. Private Sector

The role of the private sector is fundamental in delivering adaptive changes. Most 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 Chapter 15). However, the delivery of adaptation actions ranges more widely and spans different types of private enterprise, from small farmers, to SMEs to multinational companies. As suggested by Figure 14-1, **t**here are three general ways in which the private sector can become involved in adaptation (Khattri, *et al.,* 2010). The first, internal risk management is critical to firms and enterprises protecting their own interests and ensuring continuity. The second form of involvement is recognizing that business is a stakeholder and therefore, participates in public sector and civil society initiatives. One example of this type of engagement was the adaptation planning process in New York City. As part of the initiative, The New York City Panel on Climate Change was established and consisted of diverse stakeholders, including scientific experts and representatives from the private sector. In addition, the New York City Climate Change Adaptation Task Force, consisting of representatives from government agencies and the private sector was formed (Rosenzweig *et al*., 2011).

[INSERT FIGURE 14-1 HERE]
Figure 14-1: A typology of private sector engagement in adaptation (Khattri *et al*., 2010).]

Third, climate adaptation also provides new opportunities to the business community. In addition to fostering cooperation across government departments, relationships and partnerships with the private sector and NGOs can help to promote climate resilience and build the adaptive capacity of the urban poor. In an assessment of business potential in the context of adaptation, Khattri *et al*. (2010) concluded that there were a wide range of opportunities. In addition to financial instruments and risk management, they noted options for working in the healthcare, waste and water management, sanitation, housing, energy, and information sectors (Khattri *et al.,* 2010). The opportunities were based on their assessment of income potential in combination with enhancing adaptation in particular sectors as well as in building the capacity of the urban poor.

KPMG (2008) sought to identify the sectors where businesses face the greatest risks. The core risks were identified, in order of perceived importance, as regulatory, physical, reputational and litigation risk. The sectors identified as most at risk included an expected cluster around oil & gas and aviation, and also a group less commonly perceived to be at risk, including Health care, the financial sector, tourism and transport.

Despite some examples of private section engagement in adaptation, most assessments conclude that action in each in each of the potential arenas has been slow to emerge (Khattri *et al*., 2010). KPMG (2008) concluded that while

companies are well used to managing business risk they are 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 private sector appears to be unaware 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. Also, there are still questions of whether and how adaptation finance should be made available to the private sector in developing countries (Persson et al, 2009; IFC, 2010) although this is being piloted through the Pilot Program for Climate Resilience (World Bank, 2008; IFC and Asian Tiger Capital Partners, 2010).

14.4.2.4. International Organizations and Institutions

International organizations and institutions include intergovernmental organizations, multilateral and bilateral agencies, multinational corporations, and nongovernmental organizations. These actors engage in a variety of activities that affect adaptation at the international, national, and local levels. Among the roles played by intergovernmental organizations is the formation of treaties and agreements and creation of international funding mechanisms. For instance, the Adaptation Fund and the Nairobi Work Programme, among others, are international institutions designed to facilitate adaptation at the national and regional levels (Ayers, 2009; Ayers and Huq, 2009; Flam and Skjaerseth, 2009; Hardee and Mutunga, 2009; Kalame *et al*., 2011; Lu, 2011). Multilateral and bilateral agencies typically focus on the provision of development assistance and the creation and implementation of capacity building programs. Through these efforts, agencies allocate funds, transmit information, and disseminate technology.

International NGOs, particularly international development, aid, and humanitarian organizations, have long histories of working on adaptation-related activities. Organizations such as CARE and Red Cross/Red Crescent work directly with communities to plan for water and sanitation as well as offer educational programs designed to provide information about climate risks (Suarez *et al*., 2008). Numerous development organizations work on issues related to livelihood. Development initiatives not only have the potential to address poverty alleviation, but can reduce vulnerability by promoting adaptive capacity (Burton *et al*., 2002; Huq *et al*., 2003). As a number of studies show, while these activities may be oriented to promoting rural livelihoods in the context of environmental and development projects, they have co-benefits of building local capacity and promoting adaptive responses that enable communities to be better prepared to cope with climate impacts (Rojas Blanco, 2006; Pouliotte, 2009).

14.5. International, National, and Sectoral Assessments

Need introduction on purposes and types of assessments. Should there be a section on the frameworks etc and process of assessment?

14.5.1. National Communications to the UNFCCC

Under the Convention, all Parties are encouraged (Annex 1 countries are required) to report on their 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. Annex 1 countries are due to submit their 6th Communications by 2014 and most non-Annex1 countries have submitted at least one Communication and some their second.

Non-Annex I Parties are encouraged to provide information their vulnerability to the impacts of climate change in key vulnerable areas and, to the extent possible, an evaluation of strategies and measures for adapting to climate change in key areas. The UNFCCC model for dealing with adaptation was to follow three phases; (i) identifying possible impacts and options; (ii) measures to increase capacity; and (iii) measures to facilitate adaptation. There has

been concern whether the National Communications within developing countries are sufficiently well supported and frequent to move through these stages as quickly as now appears necessary (Burton *et al*. 2002).

A stronger indicator of an increased recognition of the need for adaptation actions is the increase in its inclusion in Poverty Reduction Strategy Papers (PRSP) that are prepared by developing countries through a participatory process involving domestic stakeholders as well as development partners. PRSPs describe the country's macroeconomic, structural and social policies and programs over a three-year or longer horizon to promote broad-based growth and reduce poverty, as well as associated financing needs and sources. However, there is still an opportunity for better integration of the PRSPs with NAPAs and, in the future, presumably with the NAPs (Kramer 2007).

14.5.2. National Adaptation Programmes of Action (NAPAs)

The NAPAs were born out of the seventh Conference of the Parties to the UNFCCC (COP 7), held in Marrakech in 2001. COP 7 saw the establishment of specific funds for assisting the Least Developed Countries in managing the impacts of climate change (the LDC Fund), and the first step of this assistance was the funding of National Adaptation Programmes of Action. Guidance for NAPA preparation was developed by the Least Developed Countries Expert Group (LEG).

The LEG defines the purpose of NAPAs as a vehicle for LDCs to communicate their most "urgent and immediate adaptation needs" to the UNFCCC for funding from the LDC Fund. "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 (Least Developed Countries Expert Group, 2009). Guidelines for NAPA project preparation prepared by the LEG recommend four key steps for NAPA preparation. These include:

1. The synthesis of available information on the adverse effects of climate change and coping strategies, which needs to be collated and reviewed;
2. A participatory assessment of vulnerability to current climate variability and extreme events and of areas where risks would increase due to climate change;
3. The identification of key adaptation measures;
4. The identification of prioritization criteria for selecting NAPA activities for inclusion in the NAPA document and for submission to the LDC Fund.

Based on these steps, each country produces a NAPA document that lays out this list of priority project activities, which then need to then be developed into full project documents, and can then be submitted for funding under the LDC Fund, or to other funding sources.

To date, 47 countries have submitted their NAPAs (see http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php).

Key Lessons from NAPAs

NAPAs constitute a body of early adaptation planning and reflect a growing recognition under the UNFCCC of the links between climate change and development processes; the need for context-specific and country-driven planning processes for adaptation; and the need for multi-stakeholder approaches to both planning and implementation. For example, the annotated NAPA guidelines explicitly recognise the underlying factors related to development that exacerbate vulnerability, and the need to address these to build resilience to climate change ((Least Developed Countries Expert Group, 2009). NAPAs are based on several key principles: Preparation should be 'country driven'; NAPAs should be developed through participatory processes involving a variety of stakeholders across relevant government, civil society and private sectors; prominence given to community-level input as an important source of information; and they should be complementary to and build on existing development and environmental plans and programmes ((Least Developed Countries Expert Group, 2009).

Yet, the few critical reviews of country experiences in developing NAPAs suggest that much can be learned for improving adaptation planning under other processes such as the National Adaptation Plans (NAPs) currently under discussion. These include:

First, the need to focus on medium and long term programmes and processes, rather than short term 'projects'. Schipper (2007) suggests that in taking a projectised approach to adaptation contradicts the need to see adaptation as a process of building adaptive capacity by creating the enabling conditions for adaptation to take place. Indeed, the notion of meeting 'urgent and immediate' needs reveals that adaptation is something that can be done in the short term, and not part of a longer term planning process.

Second, the need to provide adequate guidance on the engagement of multiple stakeholders (Kaur and Ayers, 2010). For example, the LDCF guidelines for NAPA preparation state that multi-stakeholder participation and the incorporation of local knowledge should be key elements of the NAPA preparation process (LEG 2002). However, critics observe that this guidance was lacking on the mechanisms of participation, and as such many NAPAs adopted a cursory 'consultation rather than participation' approach (Ayers, 2011; COWI/IIED 2009); and participation has been limited to identification of adaptation needs only, and not carried forward to implementation. Furthermore, the projects tend to overlook the role of rural institutions, whether in terms of consultation or coordination (Agrawal and Perrin, 2008).

Third, the critical role that supporting NAPAs can play in building country-capacity for adaptation planning (Ayers, 2008; Osman-Elasha and Downing, 2007). However, the extent to which capacity is built depends on the approach taken to stakeholder engagement, and the level of ownership taken in planning at the national (COWI/IIED, 2009) and sub-national (Agrawal and Perrin, 2008) level. Agrawal and Perrin suggest that NAPAs tend to build the capacity of national governments and agencies rather than local actors and local institutions (Agrawal and Perrin, 2008).

Fourth, the need for adequate implementation strategies accompanying NAPAs. Only around 30% of the NAPAs dedicate a specific paragraph on an implementation strategy or framework[4], while a little more than 20% of them have general implementation arrangements detailed[5]. From this, several observations can be drawn: the fact that the long-term role and impact of NAPAs are often not clearly defined, that the execution of the projects tend to be still very centralized and state-based and that the roles and responsibilities of non-state actors, notably NGOs, tend to be unclear. Some problems were identified (notably regarding actor's technical capacity and funding), which did not prevent some countries to devise elaborate and innovative strategies.

[FOOTNOTE 4: These countries are Bhutan, Comoros, Djibouti, Lesotho, Malawi, Maldives, Nepal, Samoa, Sao Tome E Principe, Senegal, Solomon Islands, Tanzania, and Uganda.]

[FOOTNOTE 5: These countries are Burundi, Cape Verde, Gambia, Guinea, Haiti, Kiribati, Lao PDR, Mali, Mauritania, and Tuvalu.]

_____ START BOX 14-1 HERE _____

Box 14-1. The Case of Nepal

Among the NAPAs, Nepal stands out as with a very elaborate implementation strategy that is part of a broader framework. As Ciplet *et al*.explains, it 'has gone far beyond the basic NAPA criteria to build institutional capacity for long-term adaptation planning and action' (Ciplet *et al.*, in press: 2). The Government of Nepal developed an "expanded NAPA" that 'acts as a catalyst for building broader institutional capacity, knowledge, and leveraging investment around long term adaptation planning' (Ciplet *et al*., in press: 3). The NAPA is seen as 'the basis for all support to adaptation activities in Nepal in order to ensure a coherent programmatic approach and systematic reduction of vulnerability and climate change impacts nationwide.' (Nepal: 22). This implies the setting up of a 'common coordination, management and monitoring mechanism' for the implementation of all adaptation projects to come. It is also noted that '(the) framework will facilitate the channeling of financial resources and technical expertise for adaptation to the local level as efficiently as possible'.

Concretely, the proposed framework, ensuring the long-lasting impact of the NAPA and the future use of the information and lessons it allowed to gather, is structured as follows:

- Preparation and dissemination of a NAPA document (…);
- Development and maintenance of a Climate Change Knowledge Management and Learning Platform for Nepal
- Development of a Multi-stakeholder Framework of Action for Climate Change in Nepal. (Nepal: 6).

The NAPA process in Nepal also led to the preparation of the LAPA (Local Adaptation Plan of Action) framework and LAPA manual, which aims to integrate adaptation options in the local planning process. The LAPA process provides opportunities to further assess site-specific climate vulnerabilities, identify adaptation options, and implement adaptation actions with people's participation (GON, 2011a). The LAPAs have been adopted as a National Framework, which specifies over 80 percent of the total budget of the climate change programmes will be channeled to the local level, for processes driven by local ownership and leadership (GON, 2011b).

_____ END BOX 14-1 HERE _____

Finally, the need to follow-up planning with adequate funding for implementation. So far, NAPA projects have not been substantially financed, which, according to LDC delegates, adds to the hindrances posed by the access procedures to LDCF funding and by slow funding (Ciplet *et al*., in press). Ciplet *et al*. observe that, as of May 2011, the GEF Chief Executive Officer endorsed or approved only 28 NAPA projects to be funded. One result of this financial issue seems to have been the accumulation of delays and the outdatedness today of many of the needs first assessed in the NAPAs (Ciplet *et al*., in press).

14.6. Measuring Adaptation

Work on adaptation has tended to lag behind mitigation efforts in both in research and in the climate negotiations (Burton *et al*., 2002; Arnell, 2009). A partial reason is that adaptation and development specialists, governments, NGOs and international agencies have found it difficult to clearly define and identify precisely what constitutes adaptation and what distinguishes it from effective development [14.2.1]. Also adaptation has no common reference metrics, as does mitigation; namely tonnes of GHG, or radiative forcing values.

14.6.1. Understanding Measurement

The search for metrics for adaptation will remain contentious with multiple alternatives competing for attention. This is inevitable as there are multiple purposes and viewpoints in approaching the measurement of adaptation. Institutions, communities and individuals value things differently and many of those values cannot be captured in a comparable way by metrics (Adger and Barnett, 2009).

At least three types of measurements are relevant to adaptation each requiring different characteristics of its metrics. The first are metrics to help determine the need for adaptation. These metrics usually focus on measuring vulnerability, but that term is not well defined as is discussed below. Further, even within this application often the goal is not to produce a score or rating for application but to elucidate information on the nature of vulnerability and to better identify adaptation options (Smit and Wandel, 2006). The second set of metrics relates to measuring the process of implementing adaptive actions such as spending on coastal protection, the installation of early warning plans, or the number of agricultural specialist with appropriate training in climate risks. Here the selection of appropriate metrics is usually less contentious but although there is disagreement as to how much they represent adaptation versus normal development. The third set relates to measuring the effectiveness of adaptation. This set is essential to help measure progress and provide feedback on the effectiveness of actions, but are among the most difficult to identify as adaption outcomes take time to become identifiable.

This section elaborates further on the selection of metrics for the first of the above goals; i.e. for determining the basis of vulnerability (or resilience) and the need to adapt. Section 15.2.2xx deals further with measuring the effectiveness of implementation and section 16.x.xx on the monitoring the effectiveness of adaptation activities.

14.6.2. What Needs 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 (i) exposure to specific hazards or stressors, (ii) sensitivity to their impacts and (iii) 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 (Sections 14.2.1.1.1 and 14.2.1.1.2; Eakin and Luers, 2006; Füssel and Klein, 2006; Eriksen and Kelly, 2007; Füssel, 2007; Füssel, 2010) and scientific framing versus a human-security framing of vulnerability (O'Brien, 2006). 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. But experience repeatedly cautions us to be conservative in applying common questions and metrics of vulnerability across diverse places, groups or sectors (Schröter *et al.*, 2005). Also, a system's vulnerability is not static but responds to changes in economic, social, political and institutional conditions over time (Smit and Wandel 2006; Smit and Pilifosova, 2003).

It has also been suggested that a framework based on the concept of resilience is more appropriate than a vulnerability framework in many contexts. 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" (Moss *et al.*, to appear). A resilience approach leads to more focus on interactions between social and biophysical systems (Nelson *et al.*, 2007). However, the concept of resilience has proven very 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 it has become an umbrella concept that has not been able to support effectively planning or management.

But vulnerability is not adaptation. Smit *et al.* (2001), Osman-Elasha *et al.* (2008) and others have suggested that our focus should be on increasing adaptive capacity within the context of the full range of biophysical and socio-economic stressors. But metrics designed to capture these aspects are often less suitable for distinguishing 'adaptation' from 'sustainable development' (McGray *et al.*, 2007) and thus may be less suitable for other purposes such as helping to identify "the full and additional costs of adaptation".

Vulnerability indices have usually been designed to better understand the drivers of vulnerability or to compare countries, regions, communities etc. 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 we might expect that vulnerability and coping/adaptive capacity would remain a core consideration, but so also should the ability of the recipients to absorb the funding and implement policies and projects to actually achieve the projected benefits (UNFCCC, 2007; Wheeler, 2011).

In deriving indices of vulnerability there are again two broadly different approaches. One is to deductively identify indicators that theoretically should be strongly related to vulnerability, 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, which have been concisely summarized by Perch-Nielsen (2010) in Table 14-1.

[INSERT TABLE 14-1 HERE
Table 14-1: Set of criteria for selection of indicators (Perch-Nielsen, 2010).]

14.6.3. Established Metrics

14.6.3.1. Vulnerability Metrics

Numerous metrics continue to be prepared for a variety of purposes and at scales ranging from comparing the vulnerability of communities to countries. Several reviews including Moss (2001, to appear), Srinivarsan and Prabhakar (2008), Anderson *et al*. (to appear) that discuss both the design and effectiveness of many of the existing proposals for adaptation metrics.

Eriksen and Kelly (2007) compared five measures for comparing national vulnerability published over the period 1995 to 2003. (Namely the Vulnerability-resilience indicators of Moss *et al*., 2001; the Environmental Sustainability Index of the World Economic Forum, 2002; the Dimensions of vulnerability of Downing *et al*., 1995; the Index of Human Insecurity (IHI) of Lonergan *et al*. 1999; and the Country-level risk measures, 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 top 20 ranked countries derived 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 indices were developed at different times and for different purposes. They concluded that the indices focused on measuring a snapshot of aggregate conditions nations rather than 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 (UNDP Disaster Risk Index, 2004; Hotspots Index of Dilley *et al*., 2005; the Americas Index of Cardona, 2005; and an index for South Asia of Moench *et al*., 2009). Again there has been little effort to further analyse, validate or compare these indices.

14.6.3.2. Metrics and Resource Allocation

Metrics for adaptation do come into play in major decision making processes about the allocation of funding. One of the longest running and prominent use 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 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), 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 expert group to make recommendations as to which countries might be included as pilots within the c. USD1billion program Climate Investment Fund 2008). The expert group refrained from using a simple index, but

instead country selection was done across 9 regions and based on a suite of indices appropriate for the region and on expert judgment. The twelve indicators were used by the expert group reflected both the outcome and contextual concepts of vulnerability and the most consistently used were:

1) The Human Dimension Index
2) An index based on the proportion of the population affected by climate related disasters in the past 30 years
3) The percentage of the population undernourished
4) The percentage of the population without access to improved water
5) The percentage of the population in the low elevation coastal zone.

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 bought forward (CIF 2009). None of the other governing bodies of international funding mechanisms (e.g. the GEF, 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 that science cannot be relied upon for a single objective ranking of vulnerability.

14.6.3.3. 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*. (2011) identify three specific roles of evaluation: a) ensuring reduction in societal and ecological vulnerability; b) facilitating learning and adaptive management; and c) 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 (Gagnon-Lebrun and Agrawala, 2006; Perkins *et al*., 2007; Füssel, 2008; Smith *et al*., 2009; Ford *et al*., 2011; Preston *et al*., 2011). 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; Hedger *et al*., 2008; IGES, 2008; Ford *et al*., 2011).

One of the central unresolved tensions in progressing evaluation is the relative merit of targeting adaptation processes versus outcomes. Preston *et al*. (2011) suggest the evaluation of adaptation processes may be a more robust approach to evaluation, due to the challenges 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). Much of the adaptation evaluation literature focuses on the evaluation of adaptation planning and/or programs rather than specific adaptation actions for a given sector or region and much of the adaptation activity represents capacity building rather than the reduction of vulnerabilities (Preston *et al.,* 2011).

The OECD analyzed the monitoring and evaluation processes across 106 projects across six development agencies and found that Results Based management and Logical Framework approached dominated as they do in normal development projects (Lamhauge *et al*., 2011). They drew attention to the need for appropriate baselines and complimentary sets of indicators that track not just process and implementation, but also the extent to which targeted changes are occurring. Monitoring programs themselves need careful design to ensure that they remain in place over the long timeframes 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.

14.6.4. Validation of Metrics

The practice of developing and applying metrics in adaptation has been subject 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. Downing (to appear) has made a similar critique. Nevertheless indices 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, Adger and Kelly, 2004. They used the probability of climate related mortality from the CRED data-base as a proxy for risk and a set of 46 social, governance, economic and biophysical measures as indicators of essentially social vulnerability. They then used an inductive approach to identifying indicators by analyzing the number of people killed in climate related disasters over recent decades in relation to a wide range of potential indicator variables. They found 11 that were selected as effective indicators and these were confirmed as useful by a small focus group (7 people) of 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 a 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.

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 measures needed and a systematic approach to identify measures that covered the range of countries and time scales. The derivation of the index from the separate measures was also subjected to robustness (sensitivity) testing to determine the most appropriate methods of scaling and combining the measures.

14.6.5. Assessment of Existing and Proposed Metrics for Adaptation

Srinivarsan and Prabhakar (2008) conducted a wide-ranging stakeholder survey to assess the attitudes to and requirements of indicators for 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, data checking) are badly needed. But metrics for adaptation remain a necessity. Their derivation challenges the adaptation community to clarify its goals, conceptual models, definitions and applications. But as both theory and practice has shown indicators 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.

14.7. Addressing Maladaptation

14.7.1. Defining Maladaptation

Development interventions usually contribute to reducing vulnerability and improving the overall adaptive capacity of the targeted sector or communities to potential climate change impacts. However, in some cases, the development approach followed may unintentionally result in increased vulnerability. For example, better engineering of roads to

withstand current and even future climate extremes may foster new settlement into areas highly exposed to the impacts of future climates. This is usually described as maladaptation, which was defined by the IPCC AR3 (2001) as "any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead". The IPCC further states that maladaptation results from decisions that prevent or constrain the ability of others to manage, reduce or otherwise adapt to the effects of climate change (IPCC, 2001). In AR4 the term maladaptation was not defined, although it was used occasionally. OECD (2009) in providing policy guidance on mainstreaming adaptation in development programs used a similar definition to IPCC AR3 but with more emphasis on "business-as-usual development which, by overlooking climate change impacts, inadvertently increases exposure and/or vulnerability to climate change."

Five dimensions of maladaptation were identified by Barnett and O'Neill (2010) including: actions that increase emissions of greenhouse gases such as the use of air conditions to ameliorate the high temperature resulting from climate change; actions that disproportionately burden the most vulnerable; actions that have high opportunity costs; actions that reduce incentives and capacity to adapt; and setting paths that limit future choices.

14.7.2. Causes of Maladaptation

Maladaptive actions and processes often include planned development policies and measures that deliver short-term gains or economic benefits but lead to exacerbated vulnerability in the medium to long-term. Similarly, the construction of 'hard' infrastructure may reduce flexibility and the range of future adaptation options (OECD**,** 2009). Also, failure to account for multiple interactions and feedbacks between systems and sectors may provide inadequate or inaccurate information for developing adaptive responses and lead to maladaptive strategies (Scheraga *et al*. 2003). An assessment of the downstream impacts of upstream rainwater harvesting in a semi-arid basin in Southern India showed that the net benefits were insufficient to pay back investment costs (Bouma *et al*., 2011). It is important to identify all the potential socio-economic and environmental impacts that could represent maladaptation by assessing potential risks and incorporating adaptation strategies in development planning (Satterthwaite *et al*, 2009).

Projects that are intended to reduce poverty may not contribute to reducing vulnerability (Adger *et al*., 2003; Eriksen and Kelly, 2007; Klein, 2010a). For example, the conversion of coastal mangroves into shrimp farms may increase economic productivity, but this also leads to increased vulnerability to flooding and storm surges (Klein, 2010a). In other situations, adaptation efforts aimed at armoring the coastline may result in coastal erosion elsewhere while building levees along a flood-prone area might encourage unwanted development within that area (National Research Council, 2010). Other examples of potential maladaptive actions include continued development of highly vulnerable coastal areas (Repetto 2009) and agricultural policies that promote the growing of a high yielding crop varieties through subsidies with the objective of boosting production and increasing revenues, may reduce agro-biodiversity and increase exposure and vulnerability of mono-crops to climate variability and change and finally undermining the adaptive capacity of farmers.

14.7.2.1. Experiences with Maladaptation

Maladaptation is a cause of increasing concern to adaptation planners, where intervention on one sector could increase vulnerability of another sector or group. A situation experienced by subsistence and smallholder agriculturalists in Palca, Bolivia who implemented a package of strategies, often centred on intensification of labour and inputs, to sustain their livelihoods in response to a multiple set of stressors, but faced by a number of potential negative feedbacks arising from these interventions rendering them vulnerable to the risk of insufficient adaptation and maladaptation, (Heltberg *et al.,* 2009b). Another example of maladaptive adaptation actions is the development of the Wonthaggi desalinization plant to improve water supply to Melbourne City in Australia. The plant will damage thirteen sites significant to the Bunurong Aboriginal community and it will also lead to higher water costs that will disproportionally affect the poorer households (Lee and Chung, 2007).

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 described by some as maladaptive, while a more focused studies on these responses indicated that they are appropriate and well adapted to the local circumstances, Agrawal and Perrin (2008).

14.7.2.2. Relationship between the Adaptation Deficit and Maladaptation

Adaptation deficit is a related but different concept from maladaptation. It is defined as the inadequate adaptation to the current climate conditions (Section 14.xxxx; Parry, 2009; Burton *et al*., 2002; Burton, 2004). The deficit may arise from past inaction, the mismanagement and depletion of natural resources, or maladaptive decision in the past. The adaptation deficit may also result from a low level of development and the consequential reduced capacity to cope with climate variability. Thus, the adaptation deficit may be part of a larger development deficit (World Bank, 2010). In the process of building future adaptive capacity it is important to reduce the current adaptation deficit, in addition to the need for designing effective risk management and climate change adaptation measures. (Hallegatte *et al*., 2011).

14.7.3. Screening for Maladaptation

14.7.3.1. Methods for Assessing Viability of Adaptation Measures

Adaptation to climate change is increasingly been considered in the development agenda as it became evident that it is not possible to make development or investment decisions while neglecting the potential impacts of climate change. In general terms, adaptation could be approached in the context of development through (1) responding to specific projected climate impact scenario and risk management plan (2) reducing general vulnerability and building climate resilience. A series of interventions can be introduced along the continuum ranging from mainly adaptation to mainly development activities. However, it is perceived that adaptation could be more efficient if it involves all the challenges along the wider spectrum, which has an important bearing on financing adaptation and focusing mainly on adaptation rather than development initiatives, (McGray *et al*., 2007). To avoid a state of maladaptation, screening of development interventions and adaptation measures is considered as an essential step in order to make sure that they are not going to negatively impact or increase the vulnerability of other systems, sectors or social groups. (Barnett and O'Neill 2010: 211). According to Parry *et al*. 2007, it is possible to decide if an adaptation intervention has been successful by measuring the extent to which it exploits beneficial opportunities.

14.7.3.2. Methods for Preventing Maladaptation

Maladaptation is not necessarily associated with climate change as it can take place even under normal conditions due to inappropriate decision. An example is the expansion of infrastructural development in low coastal zones, which are frequently subjected to floods and storms. Avoiding these practices would be the first step in addressing maladaptation. The next step would be, to plan and design adaptation strategies, for implementation and monitoring and evaluation of their performance. To this end it is critical to make use of existing technologies to develop information and awareness for adaptation in highly vulnerable zones (Basher, 2001).

14.8. Research Gaps and Data Gaps

[To be developed along with other chapters in next draft]

Frequently Asked Questions

FAQ 14.1: Are there different definitions of adaptation, and if so, which one is used by the IPCC AR5?
The most commonly used definitions of adaptation remain based on the IPCC AR3 definition ("adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"), but with some important elaborations being proposed. The IPCC SREX modified the definition to deal separately with human and natural systems and included an element of purposefulness in human adaptation actions (i.e. "in order to moderate...")[6]. In AR5 we will use the SREX definition and refer to 'autonomous adaptation' to explicitly cover adaptive responses triggered by factors other than perceived or anticipated climate change. Others have sought to place adaptation into a wider context of interacting non-climatic changes and more clearly to include purposeful adaptation actions that do not succeed in moderating harm. Increasing focus on the costs of adaptation and on evaluating adaptation practices has led to more attention to what constitutes *successful* adaptation. Some definitions of success emphasize reducing risks to a predetermined level while other focus on achieving predetermined levels of social and or economic well being (14.2.1).

[FOOTNOTE 6: IPCC SREX definition of adaptation: "In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate."]

FAQ 14.2: Is there a difference between adaptation to climate change and adaptation to climate variability?
Both the IPCC AR3 and SREX definitions refer only to climate stimuli, or simply to climate, and thus include actions in response to current climate variability and climate change. Actions in response to currently climate variability may be considered to be dealing with the 'adaptation deficit'; i.e. the failure to adapt adequately to existing climate risk. (14.7.3.1)

FAQ 14.3: Can adaptation be distinguished from normal development actions?
Adaptation and development are inextricably linked. Development that brings improvements in livelihoods, greater access to resources and more resilience to the wide variety of volatilities faced by household and communities, will usually also achieve adaptive outcomes (see 'autonomous adaptation' above). However, pursuing development priorities without looking ahead to a world with a changed climate could undermine development efforts either by failing to adjust to the possibility of changed climate or through actions that cut off options to deal with changed climates (maladaptation). (14.2.2.2 and 14.7.2)

FAQ 14.4: Is adaptation a facet of disaster risk management (DRM) or is it vice versa?
Neither. There is a strong overlap in the information needed, measures and policies applied, and goals of adaptation to climate change and DRM. Integration of the efforts across all levels of government and civil society will be efficient and more fruitful than their separation. But the overlap is not complete. For example, DRM deals with a wider range of hazards (e.g. earthquakes, chemical escapes etc.) while adaptation also has to take account of slow changes that are not perceived as disasters (e.g. slowly changing agricultural conditions). Any integration will be more effective if it respects and accommodates these differences. (14.2.2.3)

References

ACCCA, 2009. Synthesis Report: Lessons learned on climate change science and risk communication in the ACCCA Project, UNITAR.
Adger, W.N., 2006: Vulnerability. *Global Environmental Change*, **16**, 268–281.
Adger, N.W. and J. Barnett, 2009: Commentary: Four reasons for concern about adaptation to climate change. *Environment and Planning A*, **41**, 2800-2805.
Adger, W.N., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. Nelson, L.-O. Naess, J. Wolf, and A. Wreford, 2009: Are there social limits to adaptation to climate change? *Climatic Change*, **93(3-4)**, 335–354.
Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit, and K. Takahashi, 2007: Assessment of adaptation practices, options, constraints and capacity. In: *Climate Change*

2007: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 717-743.

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. Huq, K. Brown, D. Conway, and M. Hulme, 2003: Adaptation to climate change in the developing world. *Progress in Development Studies*, **3(3)**, 179-195.

Adger, W.N., N. Brooks, G. Bentham, M. Agnew, and & S. Eriksen, 2003: *New Indicators of Vulnerability and Adaptive Capacity*. Technical Report No. 7, Tyndall Centre, Norwich, UK, 128 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., 1999: Social vulnerability to climate change and extremes in coastal Vietnam. *World Development*, **27(2)**, 249-269.

Adger, W.N. and P.M. Kelly, 1999: Social vulnerability to climate change the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, **4(3-4)**, 253-266.

Agrawal, A., 2010, Local institutions and adaptation to climate change. In: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World* [R. Mearns and A. Norton (eds.)]. The World Bank, Washington DC, pp. 173-198.

Agrawal, A. and N. Perrin, 2008: *Climate Adaptation, Local Institutions, and Rural Livelihood*. IFRI, Working Paper #W08I-6.

Agrawala, S., 2005: Putting climate change in the development mainstream: introduction and framework. In: *Bridge Over Troubled Waters: Linking Climate Change and Development* [S. Agrawala (ed.)]. Organization for Economic Co-Operation and Development, Paris, France, pp. 23-43.

Agrawala, S. and M. Carraro, 2010: *Assessing the role of microfinance in fostering adaptation to climate change*. OECD Environment Working Papers No. 15, Organizations for Economic Co-Operation and Development Publishing, Paris, France, 38 pp.

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 Papers, No. 39. OECD Publishing, Paris, France, 56 pp.

Agrawala, S. and M. van Aalst, 2008: Adapting development cooperation to adapt to climate change. *Climate Policy*, **8(2)**, 183-193.

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.

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.

Amundsen, H., F. Berglund, and H. Westskog, 2010: Overcoming barriers to climate change adaptation—a question of multilevel governance? *Environment and Planning C: Government and Policy*, **28**, 276-289.

Anderson, S., J. Cavanagh, J. and Redman, 2008: *Skewed Priorities: How the Bailouts Dwarf Other Global Crisis Spending*. Institute for Policy Studies, London, UK, 18 pp.

Anguelovski, 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* (C. Rosenzweig, W.D. Solecki, S.A. Hammer, and S. Mehotra (eds.)]. Cambridge University Press, Cambridge, UK, pp. 262.

Anon, 2010: *Economic Vulnerability and Disaster Risk Assessment in Malawi and Mozambique: Measuring Economic Risks of Droughts and Floods*. World Bank, RMSI, IFPRI and GFDRR, Washington DC, USA, 16 pp.

Arnell, N.W., 2009: Adapting to climate change: An evolving research programme. *Climatic Change*, **100**, 107-111.

Asian Development Bank and International Food Policy Research Institute, 2009. Building climate resilience in the agriculture sector in Asia and the Pacific. Mandaluyong City, Philippines: Asian Development Bank.

Ayache, I., J.R. Thompson, R.J. Flower, A. Boujarra, F. Rouatbi, and H. Makina, 2009: Environmental characteristics, landscape history and pressures on three coastal lagoons in the southern Mediterranean region: Merja Zerga (Morocco), Ghar El Melh (Tunisia) and Lake Manzala (Egypt). *Hydriobiologica*, **622(1)**, 15-43.

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.
Ayers, J. and T. Forsyth, 2009: Community-based adaptation to climate change: strengthening resilience through development. *Environment*, **51(4)**, 22-31.
Ayers, J. and S. Huq, 2009a: Supporting adaptation to climate change: what role for official development assistance? *Development Policy Review*, **27(6)**, 675-692.
Ayers, J.M. and S. Huq, 2009b: The value of linking mitigation and adaptation: a case study of Bangladesh. *Environmental Management*, **43**, 753-764.
Ayers, J., 2008: Progress implementing NAPAs. *Tiempo: A Bulletin on Climate and Development*, issue 69, October 2008. International Institute for Environment and Development, London, UK, 28 pp.
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.
Basher, R.E., 2001: Data requirements for developing adaptations to climate variability and change. *Mitigation and Adaptation Strategies for Global Change*, **6**, 227–237.
Bauer, S. and I. Scholz, 2010: Adaptation to climate change in southern Africa: new boundaries for sustainable development. *Climate and Development*, **2**, 83-93.
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.
Berrang-Ford, L., J.D. Ford, and J. Paterson, 2011: Are we adapting to climate change*? Global Environmental Change*, **21(1)**, 25–33.
Berry, P., 2009: *Biodiversity in the Balance—Mitigation and Adaptation Conflicts and Synergies*. Sofia, Bulgaria, Pensoft Publishers. pp. 300.
Betsill, M.M. and H. Bulkeley, 2006: Cities and multilevel governance of global climate change. *Global Governance*, **12**, 141-159.
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.
Biesbroek, G.R., R.J. Swart, T.R. Carter, C. Cowan, T. Heinrichs, H. Mela, M.D. Morecroft, and D. Rey, 2010 : Europe adapts to climate change : comparing national adaptation strategies. *Global Environmental Change*, **20**, 440-450.
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.
Blaikie, P., T. Cannon, I. Davis, and B. Wisner, 1996: *At Risk: Natural Hazards, Peoples Vulnerability and Disasters*. Routledge, London and New York.
BMU, 2008: *German Strategy for Adaptation to Climate Change*. Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, Berlin, Germany, 73 pp.
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, E. De Cian, 2009: *An analysis of adaptation as a response to climate change*. Department of Economics Research Paper Series No. 26.09, University Ca'Foscari of Venice, Italy.
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.
Bradley, B.A., L.D. Estes, D.G. Hole, S. Holness, M. Oppenheimer, W.R. Turner, H. Beukes, R.E. Schulze, M.A. Tadross, and D.S. Wilcove, 2012: Predicting how adaptation to climate change could affect ecological conservation: secondary impacts of shifting agricultural suitability. *Diversity and Distributions*, **18(5)**, 425-437.
Brander, K., 2010: Impacts of climate change on fisheries. *Journal of Marine Systems*, **79(3-4)**, 389-402.
Brauch, H.G., 2008: Conceptualising the environmental dimension of human security in the UN. *International Social Science Journal*, **59(s1)**, 19-48.

Brooks, N., 2003: *Vulnerability, Risk and Adaptation: A Conceptual Framework*. Tech Working Paper 38, Tyndall Centre, Norwich, UK, 20 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.

Brown, J., N. Bird, and L. Schalatek, 2010: *Direct Access to the Adaptation Fund: Realising the Potential of National Implementing Entities*. ODI Climate Finance Policy Brief No. 3, Overseas Development Institute, London, UK, 10 pp.

Bulkeley, H. and M. Betsill, 2005: Rethinking sustainable cities: multilevel governance and the "urban" politics of climate change. *Environmental Politics*, **14(1)**, 42-63.

Burton, I. 2004: Climate change and the adaptation deficit. In: *Climate Change: Building the Adaptive Capacity* [A. French, *et al*. (eds.)]. Meteorological Service of Canada, Environment Canada, pp25–33.

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.

Cardona, O.D., 2005. Indicators of Disaster Risk and Risk Management: Program for Latin America and the Caribbean. Summary Report. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia.

Caribbean Community Climate Change Centre (CCCCC), 2011: Developing an Implementation Plan for the CARICOM 'Regional Framework for Achieving Development Resilient to Climate Change'. Acclimatise, Newark, UK. 138 pp.

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*, **106(5)**, 1305-1312.

Carr, E.R., 2008: Between structure and agency: livelihoods and adaptation in Ghana's central region. *Global Environmental Change*, **18**, 689-699.

Carter, T.J. (ed.) 2007 Assessing the adaptive capacity of the Finnish environment and society under a changing climate: FINADAPT. Summary for Policy Makers. Helsinki, Finland.

Carter, T.R., M.L. Parry, H. Harawasa, and S. Nishioka, 1994: *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*. London, UK, University College, 59p.

Challinor, A.J., F. Ewert, S. Arnold, E. Simleton, and E. Fraser, 2009: Crops and climate change: progress, trends, and challenges in simulating impacts and informing adaptation. *Journal of Experimental Botany*, **60(10)**, 2775-2789.

Christensen, J.H., M. Stendel, and S. Yang, 2012: Ways forward for climatology. In: *Adaptation to a Changing Climate in the Arab Countries* (D. Verner Ed.), World Bank, Washington DC, USA. Pp 37-89.

Chuku, C.A., 2010: Pursuing an integrated development and climate policy framework in Africa: options for mainstreaming. *Mitigation and Adaptation Strategies for Global Change*, **15(1)**, 41-52.

Ciplet, D., A. Chandani, and S. Huq, in press: Lessons for national adaptation planning from the least developed countries. *Nature*.

Climate Investment Funds, 2009: *The Selection of Countries to Participate in the Pilot Program for Climate Resilience (PPCR)*. World Bank, Washington DC, USA, 15 pp.

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*.

Convention on Biodiversity (CBD) Secretariat, 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. 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.

Corfee-Morlot, J., L. Kamal-Chaoui, M.G. Donovan, I. Cochran, A. Robert, and P.-J. Teasdale, 2009: *Cities, Climate Change and Multilevel Governance*. OECD Environmental Working Papers No. 14, OECD, Paris, France, 126 pp.

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*, **369(1942)**, 1866-1882.

Costello, A., M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friield, N. Groce, A. Johnson, M. Kett, M. Lee, C. Levy, M. Maslin, D. McCoy, B. McGuire, H. Montgomery, D. Napier, C. Pagel, J. Patel, 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.

COWI/IIED, 2009: *Evaluation of the operation of the Least Developed Countries Fund for adaptation to climate change*. Ministry of Foreign Affairs of Denmark, September 2009, 115 pp.

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

Cutter, S.L., B.J. Boruff, and W.L. Shirley, 2003: Social vulnerability to environmental hazards. *Social Science Quarterly*, **84**, 242.261.

Cutter, S.L., 1996: Vulnerability to environmental hazards. *Progress in Human Geography*, **20**, 529-539.

DAFF, 2006: *National Agriculture and Climate Change Action Plan 2006-2009*. Department of Agriculture, Fisheries, and Forestry and the Natural Resource Management Managerial Council, Canberra, Australia, 28 pp.

Davin, E. and N. de Noblet-Ducoudre, 2010: Climatic impacts of global-scale deforestation: radiative versus nonradiative processes. *Journal of Climate*, **23**, 97-112.

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.

De Bruin, K., R. Dellink, and S. Agrawala, 2009: Economic Aspects of Adaptation to Climate Change: Integrated Assessment Modelling of Adaptation Costs and Benefits, OECD Publishing, Paris, France.

del Ninno, C., K. Subbarao, and A. Milazzo, 2009: How to make public works work: a review of the experiences. Discussion Paper 0905, Social Protection and Labor, World Bank, Washington, DC.

Dessai, S., X. Lu, J.S. Risbey, 2005: On the role of climate scenarios for adaptation planning. *Global Environmental Change*, **15(2)**, 87-97.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and World Resources Institute (WRI), 2011: Making Adaptation Count: Concepts and Options for Monitoring and Evaluation of Climate Change Adaptation. Eschborn, Germany. 92 pp.

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. Washington, D.C: International Bank for Reconstruction and Development/The World Bank and Columbia University.

Dodman, D. and D. Satterthwaite, 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.)]. Institute for Environment and Development and Grantham Institute, London, UK, pp. 73-89.

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.

Douglas, I., K. Alam, M. Maghenda, Y. Mcdonnell, L. Mclean, J. Campbell, 2008: Unjust waters: climate change, flooding and the urban poor in Africa. *Environment and Urbanization*, **20(1)**, 187-205.

Dovers, S.R., 2009: Normalizing adaptation. *Global Environmental Change*, **19(1)**, 4-6.

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., R. Kasperson, and M. Bohn, 2006: Exploring the social justice implications of adaptation and vulnerability. In: *Fairness in Adaptation to Climatic Change* [W.N. Adger, J. Paavola, S. Huq, and M.J. Mace (eds.)]. Massachusetts Institute of Technology Press, Cambridge MA, USA, pp. 79-96.

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* [J. Smith, R. Klein, and S. Huq (eds.)]. Imperial College Press, London, UK, pp. 77-100.

Downing, T.E., Watts, M.J. and Bohle, H.G., 1995. Climate change and food insecurity: Towards a sociology and geography of vulnerability. In: *Climate Change and World Food Security*, [T.E. Downing (ed.)], Berlin, Springer, pp. 183–206.
Dupont, A., 2008: The strategic implications of climate change. *Survival*, **50(3)**, 29–54.
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**, 365-394.
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 J.G. Semenza, 2008: Community-based adaptation to the health impacts of climate change. *American Journal of Preventive Medicine,* **5(35)**, 501-507.
Engle, N.L., 2011: Adaptive capacity and its assessment. *Global Environmental Change*, **21(2)**, 647-656.
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.
Ensor, J. and R. Berger, 2009: *Understanding Climate Change Adaptation: Lessons from Community-Based Approaches*. Practical Action Publishing, Bourton-on-Dunsmore, UK, 208 pp.
Eriksen, S. and K. Brown, 2011: Sustainable adaptation to climate change. *Climate and Development*, **3(1)**: 3-6.
Eriksen, S.H. and J. Lind, 2009: Adaptation as a political process: adjusting to drought and conflict in Kenya's drylands. *Environmental Management*, **43(5)**, 817-835.
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.H. and K. O'Brien, 2007: Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy*, **7(4)**, 337-352.
Falaleeva, M., C. O'Mahony, S. Gray, M. Desmond, J. Gault, and V. Cummins, 2011: Towards climate adaptation and coastal governance in Ireland: Integrated architecture for effective management? *Marine Policy*, **35**, 784–793.
Fekete, B.M., D. Wisser, C. Kroeze, E. Mayorga, L. Bouwman, W.M. Wollheim, and C. Vorosmarty. Millenium ecosystem assessment scenario drivers (1970-2050): climate and hydrological alterations. *Global Biogeochemical Cycles*, **24(4)**, GB0A12.
Few, R., K. Brown, and E.L. Tompkins, 2007: Public participation and climate change adaptation: avoiding the illusion of inclusion. *Climate Policy*, **7**, 46-59.
Fields, S., 2005: Continental divide. *Environmental Health Perspectives*, **113(8)**, A534-A537.
Flam, K.H. and J.B. Skjaerseth, 2009: Does adequate financing exist for adaptation in developing countries? *Climate Policy*, **9(1)**, 109-114.
Ford, J.D., L. Berrang-Ford, and J. Paterson, 2011: A systematic review of observed climate change adaptation in developed nations. *Climatic Change*, **106**, 327-336.
Ford, J.D., B. Smit, J. Wandel, M. Allurut, K. Shappa, H. Ittusarjuat, and K. Qrunnut, 2008: Climate change in the Arctic: current and future vulnerability in two Inuit communities. *The Geographical Journal*, **174(1)**, 45-62.
Frank, E., H. Eakin, and D. López-Carr, 2011: Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global Environmental Change*, **21(1)**, 66–76.
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., 2009: An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. *Climatic Change*, **97**, 469–482.
Füssel, H.-M., 2008: Assessing adaptation to the health risks of climate change: what guidance can existing frameworks provide? *International Journal of Environmental Health Research*, **18(1)**, 37–63.
Füssel, H.-M. and R.J.T. Klein, 2006: Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change*, **75(3)**, 301–329.
Galindo, L.M. and J. Samanieg, 2010: The economics of climate change in Latin America and the Caribbean: stylized facts. *CEPAL Review*, **100**, 69-96.
Gagnon-Lebrun, F. and S. Agrawala, 2006: *Progress on Adaptation to Climate Change in Developed Countries: An Analysis of Broad Trends*. OECD, Paris, France, 63 pp.

Gemenne, F, 2011. Climate-induced population displacements in a 4°C+ world. *Philosophical Transactions of the Royal Society*, **369(1934)**, 182-195.

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

Gersonius, B., F. Nasruddin, R. Ashley, A. Jeuken, A. Pathirana, and C. Zevenbergen, 2012: Developing the evidence base for mainstreaming adaptation of stormwater systems to climate change. *Water Research*, in press.

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**, 342-345.

Ghesquiere, F. and O. Mahul, 2010: *Financial Protection of the State against Natural Disasters: A Primer*. World Bank Policy Research Working Paper 5429, World Bank, Washington DC, USA, 26 pp.

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)*. Global Public Policy Institute, Eschborn, Germany, 94 pp.

Guariguata, M., 2009: El manejo forestal en el contexto de la adaptación al cambio climático. *Revista de Estudios Sociales,* **32**, 98-112.

Guariguata, M., J. Cornelius, B. Locatelli, C. Forner, and G. Sanchez-Azofeifa, 2008: Mitigation needs adaptation: tropical forestry and climate change. *Mitigation and Adaptation Strategies for Global Change*, **13(8)**, 793-808.

Gupta, J., C. Termeer, J. Klostermann, S. Meijerink, M. van den Brink, P. Jong, S. Nooteboom, 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**, 2101-2109.

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

Hallegatte S., F. Lecocq, and C. de Perthuis, 2011: *Designing Climate Change Adaptation Policies: An Economic Framework*. Policy Research Working Paper No. 5568, World Bank, Washington DC, USA, 41 pp.

Halsnaes, K and S. Traerup, 2009: Development and climate change: a mainstreaming approach for assessing economic, social, and environmental impacts of adaptation measures. *Environmental Management*, **43(5)**, 765–778.

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.

Handmer, J.W., S. Dovers, T.E. Downing, 1999: Societal vulnerability to climate change. *Mitigation and Adaptation Strategies for Global Change*, **4(3-4)**, 267-281.

Hanson, S., R. Nicholls, N. Ranger, S. Hallegatte, J. Corfee-Morlot, C. Herweijer, and J. Chateau, 2011: A global ranking of port cities with high exposure to climate extremes. *Climatic Change*, **104(1)**, 89-111.

Hardee, K. and C. Mutunga, 2009: Strengthening the link between climate change adaptation and national development plans: lessons from the case of population in National Adaptation Programmes of Action (NAPAs)." *Mitigation and Adaptation Strategies for Global Change*, **15(2)**, 113-126.

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. Ruddel, 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.

Hedger, M.M., T. Mitchell, J. Leavy, M. Greeley, A. Downie, and L. Horrocks. 2008. Desk Review: Evaluation of adaptation to climate change from a development perspective. A study commissioned by the GEF Evaluation Office and financed by Department for International Development (DFID). Institute of Development Studies, UK.

Heltberg, R. and N. Lund, 2009: Shocks, coping, and outcomes for Pakistan's poor: health risks predominate. *Journal of Development Studies*, **45(9)**, 889-910.

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.

Hertel, T.W. and S.D. Rosch, 2010: Climate change, agriculture, and poverty. *Applied Economic Perspectives and Policy*, **32(3)**, 355-385.
Hess, U., W. Wiseman, and T. Robertson, 2006: Ethiopia: Integrated Risk Financing to Protect Livelihoods and Foster Development. World Food Programme, Rome, Italy.
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**, 411-416.
Hoegh-Guldberg, O., 2011: Coral reef ecosystems and anthropogenic climate change. *Regional Environmental Change*, **11(Suppl. 1)**, 215–227.
Hooghe, L. and G. Marks, 2003: Unraveling the central state, but how? Types of multi-level governance. *American Political Science Review*, **97(2)**, 233-243.
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, UK: Cambridge University Press, 432 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 H. Reid, 2009: Mainstreaming adaptation in development. *IDS Bulletin*, **35(3)**, 15-21.
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.
Huq, S., A. Rahman, M. Konate, Y. Sokona, and H. Reid, 2003: *Mainstreaming Adaptation to Climate Change in Least Developed Countries (LDCs)*. International Institute for Environment and Development, London, UK, 40 pp.
IEG Independent Evaluation Group, 2009: *The World Bank's Country Policy and Institutional Assessment: An Evaluation*. 170 pp.
Institute for Global Environmental Strategies (IGES), 2008: Expert Consultation on Adaptation Metrics.
International Finance Corporation, 2010: Climate Risk and Financial Institutions: Challenges and Opportunities. IFC, Washington DC, USA. 120 pp.
Ionescu, C., R.J.T. Klein, J. Hinkel, K.S. Kavi Kumar, and R. Klein, 2009: Towards a formal framework of vulnerability to climate change. *Environmental Model Assessment*, **14(1)**, 1–16.
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.
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* [R.K. Pachauri and A. Reisinger (eds.)]. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 104 pp.
IPCC, 2007b: *Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, 976 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 [J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds.)]. Cambridge University Press, Cambridge, UK.
Jentsch A., J. and C. Beierkuhnlein, 2008: Research frontiers in climate change: effects of extreme meteorological events on ecosystems. *Comptes Rendus Geoscience*, **340**, 621-628.
Jernek, A. and L. Olsson, 2008: Adaptation and the poor: development, resilience and transition. *Climate Policy*, **8(2)**, 170-182.
Juhola, S., E.C.H. Keskitalo, and L. Westerhoff, 2011: Understanding the framings of climate change adaptation across multiple scales of governance in Europe. *Environmental Politics*, **20(4)**, 445-463.
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, London, New York.
Kaur, N. and J. Ayers, 2010: Planning climate compatible development: lessons from experience. *CDKN IIED Policy Brief, December 2010/A*. 4pp.
Keskitalo, E.C.H. 2010. *Developing Adaptation Policy and Practice in Europe: Multi-Level Governance of Climate Change*. London, UK and New York, NY, USA, Springer.
Khattri, A., D. Parameshwar, and S. Pellech. 2010. *Opportunities for Private Sector Engagement in Urban Climate Change Resilience Building*. Rockefeller Foundation, Bangkok, Thailand, 94 pp.
Kithiia, J. and R. Dowling, 2010: An integrated city-level planning process to address the impacts of climate change in Kenya: the case of Mombasa. *Cities*, **27**, 466-475.
Klein, R.J.T., 2010a: Mainstreaming climate adaptation in development: a policy dilemma." In: *Climate Governance and Development* [Ansohn, Albrecht and Boris Pleskovic (eds.)]. Washington, DC, USA, The World Bank, pp. 35-52.
Klein, R.J.T., 2010b: Linking adaptation and development finance: a policy dilemma not addressed in Copenhagen. *Climate and Development*, **2(3)**, 203-206.
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., 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: *Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikot, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 745-777.
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.
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, Amstelveen, Netherlands. 75pp.
Kramer, A.M. 2007. Adaptation to Climate Change in Poverty Reduction Strategies. Human Development Report 2007/2008 Human Development Report Office Occasional Paper 2007/34.
Kuwali, D., 2008: From the West to the rest: climate change as a challenge to human security in Africa. *African Security* Review, **17(3)**, 18-38.
Lamhauge, N., E. Lanzi, and S. Agrawala, 2011: Monitoring and evaluation for adaptation: lessons from development co-operation agencies." *OECD Environment Working Papers*, No. 38, OECD Publishing, Paris, France, 50 pp.
Lane, M.B. and G. McDonald, 2005: Community-based environmental planning: operational dilemmas, planning principles and possible remedies. *Journal of Environmental Planning and Management*, **48(5)**, 709-731.
Lansigan, F.P., W.L. delos Santos, and J. Hansen, 2007. Delivering Climate Forecast Products to Farmers: Ex Post Assessment of Impacts of Advanced Climate Information on Corn Production Systems in Isabela, Philippines. In: *Climate Prediction and Agriculture: Advances and Challenges* [M.V.K. Sivakumar and J.W. Hansen (eds.)]. Springer, Berlin, Germany, pp. 41- 48.
Larsen, K. and U. Gunnarsson-Östling, 2009: Climate change scenarios and citizen-participation: mitigation and adaptation perspectives in constructing sustainable futures. *Habitat International*, **33(3)**, 260-266.
Lasco, R.D. F.B. Pulhin, P.A. Jaranilla-Sanchez, R.J.P. Delfino, R. Gerpacio, and K. Garcia, 2009: Mainstreaming adaptation in developing countries: the case of the Philippines. *Climate and Development*, **1(2)**, 130-146.
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.
Least Developed Countries 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. UNFCCC, Bonn, Germany.
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.
Leichenko, R.M. and K.L. O'Brien, 2008: *Environmental Change and Globalization: Double Exposures*. Oxford University Press, Oxford, UK.

Lemos, M.C and L. Dilling, 2007: Equity in forecasting climate: can science save the world's poor? *Science and Public Policy*, 34(2), 109-116.

Lemos, M.C., E. Boyd, E.L. Tompkins, H. Osbahr, and D. Liverman, 2007: Developing adaptation and adapting development. *Ecology and Society*, **12(2)**, 26-29.

Levina, E., 2007: Adaptation to climate change: international agreements for local needs. COM/ENV/EPOC/IEA/SLT(2007)6, OECD Publishing, Paris, France, 61 pp.

Locatelli, B., V. Evans, A. Wardell, A. Andrade, and R. Vignola, 2011: Forests and climate change in Latin America: linking adaptation and mitigation. *Forests*, **2**. 431-450.

Lonergan, S., Gustavson, K. and Harrower, M. 1999. Mapping human insecurity. In: *Environmental Change, Adaptation, and Security*, [S.C. Lonergen (ed.)], Dordrecht, NATO/Kluwer, pp. 397– 413.

Lovejoy, T.E., 2005: Conservation with a Changing Climate. In: *Climate Change and Biodiversity* [Lovejoy, T.E. and L. Hannah (eds.)]. Yale University Press, New Haven, CT, USA. Pp. 325-328.

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

Lwasa, S., 2010: Adapting urban areas in Africa to climate change: the case of Kampala. *Current Opinion in Environmental Sustainability*, **2**, 166-171.

MacLean, D., 2008: ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges. IISD Commentary, Winnipeg, Canada. 6pp.

Martens, P., 2006: Sustainability: science or fiction? *Sustainability: Science, Practice and Policy*, **2**, 1-5.

Martens, P., D. McEvoy, and C. Chang, 2009: The climate change challenge: linking vulnerability, adaptation, and mitigation. *Current Opinion in Environmental Sustainability*. **1**, 14-18.

Marttila, V., H. Granholm, J. Laanikari, T. Yrjola, A. Aalto, P. Heikinheimo, J. Honkatuki, H. Jarvinen, J. Liski, R. Merivirta, and M. Paunio (eds.), 2005: F*inland's National Strategy for Adaptation to Climate Change*. Ministry of Agriculture and Forestry, Helsinki, Finland, 281 pp.

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.

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, and A. Hammill. 2007. Weathering the Storm: Options for Framing Adaptation and Development. Washington DC: World Resources Institute (WRI).

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. Institute of Development Studies (IDS), London, UK. 60pp

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.

Measham, T.G., B.L. Preston, T.F. Smith, C. Brooke, R. Gorddard, G. Withycombe, and C. Morrison, 2011: Adapting to climate change through local municipal planning: barriers and challenges. *Mitigation and Adaptation Strategies for Global Change*, **16(8)**, 1573-2596. '

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. Washington, DC, USA, World Bank, 35 pp.

Méheux, K., D. Dominey-Howes, and K. Lloyd, 2010: Operational challenges to community participation in post-disaster damage assessments: observations from Fiji. *Disasters*, **34(4)**, 1102–1122.

Mercer, J., 2010: Disaster risk reduction or climate change adaptation: are we reinventing the wheel? *Journal of International Development*, **22(2)**, 247-264.

Mertz, O., K. Halsnaes, J.E. Olesen, and K. Rasmussen, 2009: Adaptation to climate change in developing countries. *Environmental Management*, **43(5)**, 743-752.

Moench, M., Fajber, E., Dixit, A., Caspari, E. and Pokhrel, A., 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. 338 pp.

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.

Morduch, J. and M. Sharma, 2002: Strengthening public safety nets from the bottom up. *Development Policy Review*, **20**, 569-588.

Moser, C., 2006: *Asset-based approaches to poverty reduction in a globalized context: an introduction to asset accumulation policy and summary of workshop findings*. Brookings Institution, Washington, DC, USA, 41 pp.

Moser, 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* [R. Mearns and A. Norton (eds.)]. The World Bank, Washington DC, USA, pp. 231-258.

Moser, S.C. R.E. Kasperson, G. Yohe, and J. Agyeman, 2008: Adaptation to climate change in the Northeast United States: opportunities, processes, constraints. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 643-659.

Moss, R.H., E.L. Malone, N.L. Engle, A. de Bremond, and A. Delgado, To appear: *Ready or Not: Towards a Resilience Framework for Making Climate-Change Adaptation Decisions*. To be published.

Moss, R.H., A.L. Brenkert, E.L. Malone, E.L., 2001: *Vulnerability to Climate Change: A Quantitative Approach*. Technical Report PNNL-SA-33642, Pacific Northwest National Laboratory and Department of Energy, Oak Ridge and Springfield, USA, 88 pp.

Nath, P. and B. Behera, 2011: A critical review of impact of and adaptation to climate change in developed and developing economies. *Environment, Development and Sustainability*, **13(1)**, 141-162.

National Climate Change Adaptation Research Facility (NCCARF), 2012: Climate change adaptation research in Australia: An overview of research funded by the National Climate Change Adaptation Research Facility. NCCARF, Gold Cast, Queensland, Australia. 22pp.

National Research Council, 2010: *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*. Washington, DC, USA, The National Academies Press.

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.

Nelson, K.C. and B.H.J. de Jong, 2003: Making global initiatives local realities: carbon mitigation projects in Chiapas, Mexico. *Global Environmental Change*, **13(1)**, 19-30.

Neufeldt, H., E. Jochem, J. Hinkel, D. Huitema, E. Massey, P. Watkiss, D. McEvoy, T. Rayner, A. Hof, and K. Lonsdale, 2010: Climate policy and inter-linkages between adaptation and mitigation. In: *Making Climate Change Work for Us: European Perspectives on Adaptation and Mitigation Strategies* [M. Hulme and H. Neufeldt (eds.)]. Cambridge University Press, Cambridge, UK, pp. 3-30.

O'Brien, K.L., 2009: Do values subjectively define the limits to climate change adaptation? In: *Adapting to Climate Change: Thresholds, Values, Governance* [W.N. Adger, I. Lorenzoni, and K.L. O'Brien (eds.)]. Cambridge University Press, Cambridge, UK, pp.164-180.

O'Brien, K., 2006. Are we missing the point? Global environmental change as an issue of human security. *Global Environmental Change,* **16**, 1–3.

O'Brien, K., S. Eriksen, L.P. Nygaard, and A. Schjolden, 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, **7**, 73–88.

O'Brien, K. and R. Leichenko, 2006: Climate change, equity and human security. *Die Erde*, **137(3)**, 223-240.

O'Brien, K.L., S. Eriksen, A. Schjolden, and L. Lygaard, 2004: *What's in a Word? Conflicting Interpretations of Vulnerability in Climate Change Research*. Working Paper 2004:04, Center for International Climate and Environmental Research, Oslo, Norway, 19 pp.

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, 2012: Financing Climate Change Action. OECD, Paris, France. 16 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, Paris, France, 12 pp.

OECD, 2009 : *Integrating Climate Change Adaptation into Development Co-Operation* : Policy Guidance. OECD, Paris, France, 193 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.

Osman-Elasha, B., N. Goutbi, E. Spanger-Siegfried, B. Dougherty, A. Hanafi, S. Zakieldeen, E-A. Sanjak, H.A. Atti, and H.M. Elhassan. 2009. Community development and coping with drought in rural Sudan. P.90-108. In: *Climate Change and Adaptation*. [N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds.)]. London, Earthscan.

Osman-Elasha, B. and T.E. Downing, 2007: Lessons learned in preparing National Adaptation Programmes of Action in Eastern and Southern Africa. ECBI Policy Analysis Report, European Capacity Building Initiative, Oxford, UK, 42 pp.

Oxfam, 2007: *Adapting to Climate Change. What is Needed in Poor Countries and Who Should Pay?* Oxfam Briefing Paper 104, 44 pp.

Peskett, L., N. Grist, M. Hedger, T. Lennartz-Walker, and I. Scholtz, 2009: *Climate Change Challenges for EU Development Cooperation: Emerging Issues*. Working Paper No. 3, European Development Cooperation 2020 Project, Bonn, Germany, 23 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 and Grantham Institute for Climate Change, London, UK, 113 pp.

Paterson, J.S. M.B. Araujo, P.M. Berry, J.M. Piper, and M.D. Rounsevell, 2008: Mitigation, adaptation, and the threat to biodiversity. *Conservation Biology*, **22(5)**, 1352-1355.

Patt, A.G., D.P. van Vuuren, F. Berkhout, A. Aaheim, A.F. Hof, M. Isaac, and R. Mechler, 2010: Adaptation in integrated assessment modeling: Where do we stand? *Climatic Change,* **99**, 383-402.

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.

Perch-Nielsen, S., 2010: The vulnerability of beach tourism to climate change – an index approach. *Climatic Change*, **100**, 579-606.

Perch-Nielsen, S.L., M.B. Bättig, and D. Imboden, 2008: Exploring the link between climate change and migration. *Climatic Change*, **91(3-4)**, 375–393.

Perkins, S.E., A.J. Pitman, N.J. Holbrook and J. McAneney, 2007: Evaluation of the AR4 climate models' simulated daily maximum temperature, minimum temperature, and precipitation over Australia using probability density functions. *Journal of Climate*, **20(17)**, 4356-4376.

Persson, A., R.J.T Klein, C.K. Siebert, A. Atteridge, B. Mueller, J. Hoffmaister, M. Lazarus, T. Takama, 2009: Adaptation Finance under a Copenhagen Agreed Outcome. Stockholm Environment Institute (SEI), Stockholm, Sweden. 187 pp.

Pew Center, 2008: *Adaptation Planning – What U.S. States and Localities are Doing*. 21 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.

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

Reid, H., M. Alam, R. Berger, T. Cannon, S. Huq, and A. Milligan, 2010: Community-based adaptation to climate change: an overview. *Participatory Learning and Action*, **60**: 11-33.

Repetto, R., 2008: The Climate Crisis and the Adaptation Myth. Yale School of Forestry and Environmental Studies Working Paper 13. 21pp.

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.

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. Ibisch, 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* [R. Mearns and A. Norton (eds.)]. The World Bank, Washington DC, pp. 47-74.

Roberts, D., 2010: Prioritizing climate change adaptation and local level resilience in Durban, South Africa. *Environment and Urbanization,* **22(2)**, 397-413.

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.

Rojas Blanco, A.V., 2006: Local initiatives and adaptation to climate change. *Disasters*, **30(1)**, 140–147.

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**, 93–127.

Rosenzweig, C., W. Solecki, S.A. Hammer, S. Mehrotra, 2010: Cities lead the way in climate–change action. *Nature*, **467**, 909–911.

Sánchez-Arcilla, J., A. Jiménez, H. I. Valdemoro, and V. Gracia, 2008: Implications of climatic change on Spanish Mediterranean low-lying coasts: The Ebro Delta Case. *Journal of Coastal Research*, **24(2)**, 306-316.

Satterthwaite, D., S. Huq, and 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* [J. Bicknell, D. Dodman, and D. Satterthwaite (eds.)]. Earthscan, London, UK, pp. 3-47.

Scheraga, J.D., K.L. Ebi, J. Furlow, 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, J.D. Scheraga et al (eds.)]. World Health Organization, World Meteorological Organization, United Nations Environment Programme, Copenhagen, 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.

Schipper, L. and M. Pelling, 2006: Disaster risk, climate change and international development: scope for, and challenges to, integration. *Disasters*, **30(1)**, 19-38.

Scholes, R.J., G.M. Mace, W. Turner, G.N. Geller, N. Jurgens, A. Larigauderie, D. Muchoney, B.A. Walther, and H.A. Mooney, 2008: Towards a global biodiversity observing system. *Science*, **321**, 1044-1045.

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.

Scott, D. and S. Becken, 2010: Adapting to climate change and climate policy: progress, problems and potentials. *Journal of Sustainable Tourism*, **18(3)**, 283-295.

Semenov, M.A,. 2008: Simulation of extreme weather events by a stochastic weather generator. *Climate Research*, **35(3)**, 203-212.

Semenov, M.A., 2006: Using weather generators in crop modeling. *Acta Horticulturae*, **707**, 93-100.

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.

Seto, K., R. Sanchez-Rodriguez, and M. Fragkias, 2010: The new geography of contemporary urbanization and environment. *Annual Review of Environment and Resources*, **35**, 167-194.

Shackley, S. and R. Deanwood, 2003: Constructing social futures for climate-change impacts and response studies: building qualitative and quantitative scenarios with the participation of stakeholders. *Climate Research*, **24**, 71-90.

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*, **83**, 370-373.

Sietz, D., M. Boschutz, and R.J.T. Klein, 2011: Mainstreaming climate adaptation into development assistance: rationale, institutional barriers and opportunities in Mozambique. *Environmental Science and Policy*, **14(4)**, 493-502.

Sivakumar, M.V.K. and R. P. Motha, 2007: *Managing Weather and Climate Risks in Agriculture*. Springer, Berlin, Germany, 504 pp.

Sivakumar, M.V.K. and J.W. Hansen, 2007: *Climate Prediction and Agriculture: Advances and Challenges*. Springer, Berlin, Germany, 332 pp.

Smit, B. and O. Pilifosova, 2001: Adaptation to Climate Change in the Context of Sustainable Development and Equity. In: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contributions of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, pp. 877-912.

Smit, B. and J. Wandel, 2006: Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, **16**, 282–292.

Smit, B. and O. Pilifosova, 2003: From adaptation to adaptive capacity and vulnerability reduction. In: *Climate Change, Adaptive Capacity and Development* [J.B. Smith, R.J.T. Klein, and S. Huq (eds.)]. Imperial College Press, London, UK, 9-28 pp.

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. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds., Cambridge University Press, Cambridge, 877-912.

Smith, J.B., S.H. Schneider, M. Oppenheimer, G.W. Yohe, W. Hare, M.D. Mastrandrea, A. Patwardhan, I. Burton, J. Corfee-Morlot, C.H.D. Magadza, H.-M. Fussel, A.B. Pittock, A. Rahman, A. Suarez, and J.-P. van Ypersele, 2008: Assessing dangerous climate change through and update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern." *Proceedings of the National Academy of Sciences*, **106(11)**, 4133-4137.

Solecki, W., R. Leichenko, and K. O'Brien, 2011: Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions, and synergies. *Current Opinion in Environmental Sustainability*, **3(3)**, 135-141.

Sovacool, B.K., 2011: Hard and soft paths for climate change adaptation. *Climate Policy*, **11**, 1177-1183.

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.

Speranza, C.I., B. Kiteme, P. Ambenje, U. Wiesmann, and S. Makali, 2010: Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change*, **100**, 295-315.

Srinivarsan, A., SVRK. Prabhakar, 2008. Measures of Adaptation to Climatic Change and Variability (Adaptation Metrics). Report for World Bank, IGES, Tokyo, Japan.

Stafford Smith, M., L. Horrocks, A. Harvey, and C. Hamilton, 2010: Rethinking adaptation for a 4C world. *Philosophical Transactions of the Royal Society A*, **369**, 196-216.

Stern, N., 2006: *The Economics of Climate Change*. Cambridge University Press, Cambridge, UK: 712 pp.

Stott, P.A., N.P. Gillett, G.C. Hegerl, D.J. Karoly, D.A. Stone, X. Zhange, F. Zwiers, 2010: Detection and attribution of climate change: a regional perspective. *Wiley Interdisciplinary Reviews: Climate Change*, **1(2)**, 192-211.

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.

Sveiven, S., 2010: Are the European financial institutions climate proofing their investments. Institute of Environmental Studies, Amsterdam, Netherlands, 65 pp.

Swart, R. and F. Raes, 2007: Making integration of adaptation and mitigation work mainstreaming into sustainable development policies? *Climate Policy*, **7**, 288-303.

Tanner, T. and J. Allouche, 2011: Towards a new political economy and climate change and development." *IDS Bulletin*, **42(3)**, 1-14.

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. Kangalawe, 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*, **00**, 1-9.

UK Climate Impacts Programme, 2011: Making progress: UKCIP & adaptation in the UK. UKCIP, Oxford, UK. 99pp.

UNEP, 2011: *Visions for Change: Recommendations for Effective Policies on Sustainable Lifestyles*. United National Environment Programme, Paris, France, 88 pp.

UNDP Africa Adaptation Programme, 2012: AAP Knowledge Management Needs Survey Report, 2012. UNDP, New York, USA. 110 pp.

UNDP, 2008: *Human Development Report 2007/8: Fighting Climate Change: Human Solidarity in a Divided World: Human Development and Climate Change*. United Nations Development Programme, New York, US, 399 pp.
UNDP, 2004: Reducing Disaster Risk: A Challenge for Development. New York: United Nation Development Programme, Bureau for Crisis Prevention and Recovery.
UNFCCC, 2007: Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. UNFCCC Secretariat, Bonn, Germany. 64 pp.
UNFCCC, 2007: Investment and Financial Flows to Address Climate Change. Climate Change Secretariat, Bonn, Germany, 111 pp.
UNFCCC, 2006: Technologies for Adaptation to Climate Change. UNFCCC Secretariat, Bonn, Germany. 38 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 chnage: the potential role of participatory risk assessment. *Global Environmental Change*, **18(1)**, 165-179.
Van Ierland, E.C., K. de Bruin, R.B. Dellink, A.J.W. Ruijs, L. Bolwidt, A. Van Buuren, J. Graveland, R.S. de Groot, P.J. Kuikman, E.E.M. Nillesen, M. Platteeuw, S. Reinhard, V.C. Tassone, A. Verhagen, R.P. Roetter, S.J.E. Verzandvoort-van Dijk, 2007: *A Quantitative Assessment of Climate Change Adaptation Options and Some Estimate of Adaptation Costs*. Routeplanner Projects 3,4, 5, Wageningen, Netherlands, 155 pp.
Venema, H.D. and I.H. Rehman, 2007: Decentralized renewable energy and the climate change mitigation-adaptation nexus. *Mitigation and Adaptation Strategies for Global Change*, **12**, 875-900.
Veraart, J.A., E.C. van Ierland, S.E. Werners, A. Verhagen, R.S. de Groot, P.J. Kuikman, and P. Kabat, 2010: Climate change impacts on water management and adaptation strategies in The Netherlands: stakeholder and scientific expert judgments. *Journal of Environmental Policy and Planning*, **12(2)**, 179-200.
Vignola, R., B. Locatelli, C. Martinez, and P. Imbach, 2009: Ecosystem-based adaptation to climate change: what role of policy-makers, society and scientists? *Mitigation and Adaptation Strategies for Global Change*, **14(8)**, 691-696.
VijayaVenkataRaman, S., S. Iniyan, and R. Goic, 2012: A review of climate change, mitigation and adaptation. *Renewable and Sustainable Energy Reviews*, **16**, 878-897.
Vorosmarty, C.J., P.B. McIntyre, M.O. Gessmner,D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S.E. Bunn, C.A. Sullivan, C. Reidy Liermann, and P.M. Davies, 2010: Global threats to human water security and river biodiversity. *Nature*, **467**, 555-561.
Vos, C.C., P. Berry, P. Opdam, H. Baveco, B. Nijhof, J. O'Hanley, C. Bell, and H. Kuipers. Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones. *Journal of Applied Ecology*, **45(6)**, 1722-1731.
Warner, K., M. Hamza, A. Oliver-Smith, F. Renaud, and A. Julca, 2010: Climate change, environmental degradation, and migration. *Natural Hazards*, **55(3)**, 689-715.
Wassmann, R., G.C. Nelson, S.B. Peng, K. Sumfleth, S.V.K. Jagadish, Y. Hosen, and M.W. Rosegrant, 2008: Rice and global climate change. In: *Rice in the Global Economy: Strategic Research and Policy Issues for Food Security* [Pandey, S., D. Byerlee, D. Dawe, A. Doberman, S. Mohanty, S. Rozelle, and B. Hardy (eds.)]. International Rice Research Institute, Makati City, Philippines, pp. 411-431.
Webb, J., 2011: Making climate change governable: the case of the UK climate change risk assessment and adaptation planning. *Science and Public Policy*, **38(4)**, 279–292.
Werner, A.D. and C.T. Simmons, 2009: Impact of sea-level rise on sea water intrusion in coastal aquifers. *Ground Water*, **47(2)**, 197–204.
Werner, S., J. Tabara, H. Neufeldt, X. Dai, Z. Flachner, J. West, F. Cots, G. Trombi, D. McEvoy, P. Matczak, and G. Nabuurs, 2010: Mainstreaming adaptation in regional land use and water management. In: *Making Climate Change Work For Us: European Perspectives on Adaptation and Mitigation Strategies* [Hulme, M. and H. Neufeldt (eds.)]. Cambridge, UK, Cambridge University Press, pp. 230-260.
Wertz-Kanounnikoff, S., B. Locatelli, S. Winder, and M. Brockhaus, 2011: Ecosystem-based adaptation to climate change: what scope for payments for environmental services. *Climate and Development*, **3(2)**, 143-158.
Westerhoff, L., E.C.H. Keskitalo, S. Juhola, 2011: Capacities across scales: local to national adaptation policy in four European countries. *Climate Policy*, **11**, 1071-1085.
Wheeler, D., 2011: Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance. CGD Working Paper 240. Washington, D.C.: Center for Global Development. 49 pp.

Wheeler, S.M., 2008: State and municipal climate change plans: the first generation. *Journal of the American Planning Association*, **74(4)**, 481-496.

Wilbanks, T.J. and R.W. Kates, 2010: Beyond adapting to climate change: embedding adaptation in responses to multiple threats and stresses. *Annals of the Association of American Geographers*, **100(4)**, 719-728.

Wilbanks, T.J., and J. Sathaye, 2007: Integrating mitigation and adaptation as responses to climate change: a synthesis. *Mitigation and Adaptation Strategy for Global Change*. **12**, 957-962.

Wilbanks, T.J., S.M. Kane, P.N. Leiby, R.D. Perlack, C. Settle, and J.F. Shogren, 2003: Integrating mitigation and adaptation as possible responses to global climate change. *Environment*, **45**, 28-38.

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

Wilby, R.L., C.W. Dawson, and E.M. Barrow, 2002: SDSM—A decision support tool for the assessment of regional climate change impacts. *Environmental Modeling and Software*, **17(2)**, 145-157.

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, Economics of Climate Adaptation Working Group, 2011: Shaping Climate Resilient Development: A Framework for Decision making. World Bank, Washington DC, USA, 164 pp.

World Bank, Economics of Climate Change Working Group, 2010: The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates. World bank, Washington DC, USA, 84 pp.

World Bank, 2010: World Development Report: Development in a Changing Climate—Concept Note. World Bank, Washington DC, USA, 45pp.

World Bank, 2008: The Pilot Program for Climate Resilience under the Strategic Climate Fund. Washington, DC, USA.

World Bank, 2006: *Investment Framework for Clean Energy and Development*. World Bank, Washington DC, USA, 108 pp.

World Economic Forum, 2002. Environmental Sustainability Index, An Initiative of the Global Leaders for Tomorrow Environment Task Force, World Economic Forum, Annual Meeting 2002, World Economic Forum/CIESIN/Yale Center for Environmental Law and Policy, Geneva/New York/New Haven.

World Resources Institute (WRI), 2009: Bellagio Framework for Adaptation Assessment and Prioritization. WRI Working Paper, Washington DC, USA.

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

Yohe, G. and R.S.J. Tol, 2002: Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. *Global Environmental Change*, **12(1)**, 25-40.

Ziervogel, G. and A. Taylor, 2008: Feeling stressed: integrating climate adaptation with other priorities in South Africa. Environment, **50(2)**, 32-41.

Table14-1: Set of criteria for selection of indicators.

	Criterion	Explanation
Validity	Well-founded	Based on a tested theoretical framework
	Accurate	Really measuring what it should
	Non-ambiguous	Agreement on the direction of influence between the indicator and vulnerability
Use	Comprehensible	Relatively easy for users to understand
Type	Relevant	Applicable to many geographic and economic conditions
	Responsive to changes	Can be influenced by action
	High information content	No yes/no indicators, and preferably actual performance data instead of model-based data
Data	Available	Data that is publicly and easily available
	Homogenous and periodical data	Data that is collected homogeneously, making it suitable for international comparisons

From Perch-Nielsen, 2010 based on Aitkins et al., 1998; Esty et al., 2006 Kaly et al., 2003 and OECD, 2002.

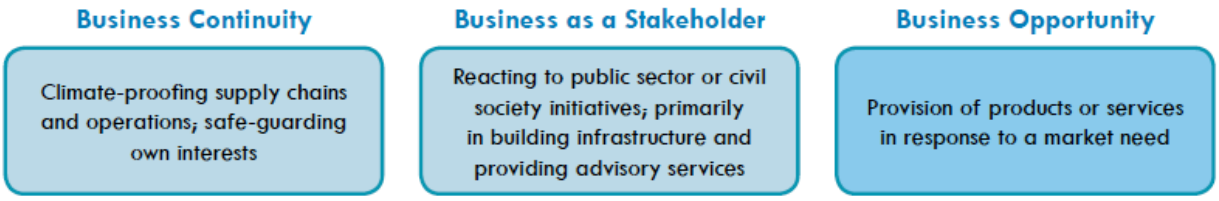

Figure 14-1: A typology of private sector engagement in adaptation (Khattri et al., 2010).