Adaptation to Climate Change in Developing Countries

Article *in* Environmental Management · February 2009

DOI: 10.1007/s00267-008-9259-3 · Source: PubMed

4 authors:

Ole Mertz
University of Copenhagen
186 PUBLICATIONS **12,003** CITATIONS
SEE PROFILE

Kirsten Halsnæs
Technical University of Denmark
97 PUBLICATIONS **4,733** CITATIONS
SEE PROFILE

Jørgen Eivind Olesen
Aarhus University
635 PUBLICATIONS **35,401** CITATIONS
SEE PROFILE

Kjeld Rasmussen
University of Copenhagen
124 PUBLICATIONS **8,116** CITATIONS
SEE PROFILE

Environmental Management (2009) 43:743–752
DOI 10.1007/s00267-008-9259-3

SPECIAL FEATURE

Adaptation to Climate Change in Developing Countries

Ole Mertz · Kirsten Halsnæs · Jørgen E. Olesen · Kjeld Rasmussen

Received: 13 February 2008 / Accepted: 16 December 2008 / Published online: 31 January 2009

Abstract Adaptation to climate change is given increasing international attention as the confidence in climate change projections is getting higher. Developing countries have specific needs for adaptation due to high vulnerabilities, and they will in this way carry a great part of the global costs of climate change although the rising atmospheric greenhouse gas concentrations are mainly the responsibility of industrialized countries. This article provides a status of climate change adaptation in developing countries. An overview of observed and projected climate change is given, and recent literature on impacts, vulnerability, and adaptation are reviewed, including the emerging focus on mainstreaming of climate change and adaptation in development plans and programs. The article also serves as an introduction to the seven research articles of this special issue on climate change adaptation in developing countries. It is concluded that although many useful steps have been taken in the direction of ensuring adequate adaptation in developing countries, much work still remains to fully understand the drivers of past adaptation efforts, the need for future adaptation, and how to mainstream climate into general development policies.

O. Mertz (✉) · K. Rasmussen
Department of Geography and Geology, University of Copenhagen, Copenhagen, Denmark
e-mail: om@geo.ku.dk

K. Halsnæs
UNEP Risø Centre, Risø-Technical University of Denmark, Risø, Denmark

J. E. Olesen
Faculty of Agricultural Sciences, University of Aarhus, Aarhus, Denmark

Keywords Adaptation · Africa · Asia · Climate change · Climate impacts · Climate projections · Developing countries · Development policy · Latin America · Mainstreaming · Small island states · Vulnerability

Introduction

With the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the documentary "An Inconvenient Truth" by Al Gore, and the Nobel Peace Prize in 2007 given to IPCC and Al Gore, international awareness and concern of the global environmental problem of human-induced climate change have reached hitherto unseen heights. Research into the possible drivers of climate change, natural as well as anthropogenic, the character and magnitude of the changes, their impacts on human living conditions and ecosystems, and the possible approaches to adaptation and mitigation has also increased in recent years, and the understanding of the complex relationships characterizing the climate system, the ecosystems interacting with it, and the human responses to climate changes is expanding. Although anthropogenic emissions of greenhouse gases associated with the use of fossil fuels mainly are from the rich industrialized—and postindustrial—countries, the impacts of climate change will be more severe in poor developing countries.

This is because (1) the physical impacts are expected to be relatively large in developing country regions, where, for example, increases in the already high temperatures are likely to lead to large evaporation losses and in many developing countries precipitation is not likely to increase as is expected in many high-latitude regions (Christensen and others 2007), (2) many developing countries, in terms of national income and employment, rely heavily on

agriculture that is directly affected by climatic change, (3) the high number of poor people in these countries is generally more vulnerable and likely to feel the negative effects of climate change (Yohe and Tol 2002), and (4) the economic and technological capacity to adapt to climatic change is often very limited in developing countries.

Adaptation to climate change did not receive much attention in the first years of the international climate change studies, where there was more focus on mitigation and impacts (Kates 2000), but adaptation has recently been covered more extensively and has an important place in the fourth assessment report of the IPCC (2007). There is an emerging process of seeing climate change as a mainstreaming issue that implies that vulnerabilities and adaptation strategies are linked to the development of poverty reduction strategies (Halsnæs and Trærup 2009). This process has so far primarily been donor driven because many developing countries—for good reasons—do not consider climatic change as one of their greatest concerns. More immediate needs for economic growth and poverty reduction take priority, and it is symptomatic that most of the first generation Poverty Reduction Strategy Papers (PRSPs) had little reference to environmental concerns (Bojö and others 2004; Bojö and Reddy 2001), let alone climate change. Part of the reasons for neglecting environmental concerns in the PRSPs is that these issues have not been highly profiled in the underlying conceptual frameworks and policy advice on these issues provided by multilateral agencies, despite the fact that PRSP growth and poverty reduction targets as well as the Millennium Development Goals (MDGs) critically depend on successful adaptation to climate change (Davidson and others 2003). Some recent PRSPs, however, have integrated environmental issues as well as the process of developing national adaptation programs of action.

Climate impacts are described with increasing confidence by IPCC (2007). These impacts might be direct (e.g., changes in agricultural potential caused by rainfall change or inundation of cities and infrastructure due to sea level rise and higher disease burden) or they might be indirect (e.g., through effects of climatic change on world market prices of agricultural and fisheries products). The need for adaptation is inevitable no matter how efficiently we manage to reduce the growth in emissions (Yohe 2000), because the inertia in the climate system will lead to climate change and resulting impacts on natural and managed systems. Measures cover a correspondingly broad range, from direct interventions such as dike building to prevent flooding, large-scale relocation of farmers, new crop selection and building of dams to expand irrigation, to capacity development in public administration, civil society, and research. There are particular concerns within the agricultural sector, and it is believed that adaptation in developed countries with temperate climates will not only reduce vulnerability but be able to realize opportunities and strengthen production (Smit and Skinner 2002; Wheaton and Maciver 1999), as there will be reduced cold weather risks. In developing countries, climate variability and change will enhance heat and moisture stresses and contribute to an already long list of existing problems (Schmidhuber and Tubiello 2007). The vulnerability of the agricultural sector in many developing countries is caused by poverty and limited economic capacities (e.g., to accumulate and sell products when prices are attractive) (Barbier and others 2009), and the current socioeconomic and technological drivers of change in agriculture have hitherto rendered climate change "just" another stressor of the system (Burton and Lim 2005; Mertz and others 2009).

Two emerging conceptual frameworks for addressing climate change adaptation in developing countries are considered in this article, including theoretically based work on vulnerabilities and adaptive capacity (Adger and others 2003) and a more pragmatic attempt to address climate change vulnerabilities and adaptation as a mainstreaming issue (Davidson and others 2003; Halsnæs and Trærup 2009). Before going into these conceptual issues, we will provide a brief overview of the observed climate changes and the projected scenarios and impacts of relevance for developing countries. In order to assess the significance of these impacts for developing countries, we will briefly discuss recent research into the concepts of vulnerability, adaptation and adaptive capacity. Moreover, we will provide an overview of key adaptation needs in developing countries by region.

Finally, this article also serves as an introduction to this special issue of *Environmental Management* on adaptation to climate change in developing countries. The seven articles of the issue present a range of case studies of adaptation as well as conceptual and methodological considerations.

Observed and Projected Climate Change in Developing Countries

Many developing countries have already experienced weather events in terms of floods, droughts, heat waves, and tropical cyclones that are more frequent or intense than previous experiences (Dai and others 2004; Trenberth and others 2007), and the resulting impacts point to the consequences on the environment, production systems, and livelihoods from future climate variability and change. In this section we briefly review the observed and projected climate change that has been summarized by the IPCC and recent literature.

Observed Climate Change

Expressed as a global average, surface temperatures have increased by about 0.74°C over the past 100 years (Trenberth and others 2007). However, the largest share of the increase (0.55°C) has occurred over the past 30 years. The largest temperature increases have occurred over land and in the arctic and subarctic regions. The observed temperature increases over the past 30 years in large parts of Africa, Asia, and Latin America are generally within the range of 0.5°C to 1.0°C, although there are regions with larger observed changes (e.g., in southeastern Brazil and North Asia) (Cruz and others 2007; Magrin and others 2007; Trenberth and others 2007). Surface air temperatures over land have risen by about double the rate of temperatures over the ocean, which means that less warming has occurred in small island states (e.g., in the Pacific). Consistent with the warming, there has been an increase in the frequency of warm extremes (Trenberth and others 2007).

Downward trends in precipitation have been observed in the tropics from 10° S to 30° N since the 1970s (Trenberth and others 2007). It has become wetter in eastern parts of South America and northern and central Asia but drier in the Sahel, southern Africa, and parts of southern Asia. In accordance with this, more intense and longer droughts have been observed over wider areas since the 1970s, mostly in the dry tropics and subtropics (Dai and others 2004). These droughts have often been linked with prolonged heat waves. There have been substantial increases in heavy precipitation events in many land regions, even in regions with no change or reductions in total rainfall (Groisman and others 2005), where droughts might be exacerbated if the reduced rainfall is increasingly falling in heavy precipitation events.

Globally, estimates of potential destructiveness of tropical cyclones show a significant upward trend since the mid-1970s (Emanuel 2005), with a trend toward longer lifetimes and greater storm intensity (Emanuel 2005). This is strongly correlated with the higher tropical sea surface temperatures. Even though these observations depend critically on data quality and the choice of start date (Chan 2006), the data available suggest that the potential destructiveness has not previously been as high as now (Trenberth and others 2007). The largest increases in intense tropical cyclones have been observed in the North Pacific, Indian, and southwest Pacific Oceans (Trenberth and others 2007).

Observations of changes in physical and biological systems across the globe are consistent with the observed changes in climate (Rosenzweig and others 2007). Particularly large effects are related to enhanced glacial melt affecting river flows and to changes in phenology and productivity of biological systems as affected by temperature and rainfall changes. There are also emerging findings of climate effects on human systems, although these are often difficult to discern from other adaptation processes. In agricultural systems, both climate change and technological developments influence agricultural land use and management, but in many developing countries with traditional land management, the effects of climate change on agriculture might be more evident (Van Duivenbooden and others 2002). The majority of the data and studies are from developed countries—in particular, in temperate climates. There is thus a need to expand the observational series in developing countries and tropical and subtropical climates. Such studies might also increase the knowledge base on vulnerability and adaptive responses in subsistence agricultural systems and rural populations in developing countries.

Projected Climate Change

Increasingly reliable regional climate projections are now available for many regions of the world, although the extent of available downscaled projections for many developing countries still lag behind those for the developed world (Christensen and others 2007). The projections generally show greater warming over many land areas than global mean warming due to less water availability for evaporative cooling and a smaller thermal inertia compared to the oceans. The warming generally increases the spatial variability of precipitation with reduced rainfall in the subtropics and increases at higher latitudes and parts of the tropics. There is a tendency for increased precipitation in monsoonal circulations due to enhanced moisture convergence, despite a tendency for a weakening of the monsoonal flows. However, there are still many uncertainties in tropical climate responses (Christensen and others 2007).

The warming in Africa is projected to be above the global annual mean warming throughout the continent and in all seasons (Boko and others 2007). The dry subtropical regions will warm more than the moister tropics. The annual rainfall is projected to decrease in much of the Mediterranean Africa, northern Sahara, and southern Africa. The mean annual rainfall in eastern Africa is likely to increase, whereas projections of changes in rainfall in the Sahel, the Guinean Coast, and the southern Sahara remain uncertain (Christensen and others 2007).

Warming is projected to be similar to global mean warming in Southeast Asia, stronger over South Asia and East Asia, and greatest in the continental interior of Asia (Cruz and others 2007). Precipitation is projected to increase in northern Asia, East Asia, South Asia, and most of Southeast Asia but to decrease in central Asia (Christensen and others 2007). These changes will be associated

with an increase in frequency of intense precipitation events in South Asia and East Asia, partly associated with likely increase in tropical cyclone intensity in East Asia, Southeast Asia, and South Asia.

The annual mean warming in Latin America is projected to be similar to the global mean warming (Magrin and others 2007). Annual precipitation is projected to decrease in most of Central America and in the southern Andes, although there might be large local and regional variations (Christensen and others 2007). The changes in annual and seasonal rainfall over northern South America, including the Amazon forest, remain uncertain. However, climate change projections indicate increasing rainfall in Ecuador and northern Peru and decreasing rainfall in northern South America and southern northeast Brazil. The climate in large parts of the region is affected by the El Niño Southern Oscillation (ENSO), so future changes in the magnitude and cycle of the ENSO will affect the climate of Latin America (Magrin and others 2007).

Vulnerability, Adaptation, and Adaptive Capacity as Conceptual Issues

Vulnerability and adaptive capacity have been discussed in the theoretical climate change adaptation literature as key concepts for understanding how developing countries cope with and adapt to climate change and variability (Adger 2006; Challinor and others 2007; Eakin and Luers 2006; Mimura and others 2007; Schröter and others 2005; Smit and Wandel 2006). Both terms are very useful for analyzing coupled human–environment interactions (Reenberg and others 2008) and frameworks for vulnerability analysis have become a key component in sustainability science (Turner and others 2003).

Vulnerability emerged as a concept in development debates in the 1990s (Bohle and others 1994; Chambers 1995; Watts and Bohle 1993) and was largely a term borrowed from life sciences. There have been quite many attempts to define vulnerability, and in relation to climate change, vulnerability has been defined as the susceptibility of exposure to harmful stresses and the ability to respond to these stresses (Adger 2006; Adger and others 2007; Bohle and others 1994). It is important to recognize that vulnerability is highly contextual and must always be linked to specific hazards and the (likely) exposure to the impacts of these hazards (Brooks and others 2005; Kelly and Adger 2000). Along this line, Luers (2005) suggested that vulnerability assessments should focus on the susceptibility of specific variables (such as food supply, income) that characterize the well-being of people to a specific damage (such as hunger and poverty). Adaptation is a broad term, and there have been many attempts to define the concept. These are reviewed by Smit and others (2000), and although the various definitions are rather similar, there are important nuances that might not answer completely the questions of "adapting to what?" "who and what adapts?" and "how does adaptation occur?" (Smit and others 2000). Identifying the precise driver of any given strategy is highly complex and it is therefore often difficult to establish the cause of an adaptive strategy or even determine whether it is adaptation or perhaps a cyclic activity occurring with longer time intervals. The IPCC Third Assessment Working Group II Report, based on Smit and Pilifosova (2001), presented a broad definition of adaptation to climate change as being "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts". This definition is retained in the IPCC Fourth Assessment Report, where it is reiterated that adaptation comprises actions to reduce vulnerability or enhance resilience (Adger and others 2007). However, the complexity of understanding adaptation—especially what exactly triggers different adaptive measures—is still frequently discussed in the literature.

The linkages between vulnerability, adaptive capacity, and adaptation are often circular rather than linear in nature. The ability of people to control the variables that determine vulnerability might be translated into their capacity to adapt (Kelly and Adger 2000; Luers 2005; Smit and Wandel 2006). If people, for example, have a secure income and a diversified food supply, they are less likely to be poor and to experience hunger. This, in turn, will often enable them to respond to stresses by allocating resources differently or abandon/relocate farming areas—in other words, they have a better capacity to adapt to stress and the degree of vulnerability determines this capacity. It is thus prior damage that makes people vulnerable and hampers their capacity to adapt to potential future stress factors. However, adapting to stress might also in itself exacerbate vulnerability; if, for example, the needed adaptive actions to drought will lead to dependence of credit schemes to purchase drought-resistant crops and crop varieties, then a complete crop loss will not only cause hunger but also leave people with debts they are unable to repay. Therefore, the true vulnerability of people can only be assessed after adaptation has taken place (Kelly and Adger 2000), and in some cases, it might be necessary to "adapt to the adaptation," as some measures might solve one problem while creating another; credit schemes and new crops, for example, might have to be accompanied by "weather insurance," as has been tried experimentally in some developing countries (Barnett and Mahul 2007).

In economic terms, adaptive capacity has been defined as "a vector of resources and assets that represent the asset base from which adaptation action can be made" (Vincent

2007), and it has also been described by the coping range of climate variability upon which communities or individuals are used to react. When extreme events or more extreme variability go beyond the coping range, the adaptive capacity might be surpassed and the system threatened (Smit and Wandel 2006). At this point, the required adaptation is beyond the capacity of the people experiencing the threat and assistance is needed. A slightly different and more operational approach to the coping range concept suggests that adaptation of the system will occur only when thresholds of the coping range are exceeded, and the coping range thus signifies the resilience of a system (Yohe and Tol 2002). In other words, coping is the short-term response to variability, whereas adaptation is the more fundamental change of the system to allow for a new coping range to be established. Thus, the coping range can been described as the "head room" or "room for maneuver" of the system (Thomas and Twyman 2005), and the whole point of successful adaptation in poor communities is to ensure that an adequate coping range is established after adaptive actions have taken place. This will eventually reduce the vulnerability of people, and in an ideal world, a "good circle" of reduced vulnerability–increased adaptive capacity–appropriate adaptation can be closed.

Following these lines of thinking, policies on adaptation to climate change must be very carefully devised as they find themselves in a complex reality of societies that are poor and vulnerable for a wide range of reasons. They must be an integral part of a development policy process that ensures mainstreaming of climate adaptation in all relevant sectors of society while not forgetting the other multiple drivers (social, economic, and environmental problems). Concretely, the policies at the national level should be specific investments in physical and institutional assets that reduce climatic vulnerability and increase coping ranges without causing counterproductive effects. Examples of physical assets can be stronger infrastructure related to transport, energy, and water supply as well as new options for agricultural techniques, whereas institutional assets can be information systems, financial and risk-sharing systems, insurance, education, and warning systems that directly or indirectly address local, national, or regional vulnerability to climate change and variability.

It is also important to consider to what extent policies should be proactive (adapting in anticipation of a change) or reactive (adapting as a response to a change)—or as suggested by several studies, they should be both (Smit and others 2000; Smit and Skinner 2002). The choice among these must be dependent on the confidence in local climate predictions, as investments in adaptation to anticipated change might be wasted or even counterproductive if predictions turn out to be wrong. This is especially crucial in developing countries, where the capacity for investment and later remedial actions to correct mistakes is limited. On the other hand, it can also be risky to base long-term adaptation strategies on observed climatic trends, as is sometimes done in National Adaptation Programs of Action (NAPA)—for example, in Sahelian countries, where the decrease in average annual precipitation since the 1960s is expected to continue or at least remain low (Gouvernement du Burkina Faso 2007; République du Mali 2007) (see further discussions on NAPAs in the following section).

This need for a better understanding of the actual and potential adaptation needs in developing countries has spurred an increasing interest in adaptation and development policy (Halsnæs and others 2008; Michaelowa and Michaelowa 2007; O'Brien and others 2008). Moreover, development of methodological frameworks for studying the links between vulnerability, poverty, and the complexity of adaptation to climate change, which is often not easily separated from adaptation to other factors that might stimulate change, has also attracted more interest (Tschakert 2007; Wheaton and Maciver 1999). It is, however, beyond the scope of this article to describe all of these approaches, but several important analytical and conceptual frameworks are presented in the recent literature (Eriksen and O'Brien 2007; Fussel 2007; Luers 2005; Tschakert 2007; Vincent 2007; Vogel and others 2007).

Climate Vulnerability and Adaptation Options in the Context of Current Development Policies

Climate variability is already creating serious impacts on major poverty alleviation goals in developing countries, and this means that the linkages between climate vulnerabilities and development policies are increasingly being addressed in the literature as well as in international climate policy debates and in development assistance. A brief overview of these activities is given here.

Climate change mainstreaming issues related to vulnerability and adaptation were put on the agenda at the Conference of the Parties (COP) 7 in Marrakech, Morocco in 2001, where it was decided that special support should be given to a group of Least Developed Countries (LDCs) to the development of NAPAs (Burton and Lim 2005). COP 7 also further supported adaptation activities by a strong recognition of the special needs of developing countries (Adger and others 2003). The NAPAs are part of the adaptation policy framework (APF) developed to aid national planning and comprises a five-step approach for studying vulnerability and for developing adaptation strategies (Adger and others 2007; Burton and Lim 2005). Despite that the NAPAs only provide limited small-scale

first attempts to initiate full-scale planning of adaptation options in developing countries, they must be considered as important elements in the APF. The NAPAs are likely to contribute to the mainstreaming of climate adaptation in development policies and programs, and although this is important for adaptation purposes, increased focus on the Clean Development Mechanism (CDM) and mitigation might entail a risk of climate overshadowing other—and perhaps more important—poverty reduction and development needs (Michaelowa and Michaelowa 2007).

According to the website of the United Nations Framework Convention on Climate Change, only 23 developing countries had submitted their NAPAs by November 2007 (http://unfccc.int/national_reports/napa/items/2719.php). Considering that the agreement was made in 2001, this appears to be relatively few and it is obvious from the list that many countries with immediate adaptation needs (e.g., small island states) and countries with a history of environmental challenges such as drought (e.g., Sahelian countries) have a high representation. However, 45 of the 50 LDCs are engaged in NAPA processes and more are likely to be ready in the near future (Jallow and Downing 2007).

Climate change vulnerability and adaptation have in the COP 12 and COP 13 meetings in 2006 and 2007 been further emphasized. The COP decisions on climate vulnerability and adaptation have been supported by various donor mainstreaming efforts, including development of an Organization for Economic Cooperation Development–Development Assistant Committee (OECD-DAC) framework, the Danish Climate Action Programme, and the United States Agency for International Development (USAID) and UK Department for International Development (DfID) guidelines. These various donor efforts are summarized in the work of Gigli and Agrawala (2007). The Danish Development Assistance (Danida) was one of the first international donor agencies to initiate the integration of climate change in its assistance (Danida 2005). Climate screening of Danida's development assistance is a key step in a process of identification and management of the risks of climate change for development cooperation and the identification and implementation of appropriate climate change adaptation and disaster-risk-reduction measures. The approach adopted is to integrate risks of climate change and opportunities for adaptation into development programs rather than as stand-alone climate adaptation or mitigation projects. Thus, climate change screening includes assessment of the effects of climate change on achieving the outcomes of the development programs, identification of adaptation measures, and the development of a process action plan for further activities in relation to "climate-proofing" of development assistance.

The World Bank in its Investment Framework for Clean Energy and Development (World Bank 2006) similarly sees climate change as a serious threat to development goals. It is stated in the Executive Summary that "failure to effectively address increasingly severe weather patterns and climate variability into development activities is a major threat to poverty alleviation. The economic impacts will be significant especially in developing countries—partial estimates of the economic impacts of a 2.5°C temperature increase (mid-range value associated with a doubling of the atmospheric concentration of CO_2) without adequate adaptive efforts range from 0.5 to 2 percent of GDP with higher losses in most developing countries. Resources that are additional to Official Development Assistance (ODA) will need to be found by donors to compensate for the increased development costs, while developing country governments will need to reassess policies and institutional structures to be proactive in reducing climate vulnerability."

Regional Impacts and Adaptation

Developing countries will experience the effects of climate change differently, not only because of differences in the projected change of climate parameters but also because vulnerabilities and adaptive capacities vary greatly between nations and regions. This section will only provide a brief overview of the main regions with developing countries, as the IPCC Fourth Assessment WG II Report provides excellent discussions on this issue.

Sub-Saharan Africa is highly vulnerable to climate change and other stressors (Boko and others 2007), and in an assessment of vulnerability to climate-related mortality, this region was represented with 33 of the 59 countries found to be highly or moderately–highly vulnerable (Brooks and others 2005). Sub-Saharan countries also come out in the lowest quintile of a ranking on adaptive capacity of nations to climate change (Haddad 2005).

Generalizing the impacts of climate change in Africa is impossible, as regions will be affected differently and there is considerable uncertainty, particularly in West Africa. Water stress will be an even larger problem than currently in northern and southern Africa, and in the same regions, agricultural production—and thereby food security—is likely to be negatively affected (Boko and others 2007). In general, climate problems, such as recurrent drought, exacerbate the many existing problems in the region (Kates 2000), and, as mentioned earlier, it can often be very complex to identify climate as a direct driver of strategies. In southern Africa, Gregory and others (2005) found climate to be among the most frequently cited drivers of food insecurity, whereas Mertz and others (2009) found that

changes in agricultural strategies in a region in Senegal were not easily identified as adaptation to climate change or variability but rather to economic and policy drivers.

It is also well established that people are generally resourceful in responding and adapting to climate variability and other external disturbances (Mortimore and Adams 2001; Thomas and Twyman 2005). IPCC provides a good overview of such adaptations already observed in Africa (Boko and others 2007), although the relative weight of climate factors compared to other stressors is not always clear in the references cited. Future adaptation needs are likely to focus on enhancing the robustness of various sectors in Africa, not only to counter the impacts of climate change but also to improve the economic and social welfare and thereby improve the adaptive capacity of individuals and communities (Boko and others 2007).

The developing countries of the Asia-Pacific region will also experience climate change very differently. Key future impacts were identified by the IPCC and included increased water stress in India, loss of mangroves and other coastal lands in Southeast Asia due to sea level rise, and disturbance of forests and agriculture due to the possibility of more intense El Niño events (Cruz and others 2007). Melting of glaciers in the Himalayas and resulting floods and water availability issues are also likely become important impacts. The small island states of the Pacific are even more vulnerable and impacts of possibly more intensive cyclones, sea level rise, drought, and coral reef degradation will be very important (Mimura and others 2007). However, small island states did not come out as highly vulnerable in the national vulnerability assessment proposed by Brooks and others (2005) and nor did Bangladesh, which is usually considered very vulnerable to climate change. In both cases, it probably was caused by the focus on mortality in the assessment, which might not be specifically high in these countries, as they have already managed to significantly reduce such very negative outcomes of climate hazards (Brooks and others 2005).

The capacity for adaptation is generally higher in Asia-Pacific than in Africa, but the magnitude and consequences of adaptation needs might be larger. Potential flooding of the many highly populated river deltas will either be extremely costly to prevent or lead to mass movement of people to other areas (Cruz and others 2007), and some Pacific islands might have to be abandoned altogether either because of flooding or loss of ecosystems needed for subsistence (Mimura and others 2007; Rasmussen and others in press). Moreover, the predicted decline in agricultural production without adaptation in Asia will affect an even larger number of poor urban and rural populations than in Africa.

Many Latin American countries are now so-called emerging economies and even the poorest countries in the region are considerably less vulnerable to climate change than the poor countries of Africa and Asia. In the earlier mentioned vulnerability assessment, only French Guyana and the Caribbean states (or territories) of Haiti, Guadeloupe, and Puerto Rico appeared among the 59 countries in the most or second most vulnerable categories (Brooks and others 2005). Moreover, the uncertainty of future climate change in much of Latin America makes it difficult to predict impacts and adaptation needs with very high confidence (Magrin and others 2007), although the likely intensification of extreme weather events will be very damaging, especially to the poorer countries of Central America and the Caribbean.

Overview of Articles in the Special Issue

With this general overview of climate change issues in developing countries in mind, we now present the seven articles in this special issue. They address a wide range of issues discussed earlier and both broader policy studies and specific case studies are represented. The first article provides an overall discussion on the adaptation–mitigation divide that has characterized international climate debates until recently (Ayers and Huq 2009). Recognizing mitigation as being generally a concern of the North and adaptation of the South, it is proposed to promote the synergies between these two approaches in order to engage developing countries more strongly in the climate debates. The article uses Bangladesh as an example of how linkages between mitigation and adaptation actions are often found on the ground.

The next two articles are specifically concerned with integrating climate concerns in development efforts. A stepwise approach to mainstreaming climate change in development policies whereby climate conditions, variability, and change are assessed and linked to development is thus provided in the second article of the special issue (Halsnæs and Trærup 2009). The article uses case studies from Tanzania (water harvesting, malaria) and Mozambique (infrastructure) to illustrate the benefits of climate-proof road design, increased rain water harvesting, and the use of bed nets to prevent increased malaria incidence. The third article also provides a model for integrating development and climate change, using malaria in India as an example (Garg and others 2009). The authors project future malaria incidence under various alternative combinations of climate change variables and sustainable development variables.

The next three articles all address adaptation to climate change in specific rural settings of Burkina Faso, Senegal, and Kenya. The study in northern Burkina Faso compares different responses of households to drought by analyzing farm decisions after years with poor and good harvests. It is concluded that the households have developed strategies for income diversification as a way of reducing dependence

on climate, but vulnerability is still considerable and prospects for further development are limited by population growth that causes land scarcity and pressure on soil fertility (Barbier and others 2009). In Senegal, a parallel study attempted to determine the drivers of agricultural change and estimate the relative importance of climate in various adaptive strategies (Mertz and others 2009). The article concludes that local climate narratives manifested themselves in group interviews. Climate factors were here assigned more importance than household interviews, from which few agricultural strategies could be attributed to climate. More intensive wet and dry season wind was the climate factor considered most destructive, but only few adaptation measures were mentioned in response to this or other climate factors.

The article on conflict and insecurity in two areas in Kenya argues that adaptation must take place at the local level to be effective and that it is more a matter of facilitating adaptation of current practices rather than imposing nationally decided adaptation options (Eriksen and Lind 2009). Examples are given of how well-intended, but inappropriate, development efforts have increased local vulnerability to climate and other stressors in the local context of insecurity. The seventh and final article presents a species–climate response surface model for simulating bird species occurrence in important bird areas in order to assess the impacts of climate change and the potential need for rethinking and adapting protected area networks (Willis and others 2009). The study focuses on the African Important Bird Area Network and uses South Africa as a case.

Conclusion and Recommendations

The COP 13 meeting in Bali in December 2007 focused considerably on adaptation to climate change and technology transfer to developing countries and LDCs increasingly recognize the need for appropriate adaptation at all levels, through mainstreaming efforts and environmental policies. However, to undertake these policies in an effective and equitable way still requires much more technical background work. As the case studies in this special issue indicate, it is not necessarily easy to design effective adaptation at the local level in many countries. As long as there are large uncertainties about the permanence of observed short-term climate effects, it is recommended to first introduce more climate resilient development strategies and robust risk management strategies that both support general development goals and climate change adaptation. Moreover, many general development efforts in the poorest communities are likely to be the most efficient way of increasing their adaptive capacity and thereby the possibility of choosing between various adaptation options. In agriculture, for example, wealthy farmers are more likely to benefit from a more flexible choice of seed and farming location that might be needed if droughts (or floods) become more frequent. At the same time, it should be recognized that investments with a long lifetime (e.g., in infrastructure, water systems, and energy conversion) should be given special attention in climate-proofing efforts, because large investments are at stake and climate change is expected to develop further over their lifetimes.

Depending on the country in question, it is also important to focus on co-benefits and risks of adaptation measures, especially of long-term investments. This implies that the selection of adaptation measures should be assessed in the context of a broader agenda than only climate change. Many examples might be given: Development of irrigation systems might be an adaptation to rainfall change, yet it might also promote economic growth in general. On the other hand, they might produce an increased risk for diseases requiring investments in health and education. Building of dikes might increase the cultivated area by reducing the effect of flooding by saline water but might also negatively affect marine ecosystems that support livelihoods.

Finally, developing research and administrative capacity to increase climate change preparedness could have positive impacts on environmental management in general and might increase income from CDM projects. This might also promote awareness and mainstreaming of climate issues in important development papers such as PRSPs, which are the main tools for guiding the joint development efforts by governments and donors in developing countries.

Acknowledgments This special issue is the final outcome of a process started by the conference "Bridging research and development assistance: Strategies for adaptation to climate change in developing countries" held in 2004 in Copenhagen and organized by Research Network for Environment and Development (ReNED, now merged into Danish Development Research Network, DDRN; www.ddrn.dk). The conference was funded by the Danish Ministry of Foreign Affairs. Development of this article was partly supported by the African Monsoon Multidisciplinary Analysis (AMMA) project. Based on a French initiative, AMMA was built by an international scientific group and is currently funded by a large number of agencies, especially from France, the United Kingdom, the United States, and Africa. It has been the beneficiary of a major financial contribution from the European Community's Sixth Framework Research Programme. Detailed information on scientific coordination and funding is available on the AMMA International website: http://www.amma-international.org.

References

Adger WN (2006) Vulnerability. Global Environmental Change 16:268–281

Adger WN, Huq S, Brown K, Conway D, Hulme M (2003) Adaptation to climate change in the developing world. Progress in Development Studies 3:179–195

Adger N, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi T (2007) Assessment of adaptation practices, options, constraints and capacity. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 717–743

Ayers JM, Huq S (2009) The value of linking mitigation and adaptation: a case study from Bangladesh. Environmental Management (this issue). doi:10.1007/s00267-008-9223-2

Barbier B, Yacouba H, Karambiri H, Zoromé M (2009) Human vulnerability to climate variability in the Sahel: farmers' adaptation strategies in northern Burkina Faso. Environmental Management (this issue). doi:10.1007/s00267-008-9237-9

Barnett BJ, Mahul O (2007) Weather index insurance for agriculture and rural areas in lower-income countries. American Journal of Agricultural Economics 89:1241–1247

Bohle HG, Downing TE, Watts MJ (1994) Climate change and social vulnerability: toward a sociology and geography of food insecurity. Global Environmental Change 4:37–48

Bojö J, Reddy RC (2001) Poverty reduction strategies and environment. A review of 40 interim and full PRSPs. World Bank, Washington, DC

Bojö J, Green K, Kishore S, Pilapitya S, Reddy RC (2004) Environment in poverty reduction strategies and poverty reduction support credits. The World Bank, Washington, DC

Boko A, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman Elasha B, Tabo R, Yanda P (2007) Africa. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 433–467

Brooks N, Adger WN, Kelly PM (2005) The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change-Human and Policy Dimensions 15:151–163

Burton I, Lim B (2005) Achieving adequate adaptation in agriculture. Climatic Change 70:191–200

Challinor A, Wheeler T, Garforth C, Craufurd P, Kassam A (2007) Assessing the vulnerability of food crop systems in Africa to climate change. Climatic Change 83:381–399

Chambers R (1995) Poverty and livelihoods: whose reality counts? IDS Discussion Paper 347:1–53

Chan JCL (2006) Comments on "Changes in tropical cyclone number, duration, and intensity in a warming environment". Science 311:1713

Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon W-T, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P (2007) Regional climate projections. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 847–940

Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C, Huu Ninh N (2007) Asia. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 469–506

Dai A, Trenberth KE, Qian T (2004) A global dataset of Palmer Drought Severity Index for 1870–2002: relationship with soil moisture and effects of surface warming. Journal of Hydrometeorology 5:1117–1130

Danida (2005) Danish climate and development action programme. Ministry of Foreign Affairs of Denmark, Copenhagen, Danida

Davidson O, Halsnæs K, Huq S, Kok M, Metz B, Sokona Y, Verhagen J (2003) The development and climate nexus: the case of sub-Saharan Africa. Climate Policy 3:S97–S113

Eakin H, Luers AL (2006) Assessing the vulnerability of social–environmental systems. Annual Review of Environment and Resources 31:365–394

Emanuel K (2005) Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436:686–688

Eriksen S, Lind J (2009) Adaptation as a political process: adjusting to drought and conflict in Kenya's drylands. Environmental Management (this issue). doi:10.1007/s00267-008-9189-0

Eriksen SH, O'Brien K (2007) Vulnerability, poverty and the need for sustainable adaptation measures. Climate Policy 7:337–352

Fussel HM (2007) Vulnerability: a generally applicable conceptual framework for climate change research. Global Environmental Change 17:155–167

Garg A, Dhiman RC, Bhattacharya S, Shukla PR (2009) Development, malaria and adaptation to climate change: a case study from India. Environmental Management (this issue). doi:10.1007/s00267-008-9242-z

Gigli S, Agrawala S (2007) Stocktaking of progress on integrating adaptation to climate change into development co-operation activities. OECD, Paris

Gouvernement du Burkina Faso (2007) Programme d'Action National d'Adaptation à la Variabilité et aux Changements Climatiques du Burkina Faso. Ministère de l'Environnement et du Cadre de Vie, Ouagadougou, Burkina Faso

Gregory PJ, Ingram JSI, Brklacich M (2005) Climate change and food security. Philosophical Transactions of the Royal Society B: Biological Sciences 360:2139–2148

Groisman PY, Knight RW, Easterling DR, Karl TR, Hegerl GC, Razuvaev VN (2005) Trends in intense precipitation in the climate record. Journal of Climate 18:1326–1350

Haddad BM (2005) Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. Global Environmental Change: Human and Policy Dimensions 15:165–176

Halsnæs K, Trærup S (2009) Development and climate change: a mainstreaming approach for assessing economic, social, and environmental impacts of adaptation measures. Environmental Management (this issue). doi:10.1007/s00267-009-9273-0

Halsnæs K, Shukla PR, Garg A (2008) Sustainable development and climate change: lessons from country studies. Climate Policy 8:202–219

IPCC (2007) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Jallow BP, Downing TE (2007) NAPAs: priorities to policies. Tiempo: A Bulletin on Climate and Development 65:14–18

Kates RW (2000) Cautionary tales: adaptation and the global poor. Climatic Change 45:5–17

Kelly PM, Adger WN (2000) Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change 47:325–352

Luers AL (2005) The surface of vulnerability: an analytical framework for examining environmental change. Global Environmental Change: Human and Policy Dimensions 15:214–223

Magrin G, Garcia CG, Choque DC, Giménez JC, Moreno AR, Nagy GJ, Nobre C, Villamizar A (2007) Latin America. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability.

Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 581–615

Mertz O, Mbow C, Reenberg A, Diouf A (2009) Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environmental Management (this issue). doi: 10.1007/s00267-008-9197-0

Michaelowa A, Michaelowa K (2007) Climate or development: is ODA diverted from its original purpose? Climatic Change 84:5–21

Mimura N, Nurse L, McLean RF, Agard J, Briguglio L, Lefale P, Payet R, Sem G (2007) Small islands. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 687–716

Mortimore MJ, Adams WM (2001) Farmer adaptation, change and 'crisis' in the Sahel. Global Environmental Change: Human and Policy Dimensions 11:49–57

O'Brien G, O'Keefe P, Meena H, Rose J, Wilson L (2008) Climate adaptation from a poverty perspective. Climate Policy 8:194–201

Rasmussen K, May W, Birk T, Mataki M, Mertz O, Yee D (in press) Climate change on three Polynesian outliers in the Solomon Islands: impacts, vulnerability and adaptation. Environmental Management

Reenberg A, Birch-Thomsen T, Mertz O, Fog B, Christiansen S (2008) Coupled human–environment timelines of SW Pacific small island societies: event driven adaptation of human coping strategies. Human Ecology 36:807–819

République du Mali (2007) Programme d'Action National d'Adaptation aux Changements Climatiques. Ministère de l'Equipement et des Transports, Bamako, Mali

Rosenzweig C, Cassassa G, Karoly DJ, Imeson A, Liu C, Menzel A, Rawlins S, Root TL, Seguin B, Tryjanowski P (2007) Assessment of observed changes and responses in natural and managed systems. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, and Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Pres, Cambridge, pp 79–131

Schmidhuber J, Tubiello FN (2007) Climate change and food security special feature: global food security under climate change. Proceedings of National Academy of Sciences USA 104:19703–19708

Schröter D, Polsky C, Patt A (2005) Assessing vulnerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change 10:573–595

Smit B, Pilifosova O (2001) Adaptation to climate change in the context of sustainable development and equity. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White C (eds) Climate change 2001: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge, pp 877–912

Smit B, Skinner MW (2002) Adaptation options in agriculture to climate change: a typology. Mitigation and Adaptation Strategies for Global Change 7:85–114

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

Smit B, Burton I, Klein RJT, Wandel J (2000) An anatomy of adaptation to climate change and variability. Climatic Change 45:223–251

Thomas DSG, Twyman C (2005) Equity and justice in climate change adaptation amongst natural-resource-dependent societies. Global Environmental Change: Human and Policy Dimensions 15:115–124

Trenberth KE, Jones PD, Ambenje P, Bojariu R, Easterling D, Klein Tank A, Parker D, Rahimzadeh F, Renwick JA, Rusticucci M, Soden B, Zhai P (2007) Observations: surface and atmospheric climate change. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 235–336

Tschakert P (2007) Views from the vulnerable: understanding climatic and other stressors in the Sahel. Global Environmental Change 17:381–396

Turner BL, Kasperson RE, Matson PA, McCarthy JJ, Corell RW, Christensen L, Eckley N, Kasperson JX, Luers A, Martello ML, Polsky C, Pulsipher A, Schiller A (2003) A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences USA 100:8074–8079

Van Duivenbooden N, Abdoussalam S, Mohamed AB (2002) Impact of climate change on agriculturalproduction in the Sahel. Part 2. Case study for groundnut and cowpea in Niger. Climatic Change 54:349–368

Vincent K (2007) Uncertainty in adaptive capacity and the importance of scale. Global Environmental Change 17:12–24

Vogel C, Moser SC, Kasperson RE, Dabelko GD (2007) Linking vulnerability, adaptation, and resilience science to practice: pathways, players, and partnerships. Global Environmental Change 17:349–364

Watts MJ, Bohle HG (1993) The space of vulnerability: the causal structure of hunger and famine. Progress in Human Geography 17:43–67

Wheaton EE, Maciver DC (1999) A framework and key questions for adapting to climate variability and change. Mitigation and Adaptation Strategies for Global Change 4:215–225

Willis SG, Hole DG, Collingham YC, Hilton G, Rahbek C, Huntley B (2009) Assessing the impacts of future climate change on protected areas networks: a method to stimulate species responses. Environmental Management (this issue). doi: 10.1007/s00267-008-9125-3

World Bank (2006) An investment framework for clean energy and development: a progress report. World Bank, Washington, DC

Yohe G (2000) Assessing the role of adaptation in evaluating vulnerability to climate change. Climatic Change 46:371–390

Yohe G, Tol RSJ (2002) Indicators for social and economic coping capacity: moving toward a working definition of adaptive capacity. Global Environmental Change: Human and Policy Dimensions 12:25–40