Sustain Sci (2007) 2:265–275
DOI 10.1007/s11625-007-0032-y

REVIEW ARTICLE

Adaptation planning for climate change: concepts, assessment approaches, and key lessons

H.-M. Füssel

Received: 22 March 2007 / Accepted: 9 May 2007 / Published online: 9 August 2007

Abstract Planned adaptation to climate change denotes actions undertaken to reduce the risks and capitalize on the opportunities associated with global climate change. This paper summarizes current thinking about planned adaptation. It starts with an explanation of key adaptation concepts, a description of the diversity of adaptation contexts, and a discussion of key prerequisites for effective adaptation. On the basis of this introduction, major approaches to climate impact and adaptation assessment and their evolution are reviewed. Finally, principles for adaptation assessment are derived from decision-analytical considerations and from the experience with past adaptation assessments.

Keywords Climate change · Adaptation assessment · Planned adaptation

Introduction

Anthropogenic climate change is associated with substantial risks for society and nature. The two fundamental societal response options for reducing these risks are *mitigation* of climate change and *adaptation* to climate change. In the climate change context, mitigation means limiting global climate change by reducing the emissions of greenhouse gases or enhancing their sinks. Adaptation means actions targeted at the vulnerable system in response to actual or expected climate stimuli with the objective of moderating harm from climate change or exploiting opportunities (McCarthy et al. 2001). Table 1 presents key characteristics of mitigation and adaptation. Burton and May (2004) have compared mitigation and adaptation regimes under the United Nations Framework Convention on Climate Change (UNFCCC).

Mitigation has traditionally received much greater attention in the climate change community than adaptation, both scientifically and from a policy perspective. The most important reason for the focus on mitigation is its ability to reduce impacts on all climate-sensitive systems whereas the potential of adaptation is limited for many systems. It is, for instance, difficult to conceive how Pacific coral atolls could successfully adapt to a substantial rise in sea-level. Second, the (long-term) benefits of mitigation are certain, because mitigation reduces the root cause of the climate-change problem whereas the effectiveness of proactive adaptation to climate change often depends on the accuracy of regional climate and impact projections, which are subject to substantial uncertainty. Third, mitigation generally applies the polluter-pays principle whereas the need for adaptation measures will be greatest in developing countries whose historical contribution to climate change has been small. Finally, greenhouse gas emissions are comparatively easy to monitor quantitatively whereas measuring the effectiveness of adaptation in terms of future impacts avoided is much less straightforward. It is particularly difficult to ensure that international assistance for adaptation would be fully additional to official development assistance, because there is no binding level for the latter. Such additionality is a key requirement for recipient countries in any international adaptation regime, because their vulnerability to climate change would not be improved by a mere relabelling of development assistance.

Despite the urgent need for mitigation there are also convincing arguments for increasing consideration of

H.-M. Füssel (✉)
Potsdam Institute for Climate Impact Research,
Potsdam, Germany
e-mail: fuessel@pik-potsdam.de

Table 1 Characteristics of mitigation and adaptation (adapted from Füssel and Klein 2006)

	Mitigation of climate change	Adaptation to climate change
Target systems	All systems	Selected systems
Scale of effect	Global	Local to regional
Lifetime	Centuries	Years to centuries
Lead time	Decades	Immediate to decades
Effectiveness	Certain	Generally less certain
Ancillary benefits	Sometimes	Often
Polluter pays	Typically	Not necessarily
Actor benefits	Only little	Almost fully
Monitoring	Relatively easy	More difficult

adaptation. First of all, anthropogenic greenhouse gas and aerosol emissions are already affecting average climate conditions and climate extremes (Hegerl and Zwiers 2007). For example, eleven of the twelve warmest years globally occurred between 1995 and 2006 (Trenberth and Jones 2007). Even the relatively small magnitude of climate change observed so far has had substantial impacts on many natural and social systems (Casassa and Rosenzweig 2007). Second, climate will continue to change for the foreseeable future. As a result of accumulation of greenhouse gases emitted in the past and the inertia of the climate system, the rate of global warming in the next few decades is projected to be substantially faster than in the last few decades, largely irrespective of the emission scenario (Meehl and Stocker 2007). Fourth, the effect of emissions reduction takes at least several decades to become fully apparent whereas most adaptation measures have a much shorter lead time. Fourth, adaptation can be implemented on a local or regional scale, and its efficacy is less dependent on the actions of others. Finally, many measures undertaken to adapt to climate change have important ancillary benefits, for example reducing current climate-sensitive risks. The increasing interest in adaptation to climate change is reflected in the development of the theory and practice of climate change assessments, and in increasing consideration by political organizations and funding bodies (Füssel 2004; Carter et al. 2007).

Mitigation and adaptation are complementary rather than mutually exclusive alternatives, because their characteristic time-scales and the actors concerned are largely distinct. These two response options can sometimes be mutually reinforcing (e.g. planting trees to provide additional shade in warming regions) but they can also work against each other (e.g. increasing air-conditioning powered by fossil fuels to cope with rising temperatures). There has recently been much political interest in integrating the two options, as exemplified by the inclusion in the IPCC Fourth Assessment Report (Klein and Huq 2007) of a separate chapter on the interaction between adaptation and mitigation.

This paper summarizes current thinking on planned adaptation to climate change. The discussion is intended to be generally applicable but it reflects a regional imbalance in the scientific literature where most of the methodological literature originates from the industrialized world. For more specific advice on particular sectors and regions, readers are referred to the rapidly increasing literature, as reviewed in Adger et al. (2007). Smith et al. (2003) discuss the links between adaptation and development in developing countries. Adger et al. (2006) discuss questions of international equity originating from the huge disparity between countries' responsibility for and vulnerability to climate change (Scientific Expert Group on Climate Change 2007).

The remainder of this paper is organized as follows. The next section introduces key adaptation concepts, distinguishes different kinds of adaptation, and compares adaptation to climate change with established practices of resource and risk management. This is followed by a section on the main approaches to adaptation assessment, which briefly reviews their evolution over time. The penultimate section identifies some general principles for adaptation planning and the final section concludes this paper.

Adaptation to climate change

What is adaptation to climate change?

Human adaptation to climate change is not a well-defined and delimited set of activities. The diversity of adaptation activity is illustrated by the following key dimensions (partly based on Smit et al. 1999):

Climate-sensitive domains: Adaptation is relevant for all climate-sensitive domains, including agriculture, forestry, water management, coastal protection, public health, and disaster prevention.

Types of climate hazard: Adaptation can be motivated by a diverse set of current and future climate hazards, including observed and expected changes in average climate, climate variability, and climate extremes.

Predictability of climatic changes: Some aspects of future climate change can be predicted with reasonably high confidence (e.g. changes in average temperature) whereas others are associated with large uncertainty (e.g. changes in hurricane tracks and intensity).

Non-climatic conditions: Adaptation occurs against a background of environmental, economic, political, and cultural conditions that vary substantially across regions.

Purposefulness: Adaptation can be either autonomous (e.g. reducing physical activity during a heatwave) or purposefully planned (e.g. adopting new building codes).
Timing: Planned adaptation can be either reactive (i.e. after some impacts have been experienced) or proactive/anticipatory (i.e. before major damage has occurred).
Planning horizon: The time horizon of planned adaptation can vary substantially, from a few months to many decades.
Form: Adaptation involves a broad range of measures, including technical, institutional, legal, educational, and behavioural measures. Research and data collection may also be considered as adaptation measures (in a wider sense), because they facilitate implementation of effective actions for reducing climatic risks.
Actors: Adaptation involves a wide range of people at different hierarchy levels in many public and private organizations.

The diversity of adaptation contexts implies there is no single approach for assessing, planning, and implementing adaptation measures. Adaptation assessments must therefore flexibly apply different methodological approaches to produce knowledge that is relevant in a particular decision context.

When and how does adaptation occur?

Figure 1 illustrates several important concepts of planned adaptation. It shows a hypothetical time series of a climate attribute, for example seasonal precipitation. The target community is assumed to be well adapted to a given range of this climate variable, denoted the "coping range", but it is vulnerable to climatic conditions outside this range. For example, insufficient precipitation may cause crop damage whereas too much precipitation may cause river flooding.

In the time period up to T_1, climate largely remains within the coping range, and the community is prepared to accept the minor damage caused by the occasional slight exceedance. Shortly after T_1, the climate event E_1 exceeds the coping range substantially, causing significant damage. In this hypothetical example extension of the coping range is assumed to be possible but costly. The community wonders whether E_1 is still an expression of natural variability or whether it is already a harbinger of more climate change to come. If the first, the community would be willing to accept the damage because the return period of a similar event would be very long. If the second, the community would prepare for costly extension of their coping range because a previously "unusual" event like E_1 would become increasingly "normal" in the future.

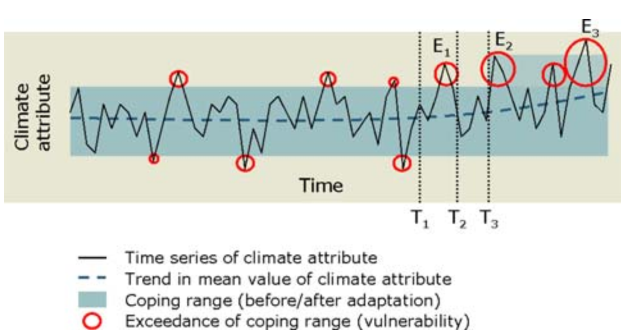

Fig. 1 Hypothetical example for the timing of planned adaptation

In this example, model projections suggest that the considered climate variable is indeed increasing (and will continue to do so for the foreseeable future) because of anthropogenic greenhouse gas emissions. As a result, the community makes a decision at T_2 to extend their coping range upwards (e.g. by building a new overflow reservoir). Implementation of this adaptation takes until T_3, when the coping range is effectively extended. Soon after T_3, another extreme event E_2 occurs. This event is even stronger than E_1 but still within the extended coping range. Hence, adaptation has prevented substantial damage that would have occurred otherwise. As climate continues to change, however, an even more extreme event E_3 occurs, which exceeds even the extended coping range, causing substantial damage despite previous adaptation. At this point, the community is faced with the question whether to accept the apparently increased risks or whether to undertake further costly adaptation.

Several important lessons can be drawn from this stylized example. First, adaptation needs arise often (but not always) from extreme events rather than from average climate conditions. Second, when vulnerability is linked to extreme events, natural climate variability and anthropogenic climate change need to be considered jointly, because risks arise from the combination of the two. Third, the distinction between reactive and proactive adaptation may be fuzzy in practice. In our example, the decision at T_2 to adapt was triggered by the previous extreme event but it was largely made in anticipation of further risk changes in the future. Fourth, adaptation to climate change is a continuous process. In the example, adaptation was effective for some time, until E_3 occurred. At that time the climate had changed so much that additional adaptation would have been necessary to prevent further damage. Finally, accurate information about future climate change often reduces the total costs of adaptation. If reliable information about climate change throughout the time depicted in the diagram had been available at T_2, the community may have decided to increase the coping range even further (e.g. by building a larger reservoir), thereby avoiding the damage caused by E_3 and/or the additional costs of retrofitting existing infrastructure at a later stage.

What is (not) new about adaptation to climate change?

Because climate is a key factor affecting agriculture and forestry, housing, transport and other infrastructure, water and energy supply, tourism and recreation, hazard mitigation, and human health and well-being, many economic agents and public institutions have a long tradition of managing climate-sensitive resources under variable climatic conditions. Is adaptation to anthropogenic climate change actually something new?

Some aspects of adaptation to climate change are indeed *not new*. First, societies have always attempted to make best use of the climatic resources in their region. They have also attempted to adapt to changes in climate conditions—sometimes successfully, sometimes less so. Second, most activities considered in adaptation to climate change are not new either. Adaptation includes well established practices from disaster risk management (e.g. early-warning systems), coastal management (e.g. structural protection), resource management (e.g. water rights allocation), spatial planning (e.g. flood zone protection), urban planning (e.g. building codes), public health (e.g. disease surveillance), and agricultural outreach (e.g. seasonal forecasts). Finally, adaptation planning for climate change often applies established methods and tools from risk management (Willows and Connell 2003; Burton et al. 2005).

Despite a long history of social adaptation to climate and climate change, several aspects of adapting to global climate change *are new*.

Unprecedented climate conditions: Most regions have already or will soon experience climatic conditions that are unprecedented in modern human history.

Unprecedented rate of change: The current and expected future rate of global climate change is unprecedented in modern human history, making adaptation to those changes particularly challenging.

Unprecedented knowledge: Previous societies that experienced changes in climate had few means of understanding its extent, identifying its causes, and predicting its future path. The current generation, in contrast, enjoys real-time climate observations from around the world, it commands models that help separate the effects of a variety of natural and anthropogenic forcings, and it has some knowledge about future changes associated with continued anthropogenic forcing on the climate system. This unprecedented wealth of knowledge about present and future climate change enables planned, and even proactive, adaptation (Hay and Mimura 2006).

Unprecedented methodological challenges: The assessment approaches applied by communities that traditionally deal with climate-sensitive risks and resources (e.g. natural hazards and water-resource management) are not well equipped for dealing with the complex, uncertain, dynamically evolving hazard "global climate change".

New actors: Managers of climate-sensitive resources (for example water planners, forest managers, urban and spatial planners, architects, tourism managers, and health care providers) have usually assumed regional climate is essentially stationary. This simplifying assumption is no longer valid under global climate change, in particular when decisions with long lifetimes are concerned. Adaptation to climate change thus requires attention and action by people who have not explicitly considered climate in their past decisions.

New measures: Concern about climate change has triggered the development of new options for coping with unprecedented climate conditions. For instance, one spectacular example from the Netherlands involves the construction of floating settlements that can sustain repeated flooding (van Ogtrop et al. 2005; de Graaf et al. 2006).

Planning and assessing adaptation to climate change

What is planned adaptation to climate change?

Planned adaptation to climate change means the use of information about present and future climate change to review the suitability of current and planned practices, policies, and infrastructure. Adaptation planning involves addressing questions such as: How will future climatic and non-climatic conditions differ from those of the past? Do the expected changes matter to current decisions? What is a suitable balance between the risks of acting (too) early and those of acting (too) late? Eventually, adaptation planning is about making recommendations about who should do what more, less, or differently, and with what resources.

Depending on the specific issue under consideration, adaptation to climate change may have close links with natural resource management, water management, disaster preparedness, urban planning, sustainable development, poverty reduction, etc. In addition to climate change, efficient adaptation requires consideration of other factors that are important for current decisions, for example current climatic risks, key non-climatic challenges, and economic development plans. In those regions and sectors where climate variability already poses a significant threat, it is particularly important to consider the synergies of addressing current and future climate risks jointly.

What is the objective of planned adaptation?

Adaptation to climate change is sometimes understood as a strategy for preventing all adverse impacts of current and future climate change. Such a goal implicitly assumes a world that is perfectly adapted to current climate conditions, that has perfect knowledge of future climate change, and that has abundant resources for adaptation. These assumptions are clearly unrealistic, in particular in the context of developing countries that already suffer from substantial climate-sensitive risks.

The objective of real-world adaptation is at the same time more and less ambitious than the "naive" objective suggested above. It is more ambitious because most actions to adapt to climate change would also reduce the risks associated with current climate variability and possibly support other societal objectives. It is less ambitious because adaptation in general cannot completely prevent adverse impacts of climate change, i.e., despite adaptation there will still be residual impacts of climate change.

Figure 2 illustrates these ideas by defining various terms related to climate impacts and adaptation. The diagram depicts hypothetical trajectories for the level of climate-related impacts on a system because of both natural variability and anthropogenic climate change. The lowest trajectory denotes the (unrealistic) reference case of an undisturbed climate. Impacts are, nevertheless, changing with time, for example because of economic growth, technological development, and demographic changes. The other trajectories depict the impacts associated with a changing climate for four different assumptions regarding adaptation. They include (in descending order of impacts) the "dumb farmer", who does not react at all to changing climate conditions; the "typical farmer", who adjusts his practice in reaction to persistent climate changes only; the "smart farmer", who uses available information on expected climate conditions to adjust proactively; and the "clairvoyant farmer", who has perfect foresight of future climate conditions and faces no restrictions in implementing adaptation measures. Of course, the metaphorical names used to characterize the effects of different assumptions on adaptive behaviour can be applied to any affected agent. They are applied here because of their frequent use in the pertinent literature (Rothman and Robinson 1997; Schneider 1997).

The vertical bars on the right of Fig. 2 illustrate different interpretations of the term (climate) impacts: *potential impacts* show the level of impacts assuming no adaptation; *expected impacts* assume only autonomous adaptation; *residual impacts* assume autonomous adaptation and feasible planned adaptation; and *unavoidable impacts* refer to the level of climate impacts assuming perfect adaptation.

In this example, climate change has some impacts that cannot be avoided even with perfect adaptation. The benefits of planned adaptation thus correspond to the difference between expected and residual impacts rather than between potential and unavoidable impacts (or even zero). In other words, the purpose of planned adaptation is to turn typical farmers (or water managers, urban planners, etc.) into smart farmers. The establishment of "acceptable" risk levels in relation to climate change involves an (explicit or implicit) evaluation of the trade-offs between the expected costs and benefits of different levels of adaptation.

What are preconditions for effective planned adaptation?

Building on work by Last (1998) in public health, Füssel and Klein (2004) have suggested several prerequisites for effective planned adaptation (assuming that a climate change-related problem either exists now or will exist in the future). The following list presents these prerequisites and shows how each of them can potentially be addressed

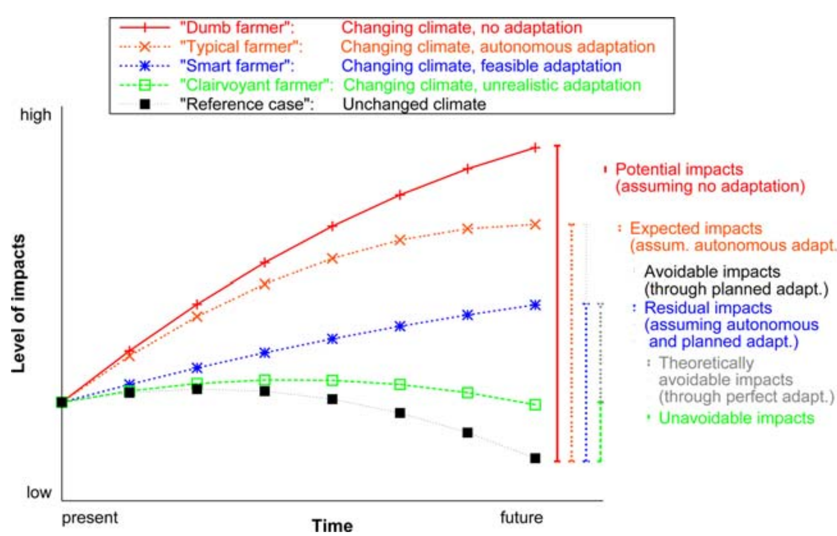

Fig. 2 Different concepts of climate impacts and adaptation (adapted from Füssel and Klein 2006)

to some extent by climate change impact, vulnerability, and adaptation assessments:

Awareness of the problem: Assessing and communicating vulnerability to climate change
Availability of effective adaptation measures: Triggering research that may lead to the development of new adaptation options
Information about these measures: Identifying and assessing effective adaptation measures
Availability of resources for implementing these measures: Evaluating co-benefits of adaptation (thus increasing perceived benefits); identifying ways for the most efficient use of resources, e.g. by mainstreaming adaptation in existing activity (thus reducing costs); and motivating the provision of additional resources, either domestically or internationally
Cultural acceptability of these measures: Educating people about risks and response options to increase the acceptability of unfamiliar measures
Incentives for implementing these measures: Identifying obstacles for implementation of effective measures and suggesting options to overcome them.

Scientific analysis and political efforts should be targeted at those preconditions that are most in need of improvement in a particular context. For example, if there is little awareness among policy-makers and other stakeholders of the health risks associated with climate variability and change, the assessment should focus on identifying and emphasizing these risks and the risk-reducing potential of adaptive measures. If stakeholders are aware of the risks but have little information about what to do about them, the assessment should suggest feasible and effective measures, preferably considering the experience of dealing with similar risks in already affected regions. If stakeholders are aware of the risks and knowledgeable about effective response measures, the assessment is more likely to focus on the expected costs and benefits of the specific options available, and on overcoming potential barriers to their implementation.

The relevance of planned adaptation is limited in two distinct cases:

1. when all prerequisites to adaptation are already fulfilled; and
2. when unsurmountable obstacles exist to fulfilling some prerequisites.

In the first case, adaptation would occur "autonomously". The second case refers to fundamental or practical "limits to adaptation". A mountain-top ecosystem that would be lost in a warming world because it cannot migrate to a new suitable habitat is an example of a fundamental limit to adaptation. Such an impact can be avoided only by timely mitigation of climate change. Practical limits to adaptation are usually a result of insufficient economic resources, technical skills, or political will. In developing countries international assistance may be able to stretch these limits to some extent.

Why is adaptation to climate change assessed?

Füssel and Klein (2006) have reviewed the practice of climate change assessments and identified four prototypical stages of assessment:

- climate impact assessments, which identify potential (biophysical) impacts of climate change;
- first and second-generation vulnerability assessments, which determine the different vulnerability of social groups or regions to climate change, considering their adaptive capacity; and
- adaptation policy assessment, which recommends specific measures for reducing the vulnerability of social groups to climate change and variability.

The evolution of assessments is characterized by a shift from science-driven assessments to policy-driven assessments, by increasing integration of climate change with non-climatic stressors to a system or sector, by finer spatial resolution, by increasing contributions of social scientists, by stronger involvement of stakeholders in the assessment, and by improved treatment of uncertainties.

Assessment of adaptation is relevant in two largely distinct contexts (Smit et al. 1999; Burton et al. 2002; Füssel 2007b). In climate impact and vulnerability assessments, consideration of adaptation enables more realistic estimation of climate impacts than simpler assessments based on a "dumb-farmer approach". The focus in this paper, however, is on the use of adaptation assessments for adaptation planning and policy-making. This purpose is reflected in the IPCC definition of adaptation assessment as "identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility" (McCarthy et al. 2001).

How is adaptation to climate change assessed?

International and national organizations have developed guidelines for climate impact and adaptation assessment. Widely applied generic guidelines include the IPCC Technical Guidelines (Carter et al. 1994; Parry and Carter 1998), the USCSP International Handbook (USCSP 1994; Benioff et al. 1996), the UNEP Handbook (Feenstra et al. 1998), the UNDP-GEF Adaptation Policy Framework (Burton et al. 2005), and the Climate Change Adaptation through Integrated Risk Assessment (CCAIRR) guidelines (ADB 2005, Chap. 8). Assessment guidelines have also been developed for several climate-sensitive sectors and systems (Kovats et al. 2003b), for specific regions (Willows and Connell 2003), and with a focus on the operations of international donor organizations (Global Environment Facility Program 2006). For a review of sectoral guidelines for climate change adaptation assessment, see Klein et al. (1999) for coastal zones and Füssel (2007a) for human health.

The two prototypical approaches applied in guidelines for climate impact and adaptation assessment are the hazards-based approach and the vulnerability-based approach (Burton et al. 2005). The hazards-based approach focuses on the incremental impacts of climate change. Assessments start from model-based climate change projections, and consideration of non-climatic factors is usually limited. This approach prevails in the IPCC Guidelines, the USCSP Guidebook and the UNEP Handbook. Several reviews have concluded that hazards-based assessments have been crucial for identifying risks of climate change but that their results have not generally been immediately useful for the purposes of adaptation policy design (Klein et al. 1999; O'Brien 2000; McMichael et al. 2001; Burton et al. 2002; Kovats et al. 2003a; ADB 2005). Important limitations of hazards-based assessments are their strong reliance on model-based climate and climate-impact projections, which may not be available on the spatial scale relevant to the decision-maker, and the long time frame of climate-change projections that has little practical relevance to many adaptation actors. Furthermore, these assessments usually give insufficient consideration to current risks associated with natural climate variability and non-climatic stressors, to key uncertainties and their implications for the design of robust adaptation policies, to non-technical aspects of adaptation (e.g. adaptive capacity and the social determinants of vulnerability), and to the wider policy context of adaptation (e.g. sustainable economic development and natural resource management).

The vulnerability-based approach assesses future climate change in the context of current climate risks. It has a strong focus on the social factors that determine the ability to cope with climatic hazards. Vulnerability-based assessments start from the experience with managing climate risks in the past, and they involve stakeholders from the outset, linking adaptation to climate change directly to their activities. This approach can produce useful results even in the absence of reliable impact projections (e.g. by identifying low or no-regret options that are robust against a wide range of plausible climate developments). Disadvantages include greater reliance on expert judgment, limited comparability across regions, because of the large qualitative nature of results, and the lack of clear methodology. The vulnerability-based approach plays a prominent role in the UNDP-GEF Adaptation Policy Framework.

The hazards-based and vulnerability-based approaches provide different views on particular climate risks. The hazards-based approach is most useful for raising awareness of the problem, for identifying research priorities, if current risks are effectively controlled, if long-term decisions are concerned, if sufficient data and resources are available to produce state-of-the-art climate scenarios at the spatial resolution relevant for adaptation, and if significant future climate impacts can be projected reliably. The vulnerability-based approach is, in contrast, most useful for identifying priority areas for action, for assessing the effectiveness of specific interventions, if current climate-related risks are unsatisfactorily controlled, if climatic stress factors are closely intertwined with non-climatic factors, if the planning horizon of adaptation actors is short, if resources (in terms of data, expertise, time, and money) are very limited, and if uncertainty about future climate impacts is very large. These conditions, which are particularly prevalent in developing countries, favour policies that provide short-term benefits by controlling current climate-sensitive risks and that are robust across the range of plausible climate and impact projections.

The initial focus on hazards-based approaches has evolved toward integration of the two approaches with strong emphasis on vulnerability-based approaches. These two approaches for assessing adaptation to climate change should be regarded as complementary not as exclusive alternatives.

How are adaptation needs defined?

Improved understanding of climate impacts and the wider policy implications of the climate problem has lead to a shift in the focus of international climate policy, the evolution of the practice of climate impact, vulnerability, and adaptation assessment, the development of a more sophisticated theory of adaptation, and a wider range of methodological approaches suggested in guidelines for adaptation assessment (Burton et al. 2002; Füssel 2004; Carter et al. 2007).

Figure 3 illustrates the development of adaptation assessments by contrasting two stylized approaches for determining adaptation needs. The top diagram shows a linear cause–effect chain in which climate scenarios are the basis for estimating future climate impacts, which then define adaptation needs. Adaptation to climate change is seen as largely separate from other social processes and activities, and adaptation needs are largely determined by scientific analysis. This approach was prominently suggested in the IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations (Carter et al.

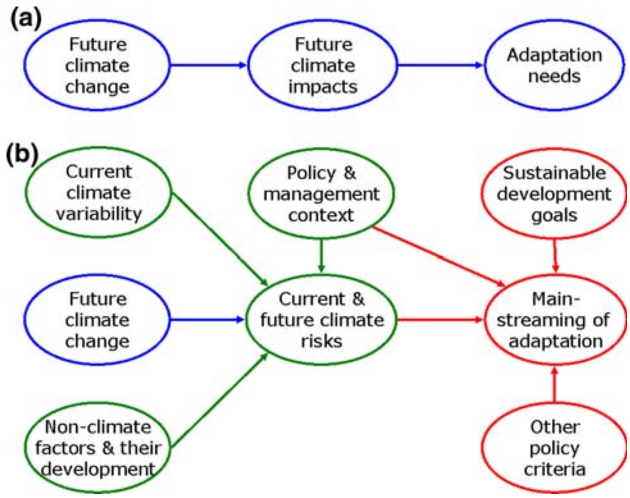

Fig. 3 Evolution of approaches for determining adaptation needs: **a** linear hazards-based approach; **b** complex integrative approach

1994). It is also typical of the initial national communications to the UNFCCC, most of which restrict considerations of adaptation to lists of potential adaptation options (Lim 2001).

The bottom diagram shows a more complex approach for determining adaptation needs which is characteristic of recent adaptation assessments. This approach arrives at a more comprehensive description of climate-related risks now and in the future by considering future climate change together with current climate variability and non-climate factors. The risk assessment is further informed by experience from management of past climatic hazards. Recommendations for adaption are determined by their potential to reduce current and future climate risks but also by their synergy with other policy objectives, for example sustainable development goals. Consideration of the wider policy context of adaptation usually leads to suggestions for mainstreaming climate adaptation into existing management activity and development plans (e.g. Huq et al. 2003). This more inclusive approach to adaptation assessment and planning is recommended, for instance, in the UNDP-GEF Adaptation Policy Framework (Burton et al. 2005). It is now applied in a variety of adaptation projects around the world, for example the Mainstreaming Adaptation to Climate Change (MACC) project implemented by the World Bank and the Climate Change Adaptation Program for the Pacific (CLIMAP) administered by the Asian Development Bank (ADB 2005).

Who should be involved in adaptation planning?

Adaptation policy assessment is a key component of planned adaptation to climate change. The following groups of participants are critical to the success of adaptation policy assessments with the objective of effectively reducing vulnerability to climate variability and change:

Scientists: Climate and impact scientists provide key knowledge why current policies, practices, and/or infrastructure may no longer be suitable in the future.

Practitioners: Natural resource managers and other adaptation actors who would actually implement the recommended changes can provide key information about how things are currently done, and why. This information is a crucial starting point for planning any changes.

Decision-makers and other stakeholders: Heads of government agencies, business managers and other stakeholders play a dual role in the adaptation process. First, they help frame the assessment process by specifying policy priorities and criteria for “good” adaptation. Second, they decide about the implementation of any changes recommended by the analysts. In some contexts, inclusion of selected representatives may be sufficient; in others, direct involvement of the intended beneficiaries of adaptation is crucial to the sustained success of an adaptation project.

Analysts: Policy analysts and economists can help prioritizing alternative adaptation options, on the basis of their expected costs and benefits (in a broad sense) and other criteria specified by relevant stakeholders.

Given their wide range of objectives, conceptual models, terminologies, background information, and time horizons, getting such a diverse group of people to work toward a common goal can be a formidable challenge. Adaptation assessments performed exclusively by scientists will, however, most probably miss elements critical to the success of recommended actions in the real world.

Where has adaptation to climate change been assessed?

Several industrialized countries have conducted comprehensive national adaptation assessments. These include the USA (National Assessment Synthesis Team 2001; Scheraga and Furlow 2001), Portugal (Santos et al. 2002), Finland (Carter and Kankaanpää 2004), and Canada (Lemmen and Warren 2004). Several assessments are currently in progress.

Adaptation assessments in developing countries have usually been conducted in the context of bilateral or multilateral assistance schemes, for example the USCSP (USCSP 1999; Smith and Lazo 2001), the UNEP country studies project (O’Brien 2000), the Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AIACC) project (http://www.aiaccproject.org/, Leary et al. 2005) the Capacity building for Stage II Adaptation to Climate Change project (http://www.gefonline.org/

projectDetails.cfm?projID=1060), the National Adaptation Programmes of Action (NAPA) process (http://www.napa-pana.org/), and the Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) process (http://www.waikato.ac.nz/igci/ccairr/ccairr.htm).

In addition to national-level assessments, adaptation to climate change is also increasingly considered in local and regional assessments.

Principles for adaptation planning

Given the diversity of adaptation contexts, any adaptation assessment must be targeted at the specific circumstances of the particular decision situation. For example, a national-level assessment of adaptation priorities for public health faces different challenges, and will use different methodological approaches, from a local-scale assessment of alternative forest-management strategies. Despite this, decision analysis and accumulated experience with past adaptation assessments suggests the following principles are robust and important:

1. The larger the importance of climatic factors compared with non-climatic factors to a particular decision, and the larger the potential increase in risks due to climate change, the greater is the need for a detailed assessment of the risks associated with climate change.
2. The better the knowledge about future changes in climate risks, the more specific is the action possible now.
3. The less the experience in managing a specific risk, the greater is the need for new and additional action.
4. When current climate risks are large, addressing these risks in combination with future climate change is usually the most effective and efficient adaptation strategy.
5. If low-regret or no-regret options exist (i.e. actions whose costs in a broad sense are small or even negative under all plausible climate scenarios), planned adaptation does not necessarily depend on reliable climate impact projections.

Preliminary adaptation assessments typically identify more adaptation options than can reasonably be implemented in the short term, given resource constraints. Hence, deciding what to do first is often as important as deciding what to do at all. Postponing adaptation involves risks in terms of unavoided impacts whereas adapting now involves risks because insufficient information about future conditions may limit the effectiveness or increase the cost of the measures adopted. The larger the former risks compared with the latter, the more urgent is it to act now.

Various authors have identified criteria for the prioritization of adaptation measures (Smit and Lenhart 1996; Smith 1997; Fankhauser et al. 1999; Reilly and Schimmelpfennig 2000). There is general agreement that anticipatory adaptation is particularly favourable if:

- climate-sensitive risks are already urgent;
- increasing risks are projected reliably;
- future impacts are potentially catastrophic or irreversible;
- decisions have long-term effects; and/or
- adaptation measures have a long lead time.

In contrast, postponing adaptation can be rational if:

- current and anticipated future risks are moderate;
- adaptation is very costly; and/or
- timely response options are readily available.

Conclusions

This paper has summarized current thinking about planned adaptation to climate change. Some of the lessons learnt from the pertinent literature are:

1. Adaptation to climate change involves a very broad range of measures directed at reducing vulnerability to a range of climatic stimuli (changes in means, variability, and extremes).
2. Adaptation planning shares many common features with risk management but involves unprecedented methodological challenges because of the uncertainty and complexity of the hazard.
3. Adaptation to climate change is highly context-specific, because it depends on the climatic, environmental, social, and political conditions in the target region and sector.
4. Although there is no single approach for assessing, planning, and implementing adaptation to climate change, some robust adaptation principles have nevertheless emerged.
5. Adaptation assessment has become more inclusive over time, linking future climate change with current climate risks and other policy concerns.
6. Adaptation planning requires close collaboration of climate and impact scientists, sectoral practitioners, decision-makers and other stakeholders, and policy analysts.
7. Consideration of global climate change is particularly important for decisions with a long planning or policy horizon.
8. Adaptation cannot avoid all impacts of climate change, because of important fundamental and practical constraints. Adaptation to climate change is, therefore, no substitute for mitigation of climate change.

Facilitating adaptation to climate change presents many challenges to scientific research and research funding. Research areas requiring particular attention include methodological developments, monitoring and indicator studies, empirical research, field and experimental research, predictive modelling, scenario development, economic costing, integrated assessment, quantification of the impacts of extreme weather events, modification of existing coping strategies, testing and evaluation of adaptation measures, and stakeholder participation (Carter 2007).

The widespread adoption of research findings on adaptation is a social learning process. This process can be facilitated by:

– establishment of dialogues in which research findings are shared (or co-created) with relevant stakeholders;
– mobilization of public and private resources to implement effective adaptation measures;
– creation of fora by means of which knowledge of what works (or does not), and why, can be exchanged across regions; and
– serious efforts to address the equity issues raised by the large disparity between the regions primarily responsible for, and those most vulnerable to, global climate change in international climate policy.

Acknowledgments A preliminary version of this paper was presented at the international symposium "Global Sustainability: Social System and Technological Strategy" in Kyoto (Japan), 15–16 January 2007. I thank Professor Takamitsu Sawa and Professor Kazuhiro Ueta for inviting me to this symposium. Professor John Hay has provided very helpful comments on an earlier version of this manuscript. The work presented here has been funded by a Marie Curie Outgoing International Fellowship of the European Commission within the Sixth Framework Programme for Research.

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