IPCC WGII Fourth Assessment Report – Draft for Government and Expert Review

Chapter 17 - Assessment of Adaptation Practices, Options, Constraints and Capacity

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Contents

Executive Summary

Adaptation can reduce vulnerability to climate variability and change

- Societies have a long record of adapting to the impacts of weather and climate through a diverse range of practices that include crop switching, irrigation, water management, disaster risk management, and insurance.

- But climate change poses novel risks often outside the range of experience, such as impacts related to permafrost melt, accelerated glacier retreat, and expansion of glacial lakes.

Adaptation to climate change is already taking place

- These measures are being implemented in both developed and developing countries, and involves policies, institutions, technologies, the private sector, and individual actions.

    - Examples of adaptations to observed changes in climate include: partial drainage of the Tsho Rolpa glacial lake in Nepal; changes in livelihood strategies in response to permafrost melt by the Inuit in Nunavut (Canada); and increased use of artificial snow-making by the alpine ski industry.

    - A limited but growing set of adaptation measures also explicitly consider future climate change. Examples include consideration of sea level rise in design of infrastructure such as the Confederation Bridge in Canada and a coastal highway in Micronesia, as well as in shoreline management policies in Maine (USA) and Western Europe.

- Adaptation actions are often undertaken to deal with current extreme events as well as expectations of how their intensity or frequency might change under climate change.

- Adaptation measures are seldom undertaken in response to climate considerations alone, but have multiple social and economic drivers. They have been implemented as part of broader development and sectoral initiatives.

Adaptation measures can be effective and sustainable, but may also entail significant costs

- Comprehensive multi-sectoral estimates of global costs and benefits of adaptation do not yet exist. Limited and speculative estimates are however available for global adaptation costs related to sea level rise, and energy expenditures for space heating and cooling. Estimates of global adaptation benefits for the agricultural sector are also available, although such literature does not explicitly consider the costs of adaptation.

- There are a growing number of adaptation cost and benefit-cost estimates at a regional and project level for sea level rise, agriculture, energy demand for heating and cooling, water resource management, and infrastructure. These studies identify a number of measures that can be implemented at low cost or with high benefit-cost ratios. The choice of optimal measures is highly dependent on local attributes, as well as on climate and socio-economic scenarios used.

Not everyone has the capacity to adapt

- There are societies and groups throughout the world that have insufficient capacity to adapt to climate change. For example, women within subsistence farming communities are disproportionately burdened with the costs of recovery and coping with drought in southern Africa.

- The capacity to adapt is dynamic and is influenced by economic and natural resources, social networks and entitlements, institutional structures, governance, human resources, and technology. Cross-national comparisons and analyses of vulnerable communities, for example, show the important role of governance in facilitating adaptation. Research in the Caribbean on hurricane preparedness, for example, shows that appropriate legislation is a necessary prior condition to implementing plans for adaptation to future climate change.

- Multiple stresses related to HIV AIDS, globalization, and violent conflict affect exposure to climate risks and the capacity to adapt. For example, farming communities in India are exposed to impacts of market changes and lower prices in addition to adverse climate change risks.

- Even high adaptive capacity does not necessarily translate into real action. For example, despite a high capacity to adapt to heat stress through relatively inexpensive adaptations, residents in urban areas in some parts of the world, including in North American and European cities, continue to experience high levels of mortality.

There are substantial limits and constraints to adaptation

- Adaptation is ultimately limited as a response strategy due to inertia and thresholds in technologies, the distribution of resources but also due to governance issues and the framing and cognition of risk. New research demonstrates that each of these areas interact with as physical and biological limits to adaptation to create significant barriers to action. There are also significant impediments to flows of knowledge and information relevant for adaptation decisions but participatory processes are recognized as important for overcoming constraints.

17.1 Concepts and methods

This chapter reports on a significant body of knowledge, practice and hypothesis testing on adaptation since the issue of adaptation was raised in the Third Assessment Report. In the TAR, adaptation was defined and many potential types of adaptation were identified (Smit *et al.*, 2001) in terms of their purpose, timing and the actors involved. The TAR did not provide a comprehensive analysis of adaptation in practice or of estimates of the effectiveness of adaptation as a response to climate change risks. The impetus for emerging research in the past five years has been (Adger *et al.*, 2005) a) actual adaptations to observed and climate changes and variability; b) planned adaptation in markets (such as water supply and insurance) in anticipation of risk; c) demand for practical information to reduce specific biophysical and social vulnerabilities; and d) policy initiatives, for example under the Framework Convention on Climate Change, that facilitate adaptation action. These new demands for knowledge have partially been met through research around the world on adaptation planning and processes (e.g. UKCIP, 2003), on appraisal techniques, and on documenting and assessing adaptation practices (Tompkins *et al*., 2005).

This chapter assesses this emerging literature focussing in particular on real-world adaptation practices, generic research on processes and determinants of adaptive capacity, and emerging critical lessons on the limits to adaptation. While adaptation is increasingly regarded as inevitable as part of a response strategy for climate change (US National Assessment, 2000), the weight of evidence in this chapter suggests two key findings. First, potential adaptations to climate change are often highly desirable in its own right in promoting resilience to many risks and hence the sustainability of development. Second, there are real limits to adaptation to particular risks and for particularly vulnerable systems and populations.

Adaptation to climate change takes place through adjustment to enhance resilience or reduce vulnerability in response to observed or expected changes in climate and its effects. Adaptation occurs in ecological, physical and human systems. Adaptation therefore involves changes in social and environmental processes, practices and functions to reduce vulnerability through moderating potential damages or to benefit from new opportunities. Adaptations to variability in weather and climate can reduce vulnerability and hence build resilience for dealing with a changing climate.

Unlike biological adaptation, individuals and societies will adapt to both observed and expected climate change. Although many sectors and sections of contemporary society are dependent on resources that vary with climate, there are well-established observations of human adaptation to climate change over the course of human history (McIntosh *et al.*, 2000; Mortimore and Adams, 2001). Nevertheless, many individuals and societies remain vulnerable to present-day climatic risks, which may be exacerbated by future climate change. Research on the processes of adaptation has increasingly demonstrated that some adaptation is undertaken by individuals in response to observed or expected change, while other types of adaptation is undertaken by governments on behalf of society, sometimes in anticipation of change but also in response to individual events (Adger, 2003; Kahn, 2003; Klein and Smith, 2003).

This chapter retains definitions and concepts outlined in the TAR and examines adaptation in the context of vulnerability and adaptive capacity. Vulnerability to climate change refers to the propensity of human and ecological systems to suffer harm and ability to respond to stresses imposed as a result of climate change impacts. Vulnerability is function of exposure and sensitivity to hazard and the capacity to adapt (Smit *et al.*, 2001). Although vulnerability depends on adaptive capacity, sensitivity, and exposure to the impacts of climatic change (Kelly and Adger, 2000; Smit *et al.*, 2000; Turner *et al.*, 2003; O'Brien *et al.*, 2004; O'Brien *et al.*, 2004), it also depends on the distribution of resources and prior stressors.

Exposure in this context is the impacts of climate change experienced by a social, physical or ecological system. Exposure can be modified by adaptation. Sensitivity is the degree to which a system will respond to the exposed change in climatic conditions. This has been measured, for example, by changes in ecosystem productivity or changes in species distributions, as a result of perturbations in temperature or precipitation (Kumar and Parikh, 2001; Parmesan and Yohe, 2003).

Adaptive capacity is the ability of a system to evolve in order to accommodate climate changes or to expand the range of variability with which it can cope (Jones, 2001; Yohe and Tol, 2002). Adaptive capacity is a vector of resources and assets that represent a resource to draw on to undertake adaptations. All societies have inherent capacities to cope with and adapt to climate variability in the present day. These capacities are, however, unevenly distributed and are influenced by the resources available to cope with exposure, the distribution of resources within populations, and the institutions which mediate both resources and coping with climate change and variability. Many comparative studies have noted that the poor and marginalized have historically been most at risk from climatic shocks (Turner *et al.*, 2003) even where societies have been, in aggregate, well adapted.

Planning effective adaptation to climate change and its associated risks requires robust and transferable methods of identifying who and what is vulnerable and the capacity of systems and social groups to cope with both climate variability and climate change. New adaptation research has focused on decision-making frameworks that elaborate the economic costs or potential welfare outcomes of adaptation decisions (Fankhauser *et al.*, 1999; Callaway, 2004; Adger *et al.*, 2005). Much of this new research is focused on adaptation decisions taken by governments or other decisions that impinge on future adaptation action. A prior question is the identification of where adaptation interventions should take place – i.e. those systems and communities vulnerable to climate change or other environmental stresses. Recent research in this area focuses on the dynamic nature of vulnerability and demonstrates that changes in vulnerability of particular groups are outcomes of changes in specific elements of adaptive capacity (Leichenko and O'Brien, 2002). In summary, human response to climate change risks is uneven: vulnerabilities remain following adaptation, and new vulnerabilities will emerge despite adaptation.

17.2 Assessment of Current Adaptation Practices

17.2.1 Adaptation practices

In this chapter, adaptation practices refer to actual adjustments, or changes in decision environments which might ultimately facilitate adjustments that enhance resilience or reduce vulnerability to observed or expected changes in climate. Thus, investment in coastal protection infrastructure to reduce vulnerability to storm surges and anticipated sea level rise is an example of actual adjustments, while the development of climate risk screening guidelines by donor agencies which might make downstream development projects more resilient to climate risks (Burton and van Aalst 2004) is an example of changes in the policy environment.

With an explicit focus on real world behaviour assessments of adaptation practices differ from the more theoretical assessments of potential responses or how such measures might reduce climate damages under hypothetical scenarios of climate change. Adaptation practices are differentiated in this chapter along several dimensions: by spatial scale (local, regional, national); by sector (water resources, agriculture, tourism, public health, and so on); by type of action (physical, technological, investment, regulatory, market); by actor (national or local government, international donors, private sector, NGOs and local communities); by climatic zone (dryland, mountains, arctic, and so on); by baseline economic development levels of the systems in which they are implemented (least developed countries, middle income countries, developed countries); or by some combination of these and other categories.

From a temporal perspective, adaptation to climate risks can therefore be viewed at three levels, including responses to: current variability (which also reflect learning from past adaptations to historical climates); observed medium and long-term trends in climate; and anticipatory planning in response to model-based scenarios of long-term climate change (Figure 17.1). The responses across the three levels are often intertwined, and indeed might form a continuum. Adapting to current climate variability is already sensible in an economic development context, given the direct and certain evidence of the adverse impacts of such phenomena (Smit *et al.*, 2001; Agrawala and Cane, 2002; Goklany, 1995). In addition, such measures can be synergistic with development priorities (Ribot *et al.*, 1996), but there could also be conflicts (OECD 2005). Adaptation to current climate variability can also increase resilience to long-term climate change. In a number of cases however anthropogenic climate change is likely to also require forward looking investment and planning responses that go beyond short-term responses to current climate variability. Examples of forward planning include the case of observed impacts such as glacier retreat and permafrost melt (Shrestha and Shrestha 2004, Schaedler 2004) (see Table 17.1). When impacts of climate change are not yet discernible, scenarios of future impacts may already be sufficient to justify building some adaptation responses into planning. In some cases it could be more cost-effective to implement adaptation measures early on, particularly for long-lived infrastructure (Shukla *et al.*, 2004), or if current activities may irreversibly constrain future adaptation to the impacts of climate change (OECD 2005).

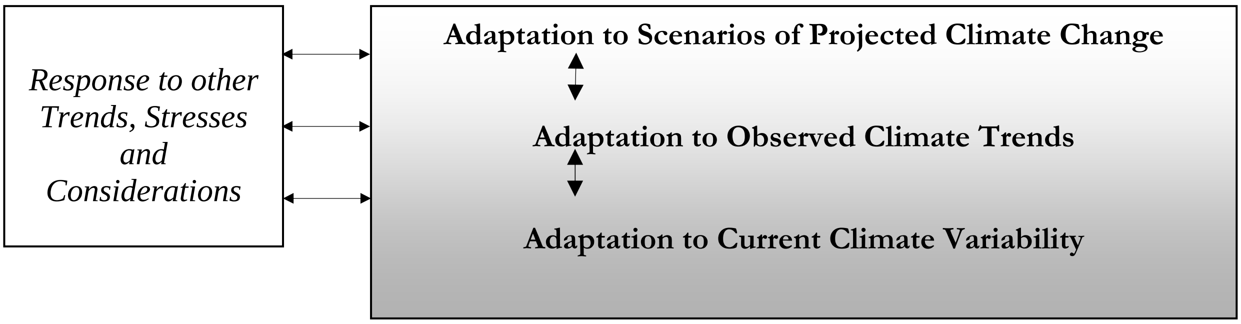


Figure 17.1: *Adaptation practices across time-scales and links to other priorities*

17.2.2 Examples of Adaptation Practices

There is a long record of practices to adapt to the impacts of weather as well as natural climate variability on seasonal to interannual time-scales – particularly to the El Niño Southern Oscillation (ENSO). These include *proactive* measures such as crop and livelihood diversification, seasonal climate forecasting, famine early warning systems, insurance, water storage, and so on. They also include *reactive* or *ex-poste* adaptations, for example, emergency response, disaster recovery, and migration. In many cases or contexts where sufficient information on anticipated climate risks is not available or too uncertain, or if resources to implement anticipatory measures are lacking, then reactive adaptation might be the only option. However, recent reviews indicate that a ‘wait and see’ or reactive approach is often inefficient and could be particularly unsuccessful in addressing irreversible or non-linear damages that may result from climate change (Smith, 1997; Easterling *et al.*, 2004).

Proactive practices to adapt to climate variability have advanced significantly in recent decades with the development of operational capability to forecast several months in advance the onset of El Niño and La Niña events (Cane *et al.*, 1986), as well as improvements in climate monitoring and remote sensing to provide better early warnings on complex climate related hazards (Dilley, 2000). Since the mid-1990s a number of mechanisms have also been established to facilitate proactive adaptation to seasonal to inter-annual climate variability. These include institutions that produce and disseminate regular seasonal climate forecasts (NOAA, 1999), and the regular regional and national forums and implementation projects worldwide to engage with local and national decision-makers to design and implement anticipatory adaptation measures in agriculture, water resource management, food security, and a number of other sectors (Basher *et al.*, 2000; Broad and Agrawala, 2000; Meinke *et al*., 2001; O'Brien and Leichenko, 2000; Patt and Gwata, 2002; Ziervogel, 2004; De Mello Lemos, 2003). A evaluation responses to the 1997-98 El Niño across 16 developing countries in Asia, Asia-Pacific, Africa, and Latin America highlighted a number of barriers to effective adaptation, including: spatial and temporal uncertainties associated with forecasts of regional climate, low level of awareness among decision-makers of the local and regional impacts of El Niño, limited national capacities in climate monitoring and forecasting, and lack of co-ordination in the formulation of responses (Glantz, 2001).

Table 17.1: *Current Adaptation Practices to Climate Risks*

This table describes examples of adaptation initiatives undertaken relative to climatic extremes, variations and changes, including conditions associated with or influenced by climate change.

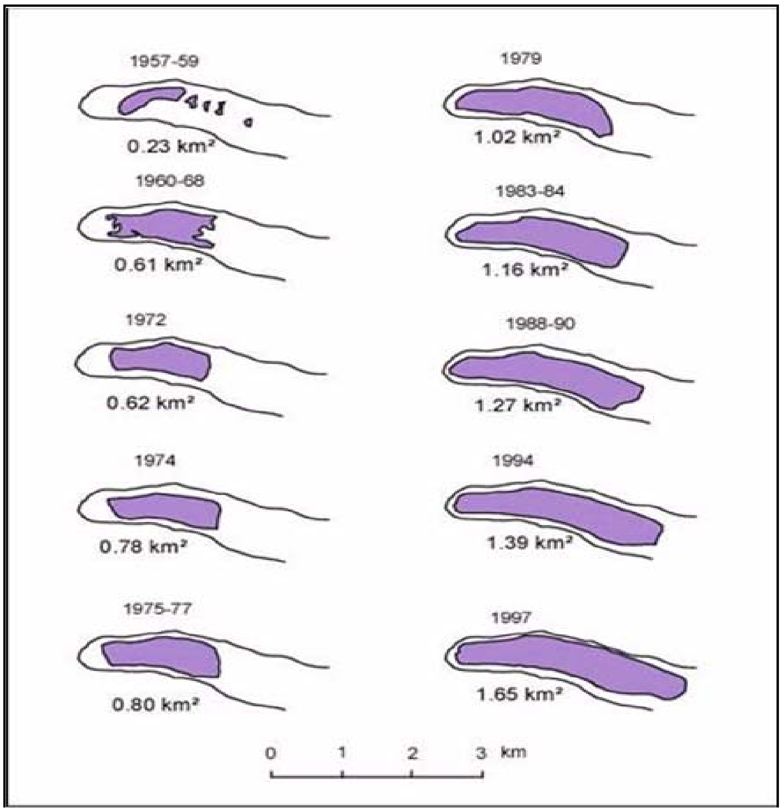
Country	**Sensitivity** *(most vulnerable)*	**Climate-related Stress**	**Adaptation Practice**	**Scale/ Actors**	**Type of Adaptation**
Austria European Environment Agency (2005) p.51	Ski resorts	Unreliable snow cover	Diversification of services (Opening spa-programs, Eco-tourism)	D,P	e
Bangladesh Schaerer (2005), Pouliotte (2005)	Livelihoods, Food, Water, Health, Gender, Income (*poor women*)	Sea level rise, salinization	Alternative crops and sources of income, marketing, low-tech water filters, water management, and mobilization	H, O, I	t, i
Germany (Bavaria) European Environment Agency (2005) p.48	Housing, Construction	Flood	Allowance made for the construction of new flood protection facilities	L,G	i,e
Botswana FAO (2004) p.121-133	Food, Livestock, Livelihood, Health, Income (*Rural poor, small subsistence farmers*)	Drought	-Drought response (Creation of employment after drought, capacity building of local authorities for disaster relief, assist livestock owners during drought) -Crop production (Assist small subsistence farmers to increase crop production)	N,G	i, t, e
Cook Islands Bettencourt *et al*. (2006) p.29	Drinking water	Droughts, saltwater intrusion	Rainwater harvesting, leak reduction, hydroponic farming, bank loan policies to facilitate purchase of rainwater storage tanks, and education.	S	i, t, e
Fiji Bettencourt *et al*. (2006) p.28	Coastal erosion	Wind, wave	Replanting of mangroves	L	t
Germany European Environment Agency (2005) p.50.	Health	Heat	Heat warning system	N,G	t
Netherlands European Environment Agency (2005) p.47	Livelihoods, food, town	Sea level rise	Periodical update of criteria for the safety features of protection infrastructure	N,G	i
Niue Bettencourt *et al*. (2006) p.28	Topsoil, vegetation, coral reefs	Cyclone, wave	Replantation of 150 different types of trees	L	t
Niue Bettencourt *et al*. (2006) p.29	Human life, Crop production, Buildings	Cyclone	Early warning system, promotion of a resilient cash crop (vanilla), relocation of all government buildings to the higher terrace areas, and lower terraces communities are encouraged to relocate.	N,G	i, t
Canada (Nunavut) (Ford and Smit 2005)	Resource Harvesting, Livelihoods, Safety	Temperature, Wind, Ice Cover	Changing hunt location, diversify hunted species, use of GPS technology, encourage food sharing	L, D	T, c, s,
Samoa Bettencourt *et al*. (2006) p.29	Infrastructure	Cyclone	Capacity building for shoreline defence system design, introduce participatory risk assessment, information sharing, provide grants to strengthen coastal resilience and rehabilitation of infrastructures.	N,G	e,s
South Africa FAO (2004) p.121-133	Food, Livestock, Livelihood, Health, Income	Drought	Drought response (Human relief, Debt relief for farmer) Water demand management Crop production (Alternative crops, Intercropping, Provide extension services)	N,R, L, H, G, P	i,t,b,e
Tonga Bettencourt *et al*. (2006) p.29	Infrastructure	Cyclone	Construction of cyclone-resistant housing units, Reconstruction of community facilities. Retrofit residential and business buildings to improved hazard standards. Review building codes.	N,G,H,D	i, t,

Scake/Actor: I=International, N=National, R=Regional, S=Sub national, L=Local, H=Household, D=Individual, G=Government, O=NGOs, P=Private
Types of Adaptation: i=Institutional, t= Technological, c=Cultural, b=Behavioural, e=Economic, s=Social

Table 17.1 provides an illustrative list of various types of adaptations that have been undertaken in practice. Such measures tend to have been undertaken in response to multiple risks that are already problematic in some way, including climatic conditions (such as weather extremes and seasonal to interannual variability). They frequently tend to be undertaken as part of existing processes or programmes, such as livelihood enhancement, water resource management, drought relief, rather than as stand alone responses to climate risks. They also involve a mix of institutional, behavioural and management responses, as well as technologies and infrastructure.

Box 17.1: Tsho Rolpa Risk Reduction Project in Nepal as observed anticipatory adaptation

Several Himalayan glacial lakes have witnessed significant expansion in size and volume as a result of rising temperatures. This increases the likelihood of catastrophic discharges of large volumes of water in events which are known as Glacial Lake Outburst Floods (GLOFs). One of the most dangerous glacial lakes in Nepal is the Tsho Rolpa lake at an altitude of about 5000m, and whose size increased from 0.23 square kilometres in 1957-58 to 1.65 square kilometres by 1997.



The Tsho Rolpa glacial lake project in one of the most significant examples of collaborative anticipatory planning by the government, donors, and experts in GLOF mitigation. Tsho Rolpa was estimated to store approximately 90-100 million m^3, a hazard that called for urgent attention. A 150-meter tall moraine dam held the lake, which if breached, could cause a GLOF event in which a third or more of the lake could flood downstream. The likelihood of a GLOF occurring at Tsho Rolpa, and the risks it posed to the 60MW Khimti hydro power plant that was under construction downstream, was sufficient to spur the government to initiate a project in 1998, with the support of the Netherlands Development Agency (NEDA), to drain down the Tsho Rolpa glacial lake. To reduce this risk, an expert group recommended lowering the lake three meters by cutting an open channel in the moraine. In addition, a gate was constructed to allow water to be released as necessary. While the lake draining was in progress, an early warning system was simultaneously established in 19 villages downstream of the Rolwaling Khola on the Bhote/Tama Koshi River to give warning in the event of a GLOF. Local villagers have been actively involved in the design of this system, and drills are carried out periodically. The World Bank provided a loan to construct the system. The four-year Tsho Rolpa project finished in December 2002, with a total cost of US$ 2.98 million from The Netherlands and an additional US$ 231,000 provided by Government of Nepal. The goal of lowering the lake level was achieved by June 2002, which reduced the risk of a GLOF by 20%. The complete prevention of a GLOF at Tsho Rolpa necessitates further reducing the lake water, perhaps by as much as 17 meters. Expert groups are now undertaking further studies, but it is obvious that the cost of mitigating GLOF risks is substantial and time consuming. The cost, however, is much less than the potential damage that would be caused by an actual event in terms of lost lives, communities, development setbacks, and energy generation.

Sources: Mool *et al*., 2001; Agrawala *et al*., 2003.

A growing number of measures are now also being put in place to adapt to the impacts of observed medium to long term trends in climate, as well as to scenarios of climate change. In particular, numerous measures have been put in place in the winter tourism sector in Alpine regions of many OECD countries to respond to observed impacts such as reduced snow cover and glacier retreat. These measures include technologies like artificial snow making and associated structures such as high altitude water reservoirs, economic and regional diversification, and the use of market based instruments such as weather derivatives and insurance (e.g. Scott *et al*., 2005 for North America; Harrison *et al*., 2005 for Scotland; Burki *et al.*, 2005 for Switzerland; and Konig, 1999 for Australia). Adaptation measures are also being put in place in developing country contexts to respond to glacier retreat and associated risks such as expansion of glacial lakes which pose serious risks to livelihoods and infrastructure. The Tsho Rolpa risk reduction project in Nepal is an example of adaptation measures being implemented to address the creeping threat of glacial lake outburst flooding as a result of rising temperatures (Box 17.1).

Recent observed weather extremes, particularly heat waves (e.g. 1995 heat wave in Chicago; the 1999 heat wave in Toronto; and the 2003 heat wave in France), have also provided the trigger for the design of hot weather alert plans. In putting these measures in place there is at times implicit or explicit recognition that such hot weather events might become more frequent or worsen under climate change and that present adaptations have often been inadequate and created new vulnerabilities (Poumadère *et al*., 2005). Public health adaptation measures have now been put in place that combine weather monitoring, early warning, and response measures in a number of places including metropolitan Toronto (Smoyer-Tomic and Rainham, 2001; Ligeti, 2004), Shanghai (Sheridan and Kalkstein 2004), several cities in Italy, and France (ONERC, 2005).

There are now also examples of adaptation measures being put in place now that take into account scenarios of future climate change and associated impacts. This is particularly the case for long lived infrastructure which may be exposed to climate change impacts over its lifespan, or if current activities may irreversibly constrain future adaptation to the impacts of climate change. Early examples where climate change scenarios have already been incorporated in infrastructure design include the Confederation Bridge in Canada and the Deer Island sewage treatment plant in Boston harbour in the United States. The Confederation Bridge is a 13 kilometre bridge between Prince Edward Island and the mainland. The bridge provides a navigation channel for ocean-going vessels with vertical clearance of about 50m (McKenzie and Parlee, 2003; Transportation Canada, 2005). Sea level rise was recognised as a principal concern during the design process and the bridge was built one metre higher than currently required to accommodate sea level rise over its hundred year lifespan (Lee, 2000; NRC, 2005). In the case of the Deer Island sewage facility the design called for raw sewage collected from communities onshore to be pumped under Boston harbour and then up to the treatment plant on Deer Island. After waste treatment the effluent would be discharged into the harbour through a downhill pipe. Design engineers were concerned that sea level rise would necessitate the construction of a protective wall around the plant, which would then require installation of expensive pumping equipment to transport the effluent over the wall (Easterling *et al.,* 2004; Klein *et al.*, 2005). To avoid such a future cost the designers decided to keep the Deer Island treatment plant at a higher elevation, and the facility was completed in 1998. Other examples where ongoing planning is incorporating scenarios of climate change in project design are the Quinghai-Tibet Railway in China (Brown, 2005); the Konkan Railway in western India (Shukla *et al.*, 2004); a coastal highway in Micronesia (Hay *et al.*, 2004); the Copenhagen metro in Denmark (Fenger, 2000); and the Thames Barrier in the UK (Hall *et al.*, 2006; Dawson *et al*., 2005).

A majority of examples of infrastructure related adaptation measures relate primarily to the implications of sea level rise. In this context, the Quinghai-Tibet Railway is an exception. The railway crosses the Tibetan Plateau with about a thousand kilometres of the railway at least 13, 000 feet (4, 000m) above sea level. Five hundred kilometres of the railway rests on permafrost, with roughly half of it "high temperature" permafrost which is only 1 °C – 2 °C below freezing (Brown, 2005). The railway line would affect the permafrost layer, which will also be impacted by thawing as a result of rising temperatures, in turn affecting the stability of the railway line. To reduce these risks design engineers have put in place a combination of insulation and cooling systems to minimize the amount of heat absorbed by the permafrost.

In addition to specific infrastructure projects there are now also examples where climate change scenarios are being considered in more comprehensive risk management policies and plans. Adaptation to current and future climate is now being integrated within the Environmental Impact Assessment (EIA) procedures of several countries in the Caribbean. It has also been extended toward incorporating natural hazard impact assessment in the project preparation and appraisal process, as well as the EIA guidelines, of the Caribbean Development Bank. Like the Caribbean countries, Samoa's EIA guidelines also include consideration of climate change. A number of other policy initiatives have also been put in place within OECD countries that take future climate change (particularly sea level rise) into account (Gagnon-Lebrun and Agrawala, 2006; Moser, 2005). For example, there is a requirement for new engineering works in The Netherlands to take 50cm sea level rise into account (The Netherlands, 1997).

There are now also examples of consideration of climate change as part of comprehensive risk management strategies at the city, regional, and national level. France and the UK have developed national strategies to and frameworks to adapt to climate change (ONERC 2005, DEFRA 2005). At the city level, meanwhile, climate change scenarios are being considered by New York City as part of the review of its water supply system. Changes in temperature, precipitation, sea level rise, and extreme events have been identified as important parameters for water supply impacts and adaptation in the New York region (Rosenzweig and Solecki, 2001; Rosenzweig *et al*., 2006). A nine-step adaptation framework and an eight step adaptation assessment procedure have now been developed. A key feature of these procedures is explicit consideration of several climate variables, uncertainties associated with climate change projections, and time horizons for different adaptation responses, including capital turnover cycles. Adaptations are divided into managerial, infrastructure, and policy categories and are assessed in terms of time-frame (immediate, interim, long-term) and in terms of the capital cycle for different types of infrastructure. Generalised risk assessments are provided for a range of impacts and adaptations, followed by detailed multi-dimensional cost-benefit analysis as the range of adaptations is refined. As examples of adaptation measures currently under examination, a managerial adaptation that can be implemented quickly is a tightening of water regulations in the event of an unusually severe drought. A longer-term infrastructure adaptation is the construction of flood-walls around low-lying wastewater treatment plants to protect against sea level rise and higher storm surges.

17.2.3 Assessment of Adaptation Costs and Benefits

An evaluation of adaptation measures is often needed to accomplish three interlinked goals: (i) establishing priorities for adaptation; (ii) screening specific adaptation measures in order to select and implement appropriate responses; and (iii) assessing the effects and effectiveness of specific measures. Some adaptations will have a public good character and as such may be provided by the state (local authorities or national governments). In making these decisions, the authorities will apply traditional decision support tools such as cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis and expert judgment (Box 17.2). Other, perhaps most, adaptation decisions will be taken by private agents (individuals or firms). The more sophisticated actors among them will base their decision on the investment appraisal techniques of corporate finance. They may, for example, calculate the net present value of an adaptation investment, analyse its risks and returns or determine the return on capital employed.

What most of these decisions have in common is that they are in some way based on a comparison of the advantages and disadvantages of a certain course of action, that is, its economic, financial and/or non-monetary costs and benefits. Assessment of adaptation costs and benefits could, in principle, also be relevant at a more global level in helping address trade-offs between mitigation and adaptation.

The literature on adaptation costs and benefits remains quite limited and fragmented in terms of sectoral and regional coverage. Adaptation costs are usually expressed in monetary terms, while benefits are typically quantified in terms of avoided climate impacts, and expressed in monetary as well as non-monetary terms (e.g. changes in yield, welfare, population exposed to risk). Much of this literature is focused on sea level rise (e.g. Fankhauser, 1995; Yohe and Schlesinger, 1998; Nicholls and Tol, 2006) and agriculture (e.g. Rozensweig and Parry, 1994; Reilly *et al*., 2001; Adams *et al.*, 2003a). Adaptation costs and benefits have also been assessed in a more limited manner for energy demand (e.g. Morrison and Mendelsohn, 1999; Sailor and Pavlova, 2003; Mansur *et al*., 2005), water resource management (e.g. Kirshen *et al.*, 2004), and transportation infrastructure (e.g. Dore and Burton, 2001). In terms of regional coverage, there has been a traditional focus on the US and other OECD countries (e.g. Fankhauser, 1995; Yohe *et al.*, 1996; Mansur *et al.*, 2005), although there is now growing literature for developing countries also (e.g. Butt *et al.*, 2005; Gomez *et al.*, 2005; Nicholls and Tol, 2006; Nkomo *et al.*, 2005).

Box 17.2: Methodologies to Assess Adaptation Practices

This box briefly outlines three key tools for evaluating adaptation practices, namely cost-benefit analysis, cost-effectiveness analysis, and multi-criteria evaluation. Information on the costs and benefits of adaptation are a key input to most of these evaluation approaches. These tools are usually used within broader assessment framework (UNDP 2005, and UNFCCC 2005).

Cost-Benefit Analysis

Cost-benefit analysis (CBA) focuses on monetised costs and benefits. In the case of adaptation it involves identifying all costs and benefits over the lifetime of proposed adaptation measures; converting costs and benefits to a single metric (usually in monetary terms); discounting the future value of benefits and costs (Dolan *et al.*, 2001). Adaptation measures where discounted benefits exceed discounted costs are considered preferable, and alternatives can be ranked according to the ratio of the benefits to the costs (Toth, 2000) or their net benefits (Fankhauser, 1996; Fankhauser *et al.*, 1997). There is a small methodological literature on the definition of costs and benefits in the context of climate change adaptation (Fankhauser, 1996; Callaway, 1997; Smith, 1997; Fankhauser *et al.*, 1998; Callaway, 2004). In addition there are a number of case studies that look at adaptation options for particular sectors (e.g., Fankhauser, 1994; Shaw *et al.*, 2000 all for sea level rise); or particular countries (e.g., Smith, 1998 for Bangladesh; World Bank, 2000 for Fiji and Kiribati; Dore and Burton, 2001 for Canada). While CBA, if done in a comprehensive manner, can facilitate direct comparison of adaptation costs and benefits along a common metric, it also has several limitations. It is data intensive, only provides aggregate numbers and not how the benefits and costs are distributed, and conversion to a single monetary metric might not adequately account for non-market costs and benefits.

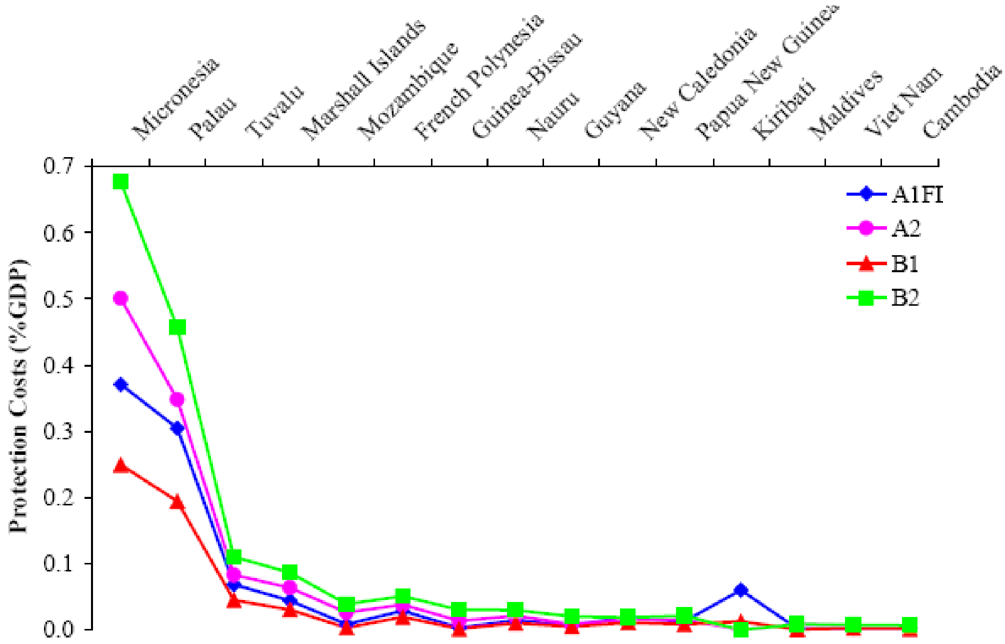
Cost-Effectiveness Analysis
Cost-effectiveness analysis (CEA) offers an alternative to CBA when adaptation benefits cannot be measured reliably or cannot be reliably monetised. Typically it is used to find the least expensive option to meet a certain goal, which could for example be costs per life saved. CEA can also be used in the case of multiple benefits which can be reduced to a common (though non-monetary) metric. This can be accomplished using an Adaptation Decision Matrix (Benioff *et al.*, 1996) which weights benefits in terms of their priority and scores specific measures in terms of their ability to achieve the various benefits. Cost-effectiveness can then be computed in terms of cost of measure per unit of incremental benefit. This approach at evaluating adaptation measures has been employed by the Uruguay Country study for evaluating measures to adapt to sea level rise.

Multi-Criteria Analysis
Multi-criteria analysis (MCA) refers to a broad array of evaluation methods which explicitly take into account multiple criteria. MCA involves the specification of objectives, alternative measures/interventions, criteria for evaluation, scoring of specific measures against the criteria, and weights ascribed to the various criteria, some of these steps involving considerable amount of expert judgment (Dolan *et al.*, 2001).

The Adaptation Decision Matrix developed by the US Country Studies Program is an example of an MCA technique used to select adaptation options in a number of national assessments in developing countries (Benioff *et al.*, 1996). Other application can be found in the literature (Mizina *et al.*1999 applied MCA to assess adaptation options for Kazakhstan agriculture under climate change. Yin 2001, uses a multi-criteria method, applying a so-called analytic hierarchy process (AHP) to assess the relative performance of adaptation options to deal with climate change impacts on agriculture, fisheries, forestry, health, water resources, energy and coastal regions in the Georgia basin of Canada. Dolan *et al.* 2001, World Bank 2000 use MCA to assess adaptation measures to climate change in Canadian Prairies. A more participatory assessment using MCA was used by the World Bank which examined the planning implications of climate change and sea level rise in Viti Levu, Fiji). MCA approaches offer the ability to incorporate a wide range of criteria which might be relevant to assess adaptation measures. They are also quite amenable to be used in a participatory setting where stakeholders are actively involved. The principal pitfalls stem from the subjectivity involved in ascribing weights to different criteria and measures, which can influence the final result considerably (Niang-diop and Bosch, 2005).

17.2.3.1 Sectoral and regional estimates

The literature on costs and benefits of adaptation to sea level rise is relatively extensive. Fankhauser (1995) used a comparative static optimisation to examine the trade-offs between investment in coastal protection and the value of land loss from sea level rise. The resulting optimal levels of coastal protection were shown to significantly reduce the total costs of sea level rise across OECD countries. The results also highlighted that the optimal level of coastal protection would vary considerably both within and across regions, based on the value of land at risk. Fankhauser (1995) concluded that almost 100% of coastal cities and harbours in OECD countries should be protected, while the optimal protection for beaches and open coasts would vary between 50 to 80%. Yohe *et al*., (1998) concluded that total (adjustment and residual land loss) costs of sea level rise would be reduced by 25 to 33% for the US coastline if the real estate market prices adjusted efficiently as land is submerged. A global study by Nicholls and Tol (2006) estimates optimal levels of coastal protection for the 15 least protected countries under SRES A1F1, A2, B1, and B2 scenarios. Nicholls and Tol also conclude that, with the exception of certain Pacific Small Island States, coastal protection investments were a very small percentage of GDP for the 15 most affected countries by 2080 (Figure 17.2).



Source: Nicholls and Tol 2006

Figure 17.2: *Sea level rise protection costs in 2080 as a percentage of GDP for most affected countries under the four SRES worlds (A1F1, A2, B1, B2)*

Ng and Mendelsohn (2005) use a dynamic framework to optimise for coastal protection, with a decadal reassessment of the protection required. It was estimated that coastal protection costs for Singapore would be between 1 and 3.08 million US$ (less than 0.01 per cent of the GDP) for a 0.49 and 0.86m sea level rise. A limitation of these studies is that they only look at gradual sea level rise and do not generally consider issues such as the implications of storm surges on optimal costal protection. In a study of the Boston metropolitan area Kirshen *et al*. (2004) include the implications of storm surges on sea level rise damages and optimal levels of coastal protection under various development and sea level rise scenarios. Kirshen *et al*. (2004) conclude that flood proofing was superior to coastal protection under 60-cm sea level rise, while coastal protection was optimal under 1m sea level rise. Another limitation of sea level rise costing studies is their sensitivity to endowment (land and structural) values which are highly uncertain at more aggregate levels. A global assessment by Darwin and Tol (2001) showed that uncertainties surrounding endowment values can lead to a “17 per cent difference in coastal protection, a 36 per cent difference in amount of land protected, and a 36 per cent difference in direct cost globally".

Adaptation studies looking at the agricultural sector literature considered autonomous farm level adaptation and many also looked at adaptation effects through market and international trade (Darwin *et al.*, 1995; Winters *et al.*, 1998; Yates and Strzepek, 1998; Adams *et al.*, 2003a; Butt *et al.*, 2005). The complex nature of impacts and numerous adaptation options gave rise to two approaches to assess the adaptation process, optimization and cross sectional estimation models (for further discussions on these methodologies see Mendelsohn and Dinar, 1999; and Darwin, 1999). The literature mainly reports adaptation benefits (in terms of yield, welfare, or people at risk of hunger) while costs where simply ignored in some early studies (Rosenzweig and Parry, 1994; Yates and Strzepek, 1998) but are now usually implicitly considered within models. Early studies (e.g. Darwin *et al.*, 1995; Rosenzweig and Parry, 1994) estimated residual climate change impacts to be minimal at the global level mainly owing to benefits of adaptation, although large inter and intraregional variations were reported. Climate change impacts are expected to be more severe in tropical regions and the potential benefits of low cost adaptation measures such as changes in planting dates, crop mixes, and cultivars are not expected to offset climate change damages in many developing countries. Tan and Shibasaki (2003) provide estimates of crop yield benefits linked to changes in planting dates for various regions (Table 17.2). More extensive adaptation measures have been evaluated in some developing countries. For the 2030 horizon in Mali, Butt *et al.*, (2005) estimate that extensive adaptation measures could offset 90 to 107 percent of welfare losses induced by climate change impacts in agriculture. Meanwhile, Gomez *et al.* (2005) estimate that investments in irrigation infrastructure would be required to reduce millet yield losses in 2100 for The Gambia (Box 17.3).

Table 17.2: *Adaptation benefits in 2050 induced by changes in planting dates for maize, soybean and wheat crops across the globe.*

Area	**Impacts**		**% change due to adaptation**
	w/o adaptation	**with adaptation**	
	Yield changes		
Asia	-12%	-8%	33%
North America	-23%	-12%	48%
South America	-29%	-18%	38%
Europe	-23%	-13%	43%
Australia	-26%	-19%	27%
Africa	-35%	-27%	23%

Source: Tan and Shibasaki 2003

Agricultural production is particularly sensitive to climate variability and extreme events. Not surprisingly the importance of adaptation benefits is found to increase when yield variability is considered. Adams *et al.* (2003a) found that adaptation welfare benefits for the American economy increased from 3.29 billion 2000 US$ to 4.70 billion 2000 US$ when yield variability is included. Butt et al. 2005 found that adaptation measures could reduce the impact of climate change on welfare variability by up to 84% in Mali. Another feature of climate variability is the El Niño Southern Oscillation pattern (ENSO). Benefits of early warning systems for current and expected future ENSO patterns have been assessed by Chen *et al.* (2001) and Adams *et al.* (2003b) leading to the conclusion that such system would be a no-regret adaptation measure as it could help in reducing adverse impacts of current and expected future climate. Even if agricultural regions can adapt fully through technologies and management practices, there are likely to be costs of adaptation in the process of adjusting to a new climate regime. Kelly *et al.* (2005) estimate these adjustment costs for farming regions in Midwest US (simulating a 'restricted' profit function) and found that these adjustment costs were 1.4 percent of land rents for one simulated unanticipated climatic shock.

A particular limitation of adaptation studies in the agricultural sector stems from the diversity of climate change impacts and adaptation options but also from the complexity of the adaptation process. Many studies of the agricultural sector make the unrealistic assumption of perfect adaptation from individual farmers. However, recent studies (Schneider *et al.*, 2000 and Easterling *et al.*, 2003) found that frictions in the adaptation process could reduce the potential of adaptation by 10 to 16% in the long-term. Those reductions could be much more severe in the shorter term as the most pessimistic estimates suggest that variability could completely erase the potential adaptation gains estimated when omitting to consider variability.

Box 17.3: Adaptation Costs and Benefits for Agriculture in The Gambia

In a case study looking at adaptation in Africa, Gomez *et al.*, 2005, investigated climate change impacts and adaptation cost and benefits in The Gambian agriculture. The Gambia is a poor country where agriculture is central to the economy despite low productivity level, and low capital investment. Local climate change information, which was extracted from ECHAM4 and HadCM3 models under A2 IPCC SRES scenarios and complemented with ENSO and precipitation information, were integrated into soil water and crop growth modules. These modules were then used to derive impacts of climate change and adaptation measures on millet yield for the various climate change scenarios. By comparing base case and climate change results the study estimated that the 2010-2039 millet yield would increase slightly, i.e. by 2 to 13%, but that the outcome for 2100 is highly dependent on changes in precipitations as it could range from a 43% increase to a 78% decrease in millet yield. However, an important result is the increase in yield variability under all scenarios. An interesting feature of the study is the assessment of benefits of irrigation as an adaptation measure not only at private level but also from a national food security point of view. When comparing production benefits of irrigation, increase in yield time price, with costs of implementation, the results suggest that for the 2010-1039 period, irrigation would not be profitable for individual farmers, even under optimistic market prices. However, the study also shows that from a public point of view, financing irrigation would be justified economically as it could eliminate the need for cereals imports and food aid, thus increasing food security and generating significant foreign exchange savings.

With regard to adaptation costs and benefits in the energy sector, there is some literature on changes in energy expenditures for cooling and heating as a result of climate change. This literature is almost entirely for the US, and most studies show that increased energy expenditure on cooling will more than offset any benefits from reduced heating (e.g. Smith and Tirpak, 1989; Nordhaus, 1991; Cline, 1992; Morrison and Mendelsohn, 1999; Mendelsohn, 2003; Sailor and Pavlova, 2003; Mansur *et al.*, 2005). Morrison and Mendelsohn (1999) meanwhile estimate net adaptation costs for the US economy ranging from 1.93 billion to 12.79 billion by 2060. They also estimated that changes in building stocks (particularly increases in cooling capacity) contributed to the increase in energy expenditure by 2.98 billion US$ to 11.5 billion US$. Mansur *et al.* (2005) meanwhile estimate increased energy expenditures for the US ranging from 4 to 9 billion US$ for 2050, and between 16 and 39.8 billion US$ for 2100.

Besides sea level rise, agriculture, and energy demand, there a few studies related to adaptation costs and benefits in water resource management (Box 17.4), and transportation infrastructure. Kirshen *et al.* (2004) assessed the reliability of water supply in Boston metropolitan region under climate change scenarios. They assess the adaptation benefits of two policy scenarios to find that demand management measures could increase the reliability of independent local system from 82% to 83% while connecting those systems to the main state water system would increase their reliability to 97%. However, costs of such policies were ignored.

Dore and Burton (2001) estimate the costs of adaptation to climate change for social infrastructure in Canada, more precisely for the roads network (roads, bridges and storm water management systems) as well as for water utilities (drinking and waste water treatment plants). In this case, the additional costs designed to maintain the integrity of the portfolio of social assets under climate change are identified as the costs of adaptation. In the water sector, potential adaptation strategies such as

Box 17.4: Adaptation Costs and Benefits in Water Management Sector of South Africa

Nkomo *et al*. 2005 provide a comprehensive treatment of adaptation possibilities in a case study of the Berg River basin, South Africa. The objective of the study was to provide information about potential adaptation measures that could improve water management under climate change scenarios. Adaptation measures investigated included the institution of an efficient water market and an increase in water storage capacity through the construction of a dam. Using a programming model which linked modules of urban and farm water demand to a hydrology module, they provided costs and benefits estimates for storage and water market adaptation strategies. The adaptation net benefits were estimated to range between 34 and 1143 billion 2000 Rand when both options where implemented, thus reducing climate change damages by up to 17.41%. However, caution is given as rising cost for urban water use could harm the urban poor which may represent a significant social cost. An interesting feature of the study is that given the uncertainty of climate change and socio-economic scenarios, the authors estimated the cost of under or overestimating climate change impacts (costs of caution and precaution). Although results of Nkomo *et al.* (2005) cannot point towards an unambiguous choice between cautious or precautious approaches, such methodology still provides valuable information to decision makers especially in cases where adaptation involves irreversible capital investment such a the erection of a dam.

building new treatment plants, improving efficiency of actual plants, or increasing retention tanks were considered and results indicated that adaptation costs for Canadian cities could be as high as 9,400 million CAN$ for a city like Toronto if extreme events are considered, while many other cities would not incur any cost. For the transportation sector, Dore and Burton estimated that replacing all ice roads in Canada would cost around 908 million CAN$. However, the study also points out that retreat of permafrost would reduce road building costs and that costs of winter control (snow clearance, sanding, and salting) could decrease by $9 to $12 per kilometre of road.

17.2.3.2 Global estimates

Comprehensive multi-sectoral estimates of the global costs and benefits of adaptation do not yet exist. Some costs of adaptation are implicitly included in estimates of global impacts of climate change. Tol *et al.* (1998) estimated that between 7% and 25% of total climate damage costs included in earlier studies such as Fankhauser (1995), Tol (1995), and Cline (1992) could be classified as adaptation costs. In addition, recent studies, including Nordhaus and Boyer (2000), Mendelsohn (2000), and Tol (2002), incorporated with greater detail the effect of adaptation on global estimation of climate change impacts. In these models, adaptation cost and benefits are usually embedded within climate damages functions which serve to relate economic and climatic variables. These functions are derived from results of sectoral studies which do not always reflect most recent findings and which sometimes need to be extrapolated to fill spatial gaps. As a result, these studies offer a global and integrated perspective but are based on coarsely defined climate change and adaptation impacts and only provide speculative estimates of adaptation costs and benefits.

Nordhaus and Boyer (2000) included adaptation effects to some extent by calibrating their damage function with results of source studies incorporating climate change responses in sectors where such estimates were available. Mendelsohn's climate-response functions are estimated from two approaches which complementarities were meant to provide improved representation of climate and adaptation impacts. These source studies covered only the US and results had to be extrapolated to the rest of the world. Mendelsohn (2000) estimated that heating and cooling cost would increase by 2 to 10 billion (1990 US$) for a two degree Celsius increase in temperature by 2100 and by 51 to 89 billion (1990 US$) for 3.5 degree increase. Tol (2002) provides new damage functions for the FUND model, including a more detailed treatment of adaptation costs and benefits for a few sectors. Tol (2002) estimated an adaptation benefit of 46 billion US related to heating and cooling energy use. A particularity of FUND is that sea level damages and adaptation costs are not obtain from a damages function but are computed directly within the model. Tol's global estimate for sea-level rise adaptation cost is 1055 US billion. The current literature does not provide estimates of global adaptation cost/benefits, and cross sectoral interactions induced by adaptation measures are still ignored.

17.3 Assessment of Adaptation Capacity, Options and Constraints

17.3.1 Elements of adaptive capacity

Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change. Responses can include adjustments or changes in characteristics or behaviour. The presence of adaptive capacity enables the design and implementation of effective adaptation strategies, in reaction to evolving risks and stresses, so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change (Brooks and Adger, 2005). It is also necessary to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism (O'Brien *et al.*, 2005). Adaptive capacity is influenced by the resources available for adaptation, and by the ability or capacity of that system to use these resources effectively in the pursuit of adaptation, consciously or unconsciously (Reilly and Schimmelpfennig, 2000). These resources may be natural, human, financial, or institutional, and might include access to ecosystems, information, expertise, and social networks.

While determinants of adaptive capacity are often linked to general indicators of development, much recent analysis of this capacity argues that adaptive capacity is not a concern unique to regions with low levels of economic activity. High income per capita is considered neither a necessary nor a sufficient indicator of the capacity to adapt to climate change (Moss *et al.*, 2001). Furthermore, even within the wealthiest developed countries, some regions, localities, or social groups have a lower adaptive capacity (O'Brien *et al.*, 2005). In short, adaptive capacity is needed to minimize risk as well as take advantage of opportunities in both developed and developing countries.

Much of the current understanding of adaptive capacity comes from vulnerability studies and assessments. Vulnerability is often considered an outcome of climate change, influenced by adaptive capacity and consequent adaptations (Smit *et al.*, 2001). However, vulnerability can also be seen as a state or condition that exists prior to exposure to climate change. Many of the same contextual factors that contribute to a state of vulnerability also undermine adaptive capacity (O'Brien and Vogel, 2004). Climate change meanwhile may alter social, economic, or institutional factors in ways that enhance contextual vulnerability. Both types of vulnerability have been demonstrated to be reduced by adaptive options. Research on climate change vulnerability has thus provided valuable insights on adaptive capacity and adaptation. Methods and frameworks for assessing vulnerability either depend upon or embed an understanding of the determinants of adaptive capacity (Turner *et al.*, 2003; Schroter *et al.*, 2005). Through a growing body of vulnerability research, it is becoming clear that the underlying causes of vulnerability must be addressed in order to develop the capacity to adapt to climate variability and long-term climate change (Kelly and Adger, 2000).

Among the methods available to assess vulnerability, the indicator approach has been widely used to make comparisons of both vulnerability and adaptive capacity across the globe, as well as regionally and nationally. For example, in quantitative approaches to vulnerability, national-level adaptive capacity was represented by proxy indicators for economic capacity, human and civic resources, and environmental capacity (Moss *et al.*, 2001). Even if vulnerability indices do not explicitly include determinants of adaptive capacity, the indicators selected often provide important insights on the factors, processes and structures that promote or constrain adaptive capacity (Eriksen and Kelly, 2005). One clear result from research on vulnerability and adaptive capacity is that some dimensions of adaptive capacity are generic, while others are specific to particular climate change impacts. Generic indicators include factors such as education, income, and health. Indicators specific to a particular impact, such as drought or floods, may relate to institutions, knowledge and technology (Yohe and Tol, 2002; Downing, 2003; Brooks *et al*., 2005).

17.3.2 Determinants of adaptive capacity, role of technology

Technology plays an important role in adaptation to climate change. Innovation, which refers to the development of new strategies or technologies, or the revival of old ones in response to new conditions (Bass, 2005), is an important aspect of adaptation, particularly under uncertain future climate conditions. Cooling systems, improved seeds, desalinisation technologies, and other engineering solutions represent some of the options that can lead to improved outcomes and increased coping under conditions of climate change. In public health, for example, there have been successful applications of seasonal forecasting and other technologies to adapt health provision to anticipated extreme events (Ebi *et al.*, 2005). Often, technological adaptations and innovations are developed through research programs undertaken by governments and by the private sector (Smit and Skinner, 2002). Technological capacity can thus be considered a key aspect of adaptive capacity. Many technological responses to climate change are, however, related to a specific type of impact, such as higher temperatures, or decreased rainfall. For this reason, determinants of adaptive capacity that take into account the nature of climate change and the characteristics of the system or population are important to understanding whether and how adaptations will take place (Brooks and Adger, 2005).

The capacity of societies to adapt to climate risks has frequently been linked with levels of economic development, with the assumption that more economically ‘developed’ societies have greater access to technology and resources to invest in adaptation (Mendelsohn *et al*. 2006). However, new studies carried out since the TAR show that adaptive capacity is influenced not only by factors that promote or constrain the adoption of technologies and management practices, but also by the economic, social, political, environmental, institutional, and cultural factors that create both external and internal incentives as well as barriers to adaptation (Klein and Smith, 2003; Berkhout *et al.*, 2004; Eriksen and Kelly, 2006; Næss *et al.*, 2005; Tompkins, 2005).

A distinction has been made between adaptation to climate change as a challenge for technology and management, and adaptation to climate change as a challenge for development in general (Burton *et al.*, 2002). There is a recognized need for theoretical frameworks to understand how decision-makers process information about climate risks, identify and assess adaptation options, and choose whether, when, and how to employ them (Parson *et al.*, 2003), in order to reduce vulnerability as an outcome of climate change. However, there is also a need to consider adaptive capacity within a development framework (Burton *et al.*, 2002), to reduce vulnerability as an existing state or condition.

National indicators of adaptive capacity

The determinants of national adaptive capacity represent an area of contested knowledge. Some studies relate adaptive capacity to levels of development, including political stability, economic well-being, human and social capital, and institutions (AfDB *et al.*, 2003). However, recent research has questioned the usefulness of equating adaptive capacity with development. Haddad (2005) has shown empirically that the ranking of adaptive capacity of nations is significantly altered when national aspirations are made explicit. He demonstrates that different aspirations (e.g., seeking to maximize the welfare of its citizens, to maintain control of their citizens, or to reduce the vulnerability of the most vulnerable groups) lead to different weightings of the elements of adaptive capacity, and hence to a set of competing rankings of the actual capacity of countries to adapt. Alberini *et al*. (2006) use expert judgement based on a conjoint choice survey of climate and health experts to examine the most important attributes of adaptive capacity and found that per capitas income, inequality in the distribution of income, universal health care coverage, and high access to information are the most important attributes allowing a country to adapt to health-related risks. Coefficients on these rankings were used to construct an index of countries with highest to lowest adaptive capacity.

This set of research on adaptive capacity, in summary shows some convergence on the importance of development and resources as indicators of generic adaptive capacity. Many studies are careful to point out, however, that indicators of adaptive capacity at one scale are not necessarily representative of adaptive capacity at other scales of analysis (Downing *et al.*, 2001; Moss *et al.*, 2001).

The literature is contested on the usefulness of these lessons on generic adaptive capacity and the sensitivity of the results. There is some evidence that national-level indicators of vulnerability and adaptive capacity are used by climate change negotiators, practitioners, and decision-makers in determining policies and allocating priorities for funding and interventions (Eriksen and Kelly, 2006). However, few studies have been globally comprehensive, and a comparison of results across five vulnerability assessments shows that the 20 countries ranked ‘most vulnerable’ show little consistency across studies (Eriksen and Kelly, 2006). Furthermore, they fail to capture many of the processes and contextual factors that influence adaptive capacity, thus provide little insight on adaptive capacity at the level where most adaptations will take place (Eriksen and Kelly, 2006).

Local context for adaptive capacity

Although national indicators can provide a relative and comparative understanding of adaptive capacity, the capacity to adapt to climate change depends heavily on the local context. Indices based on aggregated data can hide heterogeneity at smaller spatial scales. Furthermore, indicator studies generally provide only snapshots of vulnerability and fail to represent the dynamics of vulnerability and adaptive capacity over time (Leichenko and O'Brien, 2002; Eriksen and Kelly, 2005). An alternative and complementary approach is based on specific contextual studies that include both qualitative and quantitative methods for identifying vulnerability and adaptive capacity, including how it may evolve over time. Such place-based studies provide insights on the conditions that constrain or enhance adaptive capacity (Schroter *et al.*, 2005).

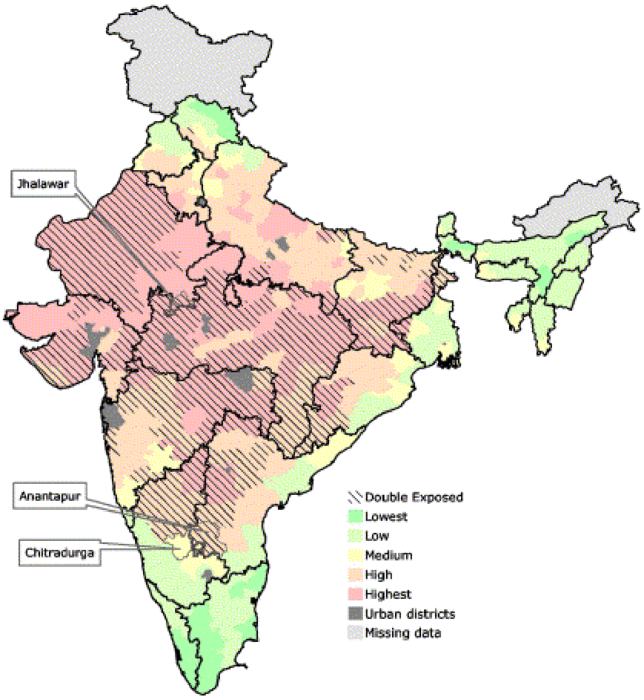
Although the lessons from studies of local-level adaptive capacity are context-specific, they establish some broad criteria by which to assess the adaptive capacity of communities. The nature of the relationships between community members is critical, as are access to and participation in the wider decision-making processes. In areas such as coastal zone management, the expansion of social networks has been noted as an important element in developing more robust management institutions (Tompkins *et al.*, 2002). Local groups and individuals often feel their powerlessness in many ways, although none so much as in the lack of access to decision makers. Building successful community-based resource management for example, in the form of co-management arrangements, can potentially enhance the resilience of communities as well as maintain ecosystem services and ecosystem resilience.

However, adaptation at any one scale may be constrained by factors outside the system in question. At the local scale, such constraints may take the form of regulations or economic policies determined at the regional or national level that limit the freedom of individuals and communities to act, or make certain potential adaptation strategies unviable. There is a growing recognition that vulnerability and the capacity to adapt to climate change are influenced by multiple processes of change (refs). Conflicts, urbanization, trade liberalization, and infectious disease can influence adaptive capacity, either positively or negatively. Mapping the capacity to adapt to climate change and trade liberalization in India, O'Brien *et al.* (2004) show that districts with low adaptive capacity are more likely to be vulnerable to both climate change and globalization (Box 17.5).

Box 17.5: Mapping Adaptive Capacity to Multiple Stressors

The capacity to adapt to climate change is not evenly distributed across or within nations. Adaptive capacity is highly differentiated within countries, where multiple processes of change interact to influence vulnerability and shape outcomes from climate change. In India, for example, both climate change and trade liberalization are changing the context for agricultural production. Some farmers are able to adapt to these changing conditions, including the discrete events such as drought and rapid changes in commodity prices. Other farmers may experience predominately negative outcomes from these simultaneous processes. Identifying the areas where both processes are likely to have negative outcomes provides a first step in identifying options and constraints in adapting to changing conditions.

Mapping vulnerability of the agricultural sector to both climate change and trade liberalization at the district level in India, O'Brien *et al.* (2004) considered adaptive capacity as a key factor that influences outcomes. A combination of biophysical, socioeconomic, and technological conditions were considered to influence the capacity to adapt to changing environmental and economic conditions. The biophysical factors included soil quality and depth and groundwater availability, whereas socioeconomic factors consisted of measures of literacy, gender equity, and the percentage of farmers and agricultural wage labourers in a district. Technological factors were captured by the availability of irrigation and the quality of infrastructure. Together, these factors provide an indication of which districts most likely to be able to adapt to drier conditions and variability in the Indian monsoons, as well as respond to import competition and export opportunities resulting from liberalized agricultural trade. The results of this mapping showed higher degrees of adaptive capacity in districts located along the Indo-Gangetic Plains (except in the state of Bihar), and lower capacity in the interior parts of the country, particularly in the states of Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka.



Districts in India that rank in the highest in terms of climate change vulnerability and globalization vulnerability are considered to be double exposed (depicted with hatching).
Source: O'Brien *et al.* (2004).

Adaptive capacity is highly heterogeneous within a society or locality and for human populations it is differentiated by age, class, gender, and social status. Box 17.6 describes how adaptive capacity and vulnerability to climate change impacts are different for men and women, with gender-related vulnerability particularly apparent in resource-dependent societies and in the impacts of extreme weather-related events.

Box 17.6: Gender aspects of vulnerability and adaptation

Empirical research on vulnerability and adaptation has established that the capacity to adapt to climate change depends on factors such as health, governance and political rights, and economic well-being (Pelling, 2003; Brooks *et al.*, 2005). At different levels of analysis, entitlements to these assets are socially differentiated along the lines of age, ethnicity, class, religion and gender (Cutter, 1995; Wisner, 1998; Enarson, 2000; Denton, 2002). Climate change therefore has gender-specific implications in terms of both vulnerability and adaptive capacity as well as in emissions and technologies (Dankelman, 2002). The role of gender in influencing adaptive capacity and adaptation is thus an important consideration for the development of interventions to enhance adaptive capacity and to facilitate adaptation.

There are structural differences between men and women through, for example, gender-specific roles in society, work and domestic life. These differences affect the vulnerability and capacity of women and men to adapt to climate change. In the developing world in particular, women are disproportionately involved in natural resource-dependent activities, such as agriculture (Davison, 1988; Shahra, 2003), compared to salaried occupations. As resource-dependent activities are directly dependent on climatic conditions, changes in climate variability projected for future climates are likely to affect women through a variety of mechanisms: directly through water availability, vegetation and fuelwood availability and through health issues relating to vulnerable populations (especially dependent children and elderly). Most fundamentally, the vulnerability of women in agricultural economies is affected by their relative insecurity of access and rights over resources and sources of wealth such as agricultural land. It is well established that women are disadvantaged in terms of property rights and security of tenure, though the mechanisms and exact form of the insecurity are contested (Agarwal, 2003; Jackson, 2003). This insecurity can have implications both for their vulnerability in a changing climate, and also their capacity to adapt productive livelihoods to a changing climate.

There is a body of research that argues that women are more vulnerable than men in particular ways to weather-related disasters. The impacts of past weather-related hazards have been disaggregated to determine the differential effects on women and men: for examine hurricane Mitch in 1998 (Bradshaw, 2004) and for natural disasters more generally (Fordham, 2003). Whilst there are not always discernable gender differences in the immediate impacts of events such as hurricanes, in terms of deaths, they are often manifest in the post-event recovery period. The disproportionate amount of the burden endured by women during rehabilitation has been related to their roles in the reproductive sphere (Nelson *et al.*, 2002). Children and the elderly tend to be based in and around the home and so are often more likely to be affected by flooding event with speedy onset. Women are usually responsible for the additional care burden during the period of rehabilitation, whilst men generally return to their pre-disaster productive roles outside the home. Fordham (2003) has argued that the key factors that contribute to the differential vulnerability of women in the context of natural hazards in South Asia include: high levels of illiteracy, minimum mobility and work opportunities outside the home; and issues around ownership of resources such as land.

Access to and responsibility for resources such as water and fuelwood are also different among men and women. Research has shown a projected change in the availability of water resources under climate change (Arnell, 2004). Although formal rights to water are rarer for women than for men, they are often able to gain access through informal mechanisms. Increasing water scarcity, however, is likely to necessitate further policy restrictions, which without explicit reference to gender equity might have a greater adverse effect on women (Zwarteveen, 1997).

The policy implications of this research are that, due to the differential effects of climate change impacts on men and women, adaptation actions and policies should take these differences into account for both equity and effectiveness reasons. Greater availability of seasonal forecasts and other climate predication tools is thought to increase adaptive capacity (Ziervogel and Calder, 2003). But to ensure maximum benefit, seasonal forecasts need to be targeted to suit the needs of the end user (Ziervogel, 2004). An empirical study in Limpopo province, South Africa, shows gender differences in the application and uptake of seasonal forecasts (Archer, 2003). Women prefer to receive the information through extension officers, whilst men would rather hear forecasts on the radio. If this gender difference is not actively considered, there is a chance that women who, by virtue of their role in agriculture in Limpopo province, might perversely be least likely to benefit. More recent work has traced the process of information transmission through stakeholder networks (Ziervogel and Downing, 2004).

Gender differences in vulnerability and adaptation reflect wider patterns of structural gender inequality. Recognition of gender issues within development discourses has a longer history, and is now routinely considered when assessing projects and initiatives (Chant, 2000; Buckingham, 2004). Lessons from the analysis of gender and development dilemmas for mainstreaming gender into climate change concerns (Denton, 2004) include: interventions that ignore gender concerns reinforce the differential gender dimensions of vulnerability; and a shift in policy focus away from reactive disaster management to more proactive capacity building (Mirza, 2003), tends to reduce gender inequality.

17.3.3 Dynamics of adaptive capacity, options and constraints

The research examining patterns in generic adaptive capacity is complemented by research that shows that, at the local level, adaptive capacity is the ability of households or a community to deal with the conditions that are important to them, such as recurring droughts or sea level rise or risks to livelihoods because of climate-related effects on crops or water or homes or sanitation. These two sets of literature converge on the importance of resources, access to resources for the vulnerable, and the multiple stressors that represent threats to the capacity to adapt.

Adaptive capacity is a reflection of a variety of forces and processes that serve to facilitate or support adaptation. Those same forces may also serve to impede, limit, constrain, restrict or prevent adaptations. Hence, determinants of adaptive capacity can have both positive and negative effects on adaptation. Determinants experienced locally and in the immediate term often reflect forces that emanate from higher levels (regional or national policies, and the global economic system) and he reflect processes that have evolved over a long time (Box 17.7). There is no evidence from the literature outlined below that one determinant is more important than others; their roles vary from country to country, community to community, household to household and from time to time. The literature that examines determinants of adaptive capacity at the local level are presented below under discrete headings, the forces do not operate independently, but they influence adaptive behaviour through their joint affects in interactions (see Box 17.7).

Resources*:* Levels of economic resources and well-being influence the capacity of households, communities and local institutions to adapt to climate change stresses. Limited income opportunities and lack of financial resources limit the ability of Inuit in Arctic Canada to adapt via the purchase of equipment that is safer and more effective under the changing conditions (Ford *et al*, 2006 a and b), Pearce 2005, Reidlinger 2001). Communities in Samoa have financial limitations to their ability to deal with storm damage, but their capacity is enhanced by their social capital and by the economic resources they draw on through family networks in the form of remittances (Sutherland *et al*, 2005).

The nature and distribution of physical and biological conditions, or natural capital, can limit and facilitate adaptation to climate related risks and opportunities. Wheat farmers in the Yaqui Valley, Mexico are vulnerable to changes in climate, including variability, and that the effects are exacerbated by the soil conditions, which limit some adaptive strategies (Luers 2005). Farm management can reduce some of the biophysical constraints imposed by soil type. Communities in Inuvialuit in Arctic Canada are vulnerable to changing conditions that reduce their access to traditional hunted food sources and affect the health and abundance of wildlife species. However, the diversity of fish and wildlife in the region provides capacity to adapt by modifying harvesting activities, including increases in the harvesting of musk-ox in light of reduced availability of Perry Caribou. (Pearce 2006, Condon 1995, Ford *et al* 2006).

Socio-Cultural**:** There are many examples where social capital, social networks, values, perceptions, customs, traditions and levels of cognition affect the capability of communities to adapt to risks related to climate change. Communities in Samoa, in the south Pacific, rely on informal non-monetary arrangements and social networks to cope with storm damage, along with livelihood diversification and financial remittances through extended family networks (Barnett 2001, Sutherland *et al* 2005, Adger 2001). Similarly, strong local and international support networks enable communities in the Cayman islands to recover from and prepare for tropical storms (Tompkins 2005).

Hillside communities in Bolivia are susceptible to multiple stresses, and community organization is an important factor in adaptive strategies to build resilience (Robledo *et al* 2004). Recovery from hazards in Cuba is helped by a sense of civicness and egalitarianism reflected in volunteers (Sygna 2005). Food-sharing expectations and networks in Inuvialuit, Canada allow community members access to “country food” at times when conditions make it unavailable to some (Pearce, 2006). The role of food-sharing as a part of a community’s capacity to adapt risks in resource provisioning is also evident among Alaskan Eskimo (Magdanz *et al* 2002). Adaptive migration options in the 1930s US Dust Bowl were greatly influenced by the access households had to economic, social and cultural capital (McLeman and Smit, 2006). The cultural change and increased individualism associated with economic growth in small island developing states has eroded the sharing of risk within extended families, thereby reducing the contribution of this social factor to adaptive capacity (Pelling and Uitto, 2001).

The ability to adapt can vary among communities, households and individuals depending on various attributes such as age, gender, ethnicity, health and education. Ziervogel *et al*. (2006) undertook a comparative study between households and communities in South Africa, Sudan, Nigeria and Mexico and showed how vulnerability to food insecurity is common across the world in semiarid areas where marginal groups rely on rain-fed agriculture. Across the case studies food insecurity was not determined solely or primarily by climate, but rather by a range of social, economic, and political factors linked to physical risks.

Box 17.7: Adaptive capacity, adaptation processes and feedbacks

Empirical research has shown that there are rarely simple cause-effect relationships between climate change, adaptation, and vulnerability. Initial adaptive responses may result in the system being more, or less, vulnerable to climatic and non-climatic stresses. These feedback mechanisms, reflecting adaptive capacity, are illustrated in many empirical studies.

In the Canadian Arctic, experienced Inuit hunters, dealing with changing ice and wildlife conditions, adapt by drawing on their traditional knowledge to alter the timing and location of harvesting, and ensure their personal survival. Young Inuit, however, do not have the same adaptive capacity. Ford *et al*. (2006) attribute this to the imposition of western education by the federal government in the 1970s and 1980s which resulted in less participation in hunting among youth and consequent reduced transmission and development of traditional knowledge. This resulted in a perception among elders and experienced hunters, who act as an institutional memory for the maintenance and transmittance of traditional knowledge, that the young are not interested in hunting or traditional Inuit ways. This further eroded traditional knowledge by reducing intergenerational contact, creating a positive feedback in which youth are locked into a spiral of knowledge erosion. The incorporation of new technology in harvesting (including GPS, snowmobiles, vhf radios), representing another type of adaptation, has re-enforced this spiral by creating a situation in which traditional knowledge is valued less among young Inuit.

Among wine producers in British Columbia, Canada, Belliveau *et al*. (2006) demonstrate how adaptations can modify vulnerability to climate-related risks. Following the North American Free

Trade Agreement, grape producers replaced low quality grape varieties with tender varieties to compete with higher quality foreign imports, many of which have lower costs of production. This change enhanced the wine industry's domestic and international competitiveness, thereby reducing market risks, but simultaneously increased its susceptibility to winter injury. Thus the initial adaptation, switching varieties, changed the nature of the system to make it more vulnerable to climatic stresses to which it was previously less sensitive. At the same time, secondary adaptations utilized to moderate the increased sensitivity to climatic stresses enhance market risks. To minimize frost risks, producers use overhead irrigation to wet the berries. The extra water from irrigation, however, can dilute the flavour in the grapes, reducing quality and increasing market risks.

Smallholder coffee farmers in Mexico, Guatemala and Honduras were subjected to severe droughts in 1997-1998 and 1999-2002. Their capacity to deal with these conditions was complicated by low international coffee prices, reflecting changes in international institutions and national policies (Eakin *et al*, 2005). The collapse of the International Coffee Agreement in 1989 led to a decline in world prices, particularly with the entry of Vietnam into the coffee market. Concurrently, Central American market liberalization in all three countries reduced state intervention in commodity production, markets and prices in the region. Furthermore, there are financial resource constraints on adaptation, with a contraction of rural finance. Mexican farmers are not a co-ordinated lobby and have inadequate political representation and few farm credit schemes. One common adaptation strategy has been to switch cash crops to maize or sugar cane, but these are at the upper limit of temperature in the region already and even a modest increase in temperature threatens yields. Alternative crops (beyond sugar cane and coffee) in these regions have poorly developed marketing mechanisms. Finally, there is a strong cultural significance attached to traditional crops, making farmers less likely to employ adaptive strategies that employ other crops. Among Central American smallholder coffee farmers, vulnerability is therefore determined by an interdependent mix of economic liberalization, international agreements, temperature, drought, local organizations, access to credit, cultural values and political representation. The vulnerability of one region is 'tele-connected' to other regions: in a study of coffee markets and livelihoods in Vietnam and Central America, Adger *et al*. (2006) found that actions in one region created vulnerability in the other through direct market interactions (Vietnamese coffee increased global supply and reduced prices) interacting with weather-related risks (coffee plant diseases and frosts).

The capacity of smallholder farmer households in Kenya and Tanzania, to cope with climate stresses, is often influenced by the ability of a household member to specialize in one activity or in a limited number of intensive cash-yielding activities (Eriksen *et al*., 2005). However, many households have limited access to this favoured coping option due to lack of labour and human and physical capital. This adaptation option is further constrained by social relations that lead to the exclusion of certain groups, especially women, from carrying out favoured activities with sufficient intensity. At present, relatively few investments go into improving the viability of these identified coping strategies. Instead, policies tend to focus on increasing the resistance of agriculture to climate variability which might actually reinforce the exclusion of population groups in dry lands where farmers are reluctant to adopt certain agricultural technologies because of their low market and consumption values and associated high costs (Eriksen *et al*., 2005). The determinants of adaptive capacity of smallholder farmers in Kenya and Tanzania are multiple and interrelated.

17.4 Enhancing adaptation: Opportunities and constraints

17.4.1 International and national action for implementing adaptation

An emerging literature on the institutional requirements for adaptation suggests that there is a clear and defined role of public policy intervention in adapting to climate change. These roles include reducing vulnerability of the most vulnerable people and infrastructures, providing information on risks for private and public investments and decision-making, and protecting so-called public goods including conservation of habitats and species and culturally important resources (Haddad *et al*., 2003; Calloway, 2004; Tompkins and Adger, 2005; Haddad, 2005). In addition, a further literature sets out the case for international transfers from polluting countries to compensate those countries exposed to the greatest impacts or most vulnerable to present and future impacts (NEF, 2000; Burton *et al*., 2002; Baer, 2006; Paavola and Adger, 2006). Baer (2006) estimates the scale of such transfers from polluting countries at $50 billion based on estimated aggregate damage estimates in net present value.

At the same time the Framework Convention on Climate Change and various multi-lateral development institutions are also distributing funds and resources for adaptation, many under the Marrakech Accords of the FCCC. Least Developed Countries are identified as being vulnerable under the FCCC and their adaptation has been facilitated through development of National Adaptation Programs of Action (NAPAs): these are a requirement of the LDC Work Program, which was laid out at Marrakech Accords. In completing a NAPA, a country identifies priority activities that must be implemented in the immediate future in order to address urgent national climate change adaptation needs (Burton *et al.*, 2002; Huq *et al*., 2003). So far, only three countries have completed their national NAPA reports (www.unfccc.de). The Bangladesh report has underscored the needs of integration of climate change within the development process so that so that it was better prepared to handle future climate change impacts (Bangladesh Country Report, 2005). Bangladesh, Mauritania and Samoa and have identified 15, 26 and nine potential adaptation actions requiring funded projects, respectively. Since NAPAs have yet to be implemented, it is not possible to assess outcomes in terms of increased adaptive capacity or reduced vulnerability to climate change risks. The process of developing NAPAs is being monitored and Box 17.8 discusses early lessons from the consultative processes, showing that the effectiveness and legitimacy of NAPAs can be undermined by narrow and unrepresentative consultation processes.

Box 17.8: Early lessons on effectiveness and legitimacy of National Adaptation Programs of Action

The UN Framework Convention on Climate Change (UNFCCC) has approved and funded the preparation of National Adaptation Programs of Action (NAPAs) by the least developed countries (LDCs). At present there is sparse documentary evidence on outcomes of NAPA planning processes or implementation. Several projects developed under NAPA processes are presently ongoing such as The Republic of Kiribati Sanitation Public Health and Environment Improvement Project developed to address problems of waste disposal and water resources as part of adaptation planning for climate change (Van Aalst and Bettencourt, 2004).

Early lessons on the planning processes are based on analyses of how national planning processes take place and their integration into wider sustainable development strategies. The UNFCCC developed a set of Guidelines and adopted them in 2001. These contain activities and criteria for selection of urgent and immediate measures for enhancing the adaptive capacity of the countries. Huq and Khan (2006) examined the NAPA Guidelines, the Bangladesh NAPA, and related policy and implementation documents. They argue on the basis of these documents that NAPAs should adopt 1) a livelihood rather than sectoral approach, 2) focus on near and medium-term impacts of climate variability as well as long term impacts, 3) should ensure integration of indigenous and traditional knowledge, and 4) should ensure procedural fairness through interactive participation and self-mobilization (Huq and Khan, 2006). They found that NAPA consultation and planning processes have the same constraints and exhibit the same problems of exclusion and narrow focus as other national planning processes (such as those for Poverty Reduction Strategies) They conclude that the fairness and effectiveness of national adaptation planning depends on how national governments already include or exclude their citizens in decision-making and that effective participatory planning for climate change requires functioning democratic structures. Where these are absent, planning for climate change is little more than rhetoric (Huq and Khan, 2006). Similar issues are raised and findings presented in Huq and Reid (2003), Paavola (2006) and Burton *et al*. (2002). The key role of non-government and community-based organizations in ensuring the sustainability and success of adaptation planning is likely to become evident over the incoming period of NAPA development and implementation.

In the climate change context, the term mainstreaming has been used to refer to integration of climate change vulnerabilities or adaptation into some aspect of related government policy such as water management, disaster preparedness and emergency planning or land use planning (Agrawala, 2005). Actions that promote adaptation include integration of climate information into environmental data sets, vulnerability or hazard assessments, broad development strategies, macro policies, sector policies, institutional or organizational structures, or in development project design and implementation (Burton and van Aalst, 1999; Huq *et al.*, 2003). By implementing mainstreaming initiatives, it is argued that adaptation to climate change will become part of or will be consistent with other well established programs, particularly sustainable development planning.

Mainstreaming initiatives can be of four levels – international, regional, national and local or community. At the international level, mainstreaming of climate change can occur at the policy formulation, project approval and country level implementation of projects are being funded by the international organizations. For example, the International Federation of Red Cross and Red Crescent (IFRC) is working to facilitate a link between local and global response through its Climate Change Center (Van Aalst and Helmer, 2003). An example of regional level is the MACC (Mainstreaming Adaptation to Climate Change in the Caribbean) project. It assesses the likely impacts of climate change on key economic sectors (i.e., water, agriculture and human health) while also defining responses at community, national and regional levels (Trotz, 2003). Various multi-lateral and bi-lateral development agencies, such as the Asian Development Bank are attempting to integrate climate change adaptation into their grant and loan activities (often known as climate-proofing) (Perez and Yohe, 2005; ADB, 2005). Other aid agencies have sought to screen out those loans and grants which are mal-adaptations and create new vulnerabilities, to ascertain the extent to which existing development projects already consider climate risks or address vulnerability to climate variability and change, and to identify opportunities for incorporating climate change explicitly into future projects. Klein *et al*. (2005) have examined the activities of several major development agencies over the past five years and found that while most agencies already consider climate change as a real but uncertain threat to future development, they have not explicitly examined how their activities affect vulnerability to climate change. Klein *et al*. (2005) develop a portfolio-screening tool to assess systematically the relevance of climate change to their ongoing and planned development projects.

There are, therefore, few examples of successful mainstreaming of climate change risk into development planning. Agrawala and van Aalst (2005) identified following five major constraints: (1) Relevance of climate information for development-related decisions; (2) Uncertainty of climate information; (3) Compartmentalization with governments; (4) Segmentation and other barriers within development-cooperation agencies; and (5) Trade-offs between climate and development objectives. The Adaptation Policy Framework (Lim *et al*., 2005) developed to support national planning for adaptation by UNDP, provides guidance on how these obstacles and barriers to mainstreaming can be overcome. Mirza and Burton (2005) found that the application of APF was feasible when they applied it for urban flooding and droughts in Bangladesh and India, respectively. However, they concluded that the APF application could encounter problems like micro-level socio-economic information and identification of gaps in the stakeholders' participation in the projects planning, design, implementation and monitoring. At present, the literature on adaptation as part of sustainable development policy within government portrays mainstreaming as a potential opportunity for good practice to build resilience and reduce vulnerability. But these opportunities are dependent on effective, equitable and legitimate actions to overcome barriers and limits to adaptation that have been identified in this literature (Agrawala and van Aalst, 2005; Lim *et al*., 2005; ADB, 2005).

17.4.2 Limits to action that make adaptation ineffective

Studies reviewed in Section 17.3 show that adaptive capacity is a prerequisite for successful adaptation to climate change The factors that contribute to low adaptive capacities can be considered constraints or barriers to adaptation. Many of the constraints to adaptation can be overcome by addressing particular determinants of adaptive capacity. As discussed in section 17.3, these may involve changing governance structures and institutions, increasing levels of well-being, improving availability of, access to, and use of technologies, improving knowledge and skills, or addressing entitlements and structures that influence access and control of resources. There is a growing recognition in the literature that assesses opportunities for adaptation that societies can change their practices, institutions, or technology to take maximum advantage of the opportunities associated with climate change, and to limit the negative effects (US National Assessment, 2000).

While it is feasible to increase the capacity of human society to adapt to a changing climate, most studies of specific adaptation plans and actions also argue that likely to be limits to adaptation as a response to climate change. It cannot be assumed that adaptation will make the aggregate impacts of climate change negligible or beneficial, nor can it be assumed that all available adaptation measures will actually be taken (U.S. National Assessment 2000). High adaptive capacity may not automatically translate into successful adaptations to climate change (Brooks 2003; O'Brien *et al*. 2006). Research on adaptation to changing flood risk in Norway, for example, has shown that high adaptive capacity is countered by weak incentives for proactive flood management (Naess *et al*. 2005). Despite increased attention to potential adaptation options, there is less understanding of the feasibility, costs, effectiveness, and the likely extent of their actual implementation (UN National Assessment, 2000). These factors are likely to be influenced by the environmental, social, economic, geopolitical, and cultural context in which an adapting system is embedded (Brooks 2003).

This section assesses some of the limits to adaptation that have been discussed in the climate change and related literatures. Limits are defined here as the conditions or factors that render adaptation ineffective as a response to climate change. These limits are, by definition, subjective and dependent upon the values of diverse groups. The perceived limits to adaptation are hence likely to vary according to different metrics. For example, the five numeraires for judging the significance of climate change impacts described by Schneider Kuntz-Duriseti, and Azar (2000)—monetary loss,

loss of life, biodiversity loss, distribution and equity, and quality of life (including factors such as coercion to migrate, conflict over resources, cultural diversity, and loss of cultural heritage sites), can lead to very different assessments of the limits to adaptation.

This section discusses six broad categories of limits to adaptation: physical and ecological limits; technological limits; financial limits; informational and cognitive limits; social and cultural limits; and institutional and political limits. These limits to adaptation are closely linked to the rate and magnitude of climate change, as well as associated key vulnerabilities discussed in Chapter 19. Limits to adaptation options become apparent in bringing new land under irrigation, in large-scale infrastructural changes to minimize the impacts of sea-level rise on coastal areas, or to realizing population movement and migration (Adger *et al*. 2003). Although these limits are not necessarily fixed, immutable, or insurmountable, they raise questions about the efficacy and legitimacy of adaptation as a response to climate change.

17.4.2.1. Physical and ecological limits

There is increasing evidence from ecological studies that the resilience of coupled socio-ecological systems to climate change will depend on the rate and magnitude of climate change, and that there may be critical thresholds, beyond which some systems may not be able to adapt to changing climate conditions without radically altering their functional state and system integrity (examples in Chapter 1). Scheffer *et al*. (2001) and Steneck *et al*. (2002), for example, find thresholds in the resilience of kelp forest ecosystems, coral reefs, rangelands and lakes affected both by climate change and under stress from other pollutants. Dramatic climatic changes may lead to transformations of the physical environment of a region that limit possibilities for adaptation (Nicholls and Tol, 2006). For example, rapid sea level rise that inundates islands and coastal settlements is likely to limit adaptation possibilities, with potential options being limited to migration (as discussed in Chapter 15, Barnett and Adger, 2003; Barnett, 2005). The loss of Arctic sea ice threatens the survival of polar bears, even if management adaptations are taken to minimize harvesting (Derocher *et al*. 2004). The loss of keystone species may cascade through the socio-ecological system, eventually influencing ecosystems services that humans rely on, including provisioning services, regulating services, cultural services, and supporting services (MEA 2005).

Changes in the physical and natural environment influence the context in which humans respond to changes, and in some cases they may pose limits to human adaptations. Economies and communities that are directly dependent on ecosystems such as fisheries and agriculture are likely to be more affected by sudden and dramatic switches and flips in ecosystems (Folke *et al*., 2005). In a review of social change and ecosystem shifts, Folke *et al*. (2005) show that there are significant challenges to resource management from ecosystem shifts and that these are often outside the experience of institutions – the acquirement of new knowledge in these circumstances is a limit on the effectiveness of adaptation (Folke *et al*., 2005).

17.4.2.2 Technological limits

Technological adaptations can serve as a potent means of adapting to climate variability and change. New technologies can be developed to adapt to climate change, and the transfer of appropriate technologies to developing countries forms an important component of the United Nations Framework Convention on Climate Change (Mace, 2006). However, there are also potential limits to technology as an adaptation response to climate change.

First, technology is developed and applied in a social context, and decision-making under uncertainty may inhibit the adoption or development of technological solutions to climate change adaptation

(Olsthoorn *et al*. 2005). For example, case studies from the Rhine delta, the Thames estuary, and the Rhone delta in Europe suggest that although protection from five meter sea level rise is technically possible, a combination of accommodation and retreat is more likely as an adaptation strategy (Tol *et al*. 2005).

Second, although some adaptations may be technologically possible, they may not be economically feasible or culturally desirable. For example, within the context of Africa, large-scale engineering measures for coastal protection are beyond the reach of many governments due to high costs (Ikeme 2003). In colder climates that support ski tourism, the extra costs of making snow at warmer average temperatures may surpass a threshold where it becomes economically unfeasible (Scott 2003). Although the construction of snow domes and indoor arenas for alpine skiing has increased in recent years, this technology may not be an affordable, acceptable, or appropriate adaptation to decreasing snow cover for many communities dependent on ski tourism. Finally, existing or new technology is unlikely to be equally transferable to all contexts and to all groups or individuals, regardless of the extent of country-to-country technology transfers (Baer, 2006). Adaptations that are effective in one location may be ineffective in other places, or create new vulnerabilities for other places or groups, particularly through negative side effects. For example, although technologies such as snowmobiles and global positioning systems (GPS) have facilitated adaptation to climate change among some Inuit hunters, these are not equally accessible to all, and they have potentially contributed to inequalities within the community through differential access to resources (Ford *et al*. 2006).

17.4.2.3 Financial limits

There is a substantial body of literature that discusses or documents the rising economic costs of hydrometeorological events such as storms and floods (Munich Re 2001, Dore and Etkin 2003, Mills 2005). The rising economic cost of disasters can be linked to increased standards of living and the concentration of populations in urban areas (e.g. Pielke, 2005). Nevertheless, it has raised awareness that the risks facing society must be addressed, regardless of whether the risks are due to climate variability, climate change, or a combination of both (Christoplos *et al.*, 2001; Goklany 2005). There is also an emerging awareness that the current mechanisms and sources of funding will not be able to cover the financial requirements of rehabilitation, and adaptation in the face of climate change. Indeed, unanticipated changes in the nature, scale, or location of hazards are considered among the most important threats to the insurance system, which represents the world's largest industry (Mills 2005).

The role of the insurance industry has been widely discussed as a channel of resources and risk pooling for both dealing with the impact of disasters and for promoting risk mitigation and transfer (Christoplos *et al.* 2001; Linnerooth-Bayer *et al*. 2005). Insurance facilitates the transfer of risk from individuals and governments to insurance companies and capital markets, thereby alleviating extended hardship after a disaster and disruption to development programmes due to unforeseen expenditure on rehabilitation. Along with active hazard mitigation and land planning, insurance can become an effective risk financing technique available to governments to manage the funding gap between traditional sources of funding and the losses resulting from severe natural disasters (Gurenko, 2004). Other types of risk pooling mechanisms, such as public-private systems for reducing and sharing disaster losses, international support for microinsurance schemes, weather hedges, and assisting to governments in financing risk to critical public infrastructure have been assessed as a means to address the financial costs of extreme weather events (Linerooth-Bayer and Vári, 2006). Nevertheless, the lack of information by which insurers and household can accurately judge risk present major challenges to the expansions of such mechanisms, particularly for poor people (Christoplos *et al.*, 2001). Studies show that the impact of natural disasters and the ability of countries to absorb them is a direct function of the size of national economies, concentration of major economic activities and assets in disaster prone areas, the size of government tax base and, of course, the level of insurance penetration (Gurenko, 2004). The insurance sectors in many countries are underdeveloped and unresponsive to the insurance challenges of climate change (Ikeme 2003).

Post-emergency reconstruction lending as a financial and humanitarian response to climate change also has significant limitations, not the least because it has failed to meet the needs of developing countries in reducing risk and financing recovery (Linnerooth-Bayer *et al*. 2005; DFID 2005, Tearfund 2005). First, reliance on anticipated reconstruction funding provides little incentives for countries to engage in active pre-disaster risk management to reduce their vulnerabilities (Linnerooth-Bayer *et al*. 2005; Thomalla *et al*., 2006). As a result, many countries find themselves unprepared to cope with the impacts of natural disasters, and little attention is paid to the development of adaptive capacity, including risk management solutions. Second, since funding is often delayed, government efforts to quickly revive the economy are jeopardized and countries are usually left with higher debt burdens, which further dampen the incentives for active adaptive capacity building (Gurenko, 2004).

This literature on financial mechanisms to enable adaptation confirms the finding of the Third Assessment Report (Vellinga and Mills, 2001) that increased uncertainty regarding the frequency, intensity or spatial distribution of weather-related losses will increase the vulnerability of insurance sectors and complicate adaptation measures (Vellinga and Mills, 2001, p.419). While growing awareness of risks represents an opportunity for wider adoption of government or private insurance and risk-spreading, insurance is limited by its affordability and ultimately is regarded by many as not an adaptation in the way it is discussed in this chapter (Mills, 2005).

17.4.2.4 Informational and cognitive limits

A lack of scientific understanding and information about future climate change represents a limit to adaptation, for it is difficult to implement specific adaptation measures when knowledge of the magnitude and rate of change is highly uncertain (Lorenzoni *et al*. 2005). One of the major informational barriers to adaptation are standards for sector-specific adaptation. Although it may be relatively easy to allocate adaptation funds to engineered structural adaptations, it cannot be safely assumed that such adaptation measures will be cost-effective in reducing vulnerability to climate change in the long run, given the uncertainty in climate change projections. Hanneman (2000) argues that many economic studies of adaptation (e.g. Mendelsohn *et al*., 2000) conflate soc-called normative and positive analysis and hence assume that adaptation will be efficient. But many examples show that decision-making in adaptation depends on institutional inertia and cognitive dissonance. In the case of coastal management in southern England, for example, Few *et al*. (2004) found that potential adaptive measures to increased storm surges and coastal erosion often involved some kind of radical change—such as large-scale defence works, major alteration of infrastructure or phased abandonment of dwellings that led to loss of property and amenities, changes to local economies and landscapes, biodiversity changes, and even threats to place-based identity. Uncertainty about future climate change combines with public perceptions of risk, public opinion and values to influence judgment and decision-making concerning climate change (Oppenheimer and Todorov, 2006). It is increasingly clear that interpretations of danger are context specific (Lorenzoni *et al*. 2005), and that adaptation responses to climate change can be limited by human cognition (Grothmann and Patt, 2005).

A small but growing literature addresses the psychological dimensions of evaluating long-term risk, and most of this literature is focused on behavior changes in relation to climate change mitigation policies. However, some studies focus on the behavioral foundations of adaptive responses, including the identification of thresholds, or a point at which adaptive behavior begins (Niemeyer *et al*. 2005; Grothmann and Patt, 2005). Key findings from these studies point to different types of cognitive limits to adaptive responses to climate change. For example, Niemeyer *et al*. (2005) found that thresholds in human behavioral response pose important challenges to climate change adaptation, resulting in adaptive, non-adaptive, and maladaptive behaviors. Hansen *et al*. (2004) found evidence for a finite pool of worry among farmers in the Argentine Pampas. As concern about one type of risk increases, worry about other risks decreases. Consequently, concerns about violent conflict, disease and hunger, terrorism, and other risks thus may overshadow the impacts of climate change and concerns for adaptation. Finally, Weber (2006) found that strong visceral reactions towards the risk of climate change are needed to provoke behavioral changes. Since most of the risks from climate change are presented in a time-delayed, abstract, and statistical manner, most people are not alarmed and thus take no precautionary actions.

Other psychological research, for example, has provided empirical evidence that those who perceive themselves to be vulnerable to environmental risks, or who perceive themselves to be victims of injustice, also perceive themselves to be more at risk from environmental hazards of all types (Satterfield *et al*., 2004). Similarly, perceptions of barriers to actually adapting by the vulnerable do in fact limit adaptive actions, even when there are capacities and resources to adapt. Grothman and Patt (2005) examined populations living with flood risk in Germany and farmers dealing with drought risk in Zimbabwe to examine cognitive constraints. They found that perceived abilities to adapt are as important as observable capacities as determinants of action in both cases. They conclude that a divergence between perceived and actual adaptive capacity is a real and often intransigent limit to adaptive action.

Restricting attention to a subset of possible climate futures misleads decision-makers by obscuring the range of possible futures they may face (Social Learning Group, 2001). As observed in the Working Group 1 synthesis, climate phenomena that generate impacts in different parts of the world such as ENSO, the PDO, and decadal-scale hurricane variability are not well reproduced in present GCMs. As such, most scenarios are limited by these constraints, i.e., they do not capture changes in climate variability, including changes in wave height and intensity with increasing sea level rise. Output from multiple climate models does allow some appraisal of the uncertainties, but the range of futures depicted from multiple models is still much smaller than the range of futures expected if uncertainties are treated explicitly (Dessai *et al*., 2005). On very broad average it takes island nations in the Caribbean at least 5 years to recover from the impacts of a major hurricane without the impact of a second event in the intervening time (Caribbean Development Bank Report). Mainstreaming of climate considerations may therefore be more difficult where the climate sensitivity of development-related decisions is to variables that cannot be reliably projected.

17.4.2.5 Social and cultural limits

Social and cultural limits to adaptation can be related to the different ways in which people and groups experience, interpret, and respond to climate change. Individuals and groups may have different risk tolerance as well as different preferences about adaptation measures, depending on their worldviews, values, and beliefs. Conflicting understandings can impede adaptive actions. Differential power and access to decision-makers may promote adaptive responses by some, while constraining them for others. Thomas and Twyman (2005) analysed natural resource policies in southern Africa and showed that even so-called community-based interventions to reduce vulnerability create excluded groups without access to decision-making. In addition, diverse understandings and prioritizations of climate change issues across different social and cultural groups can limit adaptive responses (Ford and Smit, 2004).

Although scientific research indicates that forest ecosystems in northern Canada are among those regions at greatest risk to the impacts of climate change, the social dimensions of forest-dependent communities indicate both a limited community capacity and a limited potential to perceive climate change as a salient risk issue that warrants action. Climate change messages are often associated with environmentalism, and environmentalists, who have been perceived by many residents of resource-dependent communities as an oppositional political force. Risk perceptions tend to be higher for women than for men, the higher concern levels of women may either be stifled or simply be unexpressed in a highly male-dominated environment. (Davidson, *et al*., 2003).

The capacity of society to understand and learn from experience represents a potential limit to adaptation. Experience from past lessons can be broken down into five principal tasks (Brunner and Klein, 1999) (1) is to identify and describe policies provisionally appraised as successful, (2) to verify that they have in fact succeeded according to the mitigation or adaptation criteria of national policymakers and the `no regrets' criteria of localized or specialized policymakers, and (3) to explain formal and effective responsibility for those successes, (4) to assess how the policies and practices have been diffused to other localized or specialized policy processes that might consider and adapt them to their own circumstances and (5) to stimulate the innovation and field-testing of new policies in promising but neglected areas, such as transportation or impoverished places. This latter activity has found itself embedded in the "mainstreaming adaptation to climate change" activities being undertaken in different parts of the world (Agrawala, 2005). Some research shows that `no regrets' policies have succeeded on small scales in mitigating or adapting to climate change without compromising economic, democratic, and other aspects of the common interest (Brunner *et al*, 2005).

These complexities, particularly the societal modifications of environments and the social divisions, make it difficult to correlate scales of climate with simple metrics by which complex historical processes can be summarized. The scale and novelty of climate changes and impacts on climate fluctuations are not the sole determinants of degree of impact (Orlove, 2005). Societies change their environments, and thus alter their own vulnerability to climate fluctuations. The experience of development of the Colorado River Basin in the face of environmental uncertainty clearly illustrates that impacts and interventions can reverberate through the systems in ways that can only be partially traced and predicted (Pulwarty *et al*, 2005).

Accounting for future economic and social trends, involves problems of indeterminacy (imperfectly understood structures and processes), discontinuity (novelty and surprise in social systems), reflexivity (the ability of people and organizations to reflect on and adapt their behaviour) and framing (legitimately diverse views about the state of the world) (see Berkhout *et al*, 2002, Pulwarty *et al*, 2003). Case studies reveal that there exists a diversity of local or traditional practices for ecosystem management under environmental uncertainty. These include rules for social regulation; mechanisms for cultural internalization of traditional practices; and the development of appropriate world views and cultural values (Pretty, 2004).

Although many societies are highly adaptive to climate variability and change, vulnerability is dynamic and likely to change in response to multiple processes, including economic globalization (Leichenko and O'Brien 2002). The Inuit, for example, have a long history of adaptation to changing environmental conditions. However, flexibility in group size and group structure to cope with climate variability and unpredictability is no longer a viable strategy due to settlement in permanent communities (Ford *et al*. 2006). Also memories and hunting narratives are appearing unreliable because of rapid change (see Fox, 2003). Furthermore, there are emerging vulnerabilities, particularly among the younger generation through lack of knowledge transfer and among those who do not have access to monetary resources to purchase equipment necessary to hunt in the context of changing conditions (Ford *et al*. 2006).

The social and cultural limits to adaptation are not well researched. Cognitive barriers may play a part but something deeper is at work. Jamieson (2005) notes that a large segment of the U.S. population think of themselves as environmentalists but often vote for environmentally negative candidates. In addition, support for green policies flag as policies are more carefully specific and precise costs associated with them.

Most analyses of adaptation propose that successful adaptations involve marginal changes to material circumstances rather than wholesale changes in location and development paths. A few studies have examined the need for and potential for migration, resettlement and relocation as an adaptive strategy, for example, but the cultural implications of large-scale migration are not well understood and could represent significant limits to adaptation. Box 17.9 presents evidence that demonstrates that while relocation and migration have been used as adaptation strategies in the past, there are often large social costs associated with these and unacceptable impacts in terms of human rights and sustainability. The possibility of migration as a response to climate change is still rarely broached in the literature on adaptation to climate change, perhaps because it entirely outside the acceptable range of proposals (Orlove, 2005).

Box 17.9: Does migration and resettlement represent successful adaptation?

Migration may be one adaptive response option when local environments surpass a threshold beyond which the system is no longer able to support most or all of the population (e.g., when islands become uninhabitable due to sea level rise) (Barnett, 2001). The Pacific Island atoll states of Kiribati, Tuvalu, Tokelau, and Marshall Islands are vulnerable to sea level rise, which at some threshold may pose risks to sovereignty or existence (Barnett 2001). Barnett and Adger (2003) argue that this loss of sovereignty itself represents a dangerous climate change and show that the implications of dangerous climate change being defined as rights of citizens to avoid such risks would necessitate mitigative action to prevent the need for migration.

There has been some discussion of the possibility that sea-level rise will make it impossible for human populations to remain on specific islands. For instance New Zealand has been discussed as a possible site of relocation in Tuvalu, a nation consisting of low-lying atolls in the western Pacific. It is certainly the case that there would be enormous economic, cultural and human costs if large populations were to abandon their long-established home territories and move to new places, but the relative absence of the recognition of this possibility is also a striking form of silence. In the present international order, each country is granted considerable autonomy in controlling its borders and in setting policies on immigration; it would be a violation of presuppositions about the obligations of states to their citizens to propose pro-emigration policies (Patel, 2006).

The ability to migrate as an adaptive strategy is not equally accessible to all, and decisions to migrate are not controlled exclusively by individuals, households, or local and state governments (McLeman 2006). McLeman and Smit (2006), Winkels (2004), Adger *et al*. (2002) show that strong social capital can obviate the need for relocation in the face of risk and is also important in determining the success and patterns of migration as an adaptive strategy: the spatial patterns of existing social networks in a community influence their adaptation to climate change. Where household social networks are strong at the local scale, adaptations that do not lead to migration, or that lead to local-scale relocations, are more likely responses than long-distance migration away from areas under risk. Conversely, if the community has widespread social networks, or is part of a transnational community then far-reaching migration is possible. McLeman and Smit (2006) show that a range of economic, social and cultural processes play roles in shaping migration behaviour and migration patterns to climate conditions and resulting long-term drought in rural Eastern Oklahoma in the 1930s. While temporary migration has often been used as a risk management response to climate variability, permanent migration may be required when physical or ecological limits to adaptation have been surpassed.

Mendelsohn *et al*. (2006), examined correlations between incomes in rural districts in the USA and in Brazil with parameters of present climate and physical parameters of agricultural productivity. They argue that climate affects agricultural productivity which in turn affects per capita income (even when this is defined as both farm and non-farm incomes for a district) and that climatic changes that reduce productivity may have direct consequences in rural poverty: 'hostile climates make it difficult for rural families to earn a living through agriculture'. They argue that climate change impacts in rural economies may make migration and relocation a necessity, but undesirable adaptation. In the case of island states, Barnett (2005) argues that adaptation should already be deemed as unsuccessful if it has limited development opportunities.

17.4.2.6 Institutional and Political Limits

A large literature on the institutional dimensions of adaptation has emphasized the important role of institutional capital. Appropriate institutions are needed to facilitate, implement, and sustain adaptations to climate change policy. However, formal organizational structure and institutional mechanisms are absent, as for instance, in many parts of sub-Saharan Africa (Ikeme 2003). Problems of fit, interplay and scale between institutions and climate change issues influence the capacity to respond through adaptation (Young 2002; Few *et al* 2004).

Another institutional barrier to adaptation may be the fit or location of climate change policymaking within government ministries and civil society, both in developed and developing countries. Natural disaster risk management is often overlooked by humanitarian policymakers and practitioners as a result of organisational divisions between relief and development. Plus, the roles of state and civil society when dealing with risks are often contested. For example, the structural adjustments and the decline of state control over public services as a result of decentralisation effects the traditional role of NGOs to fill temporary gaps in state capacity. Instead, NGOs may be responsible for providing the services that have been handed over by governments to civil society, services that they may not be able to sustain (Christoplos *et al.*, 2001). Wisner *et al*. (2004) also points out that although declarations concerning the reforming of institutions and regulatory frameworks usually accompany disasters, systems often lack the political will and capacity to carry through with these reforms. In addition for the United States, the constituency that supports improved risk management has historically proven too small to bring about many of the changes that have been recommended by disaster researchers, especially those practices that focus on strengthening the social fabric to decrease vulnerability. However, efforts are being made to increase cooperation and bridges between different actors and different perspectives. For example, ProVention is a global coalition of governments, international organisations, academic institutions, the private sector and civil society organisations, led by the World Bank, the International Federation of Red Cross and Red Crescent Societies and UNDP, aimed at addressing the conceptual and operational gaps between these actors and promoting adaptation and risk management within development and humanitarian agendas (Christoplos *et al.*, 2001).

One of the major limitations on assessing learning in the context of adaptation occurs from the fact that very few longitudinal evaluation studies can be carried out. In one case (Bolivia) the country started a process of decentralization ("Participación Popular") 15 years ago that might enhance the capacity of the country to respond to climate change. However, ongoing short term decentralization of implementation makes assessment and lesson drawing difficult (Iwanciw *et al*, 2004).

Political action on climate change may be influenced by the impact of other stressors, such as violent conflict, disease and hunger, which often overshadow the impacts of climate change. Many deaths that are caused by naturally occurring weather-related hazards, might not have resulted under different economic and political circumstances. However, the risks involved in disasters are often connected with the vulnerability inherent in normal life. For example, wars are often inextricable linked with famine and disease and have sometimes coincided with drought. The multiplication of stressors makes it harder for a system to cope with each stressor individually. Plus, the large debts faced by developing countries make the cost of building adaptive capacity unattainable. Therefore, equal emphasis should be put on the natural hazard itself as well as the surrounding social environment (Wisner *et al.*, 2004).

In response to the recommendations by the UNFCCC to improve adaptive capacity in order to decrease vulnerability to climate change, many countries are now giving attention to the identification of possible adaptation measures. Although National Communications to the Climate Convention and many independent climate studies list possible adaptation measures, the limits of many adaptation options are already apparent. Burton and Van Aalst (2004) also suggest that little effort is made to show how these measures relate to existing policy. This could be attributed to the inevitable difficulties that are involved in addressing policy issues or the expectation that separate adaptation measures could more easily be funded from upcoming adaptation funds rather than measures that are mainstreamed within other developmental schemes. In addition, many policies may discourage sound adaptation or may serve to increase vulnerability.

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