

# 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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### Executive Summary

**Adaptation to climate change is already taking place, but on a limited basis (very high confidence).**

- Societies have a long record of adapting to the impacts of weather and climate through a

range of practices that include crop diversification, irrigation, water management, disaster risk management, and insurance. But climate change poses novel risks often outside the range of experience, such as impacts related to drought, heat-waves, accelerated glacier retreat, and hurricane intensity. [17.2.1]

- Adaptation measures that also consider climate change are being implemented, on a limited basis, in both developed and developing countries. These measures are undertaken by a range of public and private actors through policies, investments in infrastructure and technologies, and behavioural change.
  - Examples of adaptations to observed changes in climate include partial drainage of the Tsho Rolpa glacial lake (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 (Europe, Australia and North America). [17.2.2]
  - A limited but growing set of adaptation measures also explicitly considers scenarios of future climate change. Examples include consideration of sea level rise in design of infrastructure such as the Confederation Bridge (Canada) and in coastal zone management (United States and Netherlands) [17.2.2]

**Adaptation measures are seldom undertaken in response to climate change alone (very high confidence).**

- Many actions that facilitate adaptation to climate change are undertaken to deal with current extreme events such as heat waves and cyclones. Often, planned adaptation initiatives are also not undertaken as stand-alone measures, but embedded within broader sectoral initiatives such as water resource planning, coastal defence, and disaster planning. [17.2.2, 17.3.3] Examples include consideration of climate change in the National Water Plan of Bangladesh, and the design of flood protection and cyclone-resistant infrastructure in Tonga. [17.2.2]

**Many adaptations can be implemented at low cost, but comprehensive estimates of adaptation costs and benefits are currently lacking (high confidence).**

- There are a growing number of adaptation cost and benefit-cost estimates at 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. However, some common adaptations may have social and environmental externalities. Adaptations to heat waves, for example, have involved increased demand for energy-intensive air-conditioning. [17.2.3]
- Limited estimates are also 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. Comprehensive multi-sectoral estimates of global costs and benefits of adaptation are currently lacking. [17.2.3]

**Adaptive capacity is uneven across and within societies (very high confidence).**

- There are individuals and groups within all societies that have insufficient capacity to adapt to climate change. For example, women in subsistence farming communities are disproportionately burdened with the costs of recovery and coping with drought in southern Africa. [17.3.2]
- The capacity to adapt is dynamic and influenced by economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology. [17.3.3]
- Multiple stresses related to HIV/AIDS, land degradation, trends in economic globalisation,

and violent conflict affect exposure to climate risks and the capacity to adapt. For example, farming communities in India are exposed to impacts of import competition and lower prices in addition to climate risks; marine ecosystems over-exploited by globalised fisheries have been shown to be less resilient to climate variability and change. [17.3.3]

#### **There are substantial limits and barriers to adaptation (very high confidence).**

- High adaptive capacity does not necessarily translate into actions that reduce vulnerability. 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 European cities, continue to experience high levels of mortality. [17.4.2]
- There are significant barriers to implementing adaptation. These include both the inability of natural systems to adapt to the rate and magnitude of climate change, as well as technological, financial, cognitive and behavioural, as well as social and cultural constraints. There are also significant knowledge gaps for adaptation as well as impediments to flows of knowledge and information relevant for adaptation decisions. [17.4.1, 17.4.2]
- New planning processes are attempting to overcome these barriers at local, regional and national levels in both developing and developed countries. For example, Least Developed Countries are developing National Adaptation Plans of Action and some developed countries have established national adaptation policy frameworks. [17.4.1]

### **17.1 Concepts and methods**

This chapter is an assessment of knowledge and practice on adaptation since the Third Assessment Report (TAR). In the TAR, adaptation and vulnerability were defined, types of adaptation were identified, and the role of adaptive capacity was recognised (Smit *et al.*, 2001). Notable developments that occurred since the TAR include insights on: a) actual adaptations to observed climate changes and variability; b) planned adaptations to climate change in infrastructure design, coastal zone management, and other activities; c) the variable nature of vulnerability and adaptive capacity; and d) policy developments, under the UNFCCC and other international, national and local initiatives, that facilitate adaptation processes and action programmes (Adger *et al.*, 2005; West and Gawith, 2005; Tompkins *et al.*, 2005).

This chapter assesses the recent literature, focussing on real-world adaptation practices and processes, determinants and dynamics of adaptive capacity, and opportunities and constraints of adaptation. While adaptation is increasingly regarded as inevitable part of the response to climate change, the evidence in this chapter suggests that climate change adaptation processes and actions face significant limitations, especially in vulnerable nations and communities. In most of the cases, adaptations are being implemented to address climate conditions as part of risk management, resource planning and initiatives linked to sustainable development.

This chapter retains the 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 their ability to respond to stresses imposed as a result of climate change effects. The vulnerability of a society is influenced by its development path, physical exposures, the distribution of resources, prior stresses and social and government institutions (Kelly and Adger, 2000; Smit and Wandel, 2006; Turner *et al.*, 2003; O'Brien *et al.*, 2004; Jones, 2001; Yohe and Tol, 2002). All societies have inherent abilities to deal with certain variations in climate, yet adaptive capacities are unevenly distributed, both across countries and within societies. The poor and marginalised have historically been most at risk, and are most vulnerable to the impacts of climate change. Recent analyses in Africa, Asia and Latin America,

for example, show that marginalised, primary resource dependent livelihood groups are particularly vulnerable to climate change impacts if their natural resource base is severely stressed and degraded by overuse or if their governance systems are in or near a state of failure and hence not capable of responding effectively (Leary *et al.*, 2006).

Adaptation to climate change takes place through adjustments to reduce vulnerability or enhance resilience in response to observed or expected changes in climate and associated extreme weather events. Adaptation occurs in physical, ecological and human systems. It involves changes in social and environmental processes, perceptions of climate risk, practices and functions to reduce potential damages or to realise new opportunities. Adaptations include anticipatory and reactive actions, private and public initiatives, and can relate to projected changes in temperature and current climate variations and extremes that may be altered with climate change. In practice, adaptations tend to be on-going processes, reflecting many factors or stresses, rather than discrete measures to address climate change specifically.

Biological adaptation is reactive (Chapter 4), whereas individuals and societies adapt to both observed and expected climate through anticipatory and reactive actions. 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). Despite evidence of success stories, many individuals and societies still remain vulnerable to present-day climatic risks, which may be exacerbated by future climate change. Some adaptation measures are undertaken by individuals, while other types of adaptation are planned and implemented by governments on behalf of societies, sometimes in anticipation of change but mostly in response to experienced climatic events, especially extremes (Adger, 2003; Kahn, 2003; Klein and Smith, 2003).

The scientific research on adaptation is synthesised in this chapter according to: current adaptation practices to climate variability and change; assessment of adaptation costs and benefits; adaptive capacity and its determinants, dynamics and spatial variations; and the opportunities and limits of adaptation as a response strategy for climate change.

## 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 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. Meanwhile, the development of climate risk screening guidelines, which might make downstream development projects more resilient to climate risks (Burton and van Aalst, 2004; ADB, 2005), 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 can be differentiated 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, local communities and individuals); by climatic zone (dryland, floodplains, mountains, arctic, and so on); by baseline income/development levels of the systems in which they are implemented

(least developed countries, middle income countries, and developed countries); or by some combination of these and other categories.

From a temporal perspective, adaptation to climate risks can 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. 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 adaptation measures can be synergistic with development priorities (Ribot *et al.*, 1996), but there could also be conflicts. For example, activities such as shrimp farming and conversion of coastal mangroves, while profitable in an economic sense, can exacerbate vulnerability to sea level rise (Agrawala *et al.*, 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. This is true, for example, in the case of observed impacts such as glacier retreat and permafrost melt (Shrestha and Shrestha 2004, Schaedler 2004). Even when impacts of climate change are not yet discernible, scenarios of future impacts may already be of sufficient concern 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 infrastructure with long economic life (Shukla *et al.*, 2004), or if current activities may irreversibly constrain future adaptation to the impacts of climate change (Smith *et al.*, 2005).

### 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, community-based disaster risk reduction, famine early warning systems, insurance, water storage, supplementary irrigation and so on. They also include *reactive* or *ex-poste* adaptations, for example, emergency response, disaster recovery, and migration (Sperling and Szekely, 2005). Recent reviews indicate that a ‘wait and see’ or reactive approach is often inefficient and could be particularly unsuccessful in addressing irreversible damages, such as species extinction or unrecoverable ecosystem damages, that may result from climate change (Easterling *et al.*, 2004; Smith, 1997).

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 related to ENSO (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 generate 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

1 Agrawala, 2000; Meinke *et al.*, 2001; O'Brien and Vogel, 2003; Patt and Gwata, 2002; Ziervogel,  
2 2004; De Mello Lemos, 2003). An evaluation of the responses to the 1997-98 El Niño across 16  
3 developing countries in Asia, Asia-Pacific, Africa, and Latin America highlighted a number of  
4 barriers to effective adaptation, including: spatial and temporal uncertainties associated with forecasts  
5 of regional climate, low level of awareness among decision-makers of the local and regional impacts  
6 of El Niño, limited national capacities in climate monitoring and forecasting, and lack of co-  
7 ordination in the formulation of responses (Glantz, 2001). Recent research also highlights that  
8 technological solutions such as seasonal forecasting are not sufficient to address the underlying social  
9 drivers of vulnerabilities to climate (Agrawala and Broad 2002). Furthermore, social inequities in  
10 access to climate information and the lack of resources to respond, can severely constrain  
11 anticipatory adaptation (Pfaff *et al.*, 1999).

12  
13 Table 17.1 provides an illustrative list of various types of adaptations that have been implemented by  
14 a range of actors including individuals, communities, governments and the private sector. Such  
15 measures involve a mix of institutional and behavioural responses, the use of technologies, and the  
16 design of climate resilient infrastructure. They are typically undertaken in response to multiple risks,  
17 and often as part of existing processes or programmes, such as livelihood enhancement, water  
18 resource management, and drought relief.  
19

**Table 17.1: Examples of adaptation initiatives by region, undertaken relative to present climate risks, including conditions associated with climate change.**

| <b>REGION</b><br><b>Country</b><br><i>Reference</i>                                   | <b>Climate-related stress</b>            | <b>Adaptation practices</b>  |
|---|--|--|
| <b>AFRICA</b>   |  |  |
| <b>Egypt</b><br><i>El Raey (2004)</i>   | Sea level rise                           | Adoption of National Climate Change Action Plan integrating climate change concerns into national policies; adoption of law 4/94 requiring EIA for project approval and regulating setback distances for coastal infrastructure; installation of hard structures in areas vulnerable to coastal erosion  |
| <b>Sudan</b><br><i>Osman-Elasha et al. (2006)</i>                                     | Drought                                  | Expanded use of traditional rainwater harvesting and water conserving techniques; building of shelter belts and wind breaks to improve resilience of rangelands; monitoring of the number of grazing animals and cut trees; set-up of revolving credit funds   |
| <b>Botswana</b><br><i>FAO (2004)</i>  | Drought                                  | National government programmes to re-create employment options after drought; capacity building of local authorities; assistance to small subsistence farmers to increase crop production  |
| <b>ASIA &amp; OCEANIA</b>   |  |  |
| <b>Bangladesh</b><br><i>OECD (2003a); Pouliotte (2005)</i>                            | Sea level rise; salt-water intrusion     | Consideration of climate change in the National Water Management Plan; building of flow regulators in coastal embankments; use of alternative crops and low-tech water filters   |
| <b>Philippines</b><br><i>Lasco et al. (2006)</i>                                      | Drought; floods                          | Adjustment of silvicultural treatment schedules to suit climate variations; shift to drought-resistant crops; use of shallow tube wells; rotation method of irrigation during water shortage; construction of water impounding basins; construction of fire lines and controlled burning; adoption of soil and water conservation measures for upland farming  |
| <b>Small Islands (Samoa, Tonga, Cook Islands)</b><br><i>Bettencourt et al. (2006)</i> | Sea level rise; storm surges             | Capacity building for shoreline defence system design; introduction of participatory risk assessment; provision of grants to strengthen coastal resilience and rehabilitation of infrastructures; construction of cyclone-resistant housing units; retrofit of buildings to improved hazard standards; review of building codes; reforestation of mangroves  |
|   | Drought; salt-water intrusion            | Rainwater harvesting; leakage reduction; hydroponic farming; bank loans allowing for purchase of rainwater storage tanks   |
| <b>AMERICAS</b>   |  |  |
| <b>Canada</b><br><i>(1) Ford and Smit (2004)</i><br><i>(2) Mehdi (2006)</i>           | (1) Permafrost melt; change in ice cover | Changes in livelihood practices by the Inuit, including: change of hunt locations; diversification of hunted species; use of GPS technology; encouragement of food sharing   |
|   | (2) Extreme temperatures                 | Implementation of heat health alert plans in Toronto, which include measures such as: opening of designated cooling centres at public locations; information of the public through local media; distribution of bottled water through the Red Cross to vulnerable people; operation of a heat information line to answer heat-related questions; availability of a emergency medical service vehicle with especially trained staff and medical equipment   |
| <b>United States</b><br><i>Easterling et al. (2004)</i>                               | Sea level rise                           | Land acquisition programmes taking account of climate change (e.g. New Jersey Coastal Blue Acres land acquisition programme to acquire coastal lands damaged/prone to damages by storms or buffering other lands; the acquired lands are being used for recreation and conservation); establishment of a “rolling easement” in Texas, an entitlement to public ownership of property that “rolls” inland with the coastline as sea level rises; other coastal policies that encourage coastal landowners to act in ways that anticipate sea level rise   |
| <b>Mexico &amp; Argentina</b><br><i>Wehbe et al. (2006)</i>                           | Drought                                  | Adjustment of planting dates and crop variety (e.g. inclusion of drought resistant plants such as agave and aloe); accumulation of commodity stocks as economic reserve; spatially separated plots for cropping and grazing to diversify exposures; diversification of income by adding livestock operations; set-up/provision of crop insurance; creation of local financial pools (as alternative to commercial crop insurance)  |
| <b>EUROPE</b>   |  |  |
| <b>Netherlands</b><br><i>Government of the Netherlands (1997 and 2005)</i>            | Sea level rise                           | Adoption of Flooding Defence Act and Coastal Defence Policy as precautionary approaches allowing for the incorporation of emerging trends in climate; building of a storm surge barrier taking a 50-cm sea level rise into account; use of sand supplements added to coastal areas; improved management of water levels through dredging, widening of river banks, allowing rivers to expand into side channels and wetland areas; deployment of water storage and retention areas; conduct of regular (every 5 years) reviews of safety characteristics of all protecting infrastructure (dykes etc.); preparation of risk assessments of flooding and coastal damage influencing spatial planning and engineering projects in the coastal zone, identifying areas for potential (land inward) reinforcement of dunes |

|  |   |   |
|--|---|---|
| <b>Austria, France, Switzerland</b><br><i>Austrian Federal Government (2006); Direction du Tourisme, France (2002); Swiss Confederation (2005)</i> | Upward shift of natural snow-reliability line; glacier melt | Artificial snow-making; grooming of ski slopes; moving ski areas to higher altitudes and glaciers; use of white plastic sheets as protection against glacier melt; diversification of tourism revenues (e.g. all-year tourism)  |
|  | Permafrost melt; debris flows                               | Erection of protection dams in Pontresina (Switzerland) against avalanches and increased magnitude of potential debris flows stemming from permafrost thawing   |
| <b>United Kingdom</b><br><i>DEFRA (2006)</i>   | Floods; sea level rise                                      | Coastal realignment under the Essex Wildlife Trust, converting over 84 hectares of arable farmland into salt marsh and grassland to provide sustainable sea defences; maintenance and operation of the Thames Barrier through the Thames Estuary 2100 project that addresses flooding linked to the impacts of climate change; provision of guidance to policy makers, chief executives, and parliament on climate change and the insurance sector (developed by the Association of British Insurers) |



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 the 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 (see Box 17.1).

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

The Tsho Rolpa is a glacial lake located at an altitude of about 4580 metres in Nepal. Glacier retreat and ice melt as a result of warmer temperature increased the size of the Tsho Rolpa from 0.23 km<sup>2</sup> in 1957/58 to 1.65 km<sup>2</sup> in 1997. The 90-100 million m<sup>3</sup> of water, which the lake contained by this time, were only held by a moraine dam – a hazard that called for urgent action to reduce the risk of a catastrophic glacial lake outburst flood (GLOF).

[Figure (A) to be inserted here (see separate WORD file).]

If the dam were breached, one-third or more of the water could flood downstream. Among other considerations, this posed a major risk to the Khimti hydropower plant, which was under construction downstream. These concerns spurred the Government of Nepal, with the support of international donors, to initiate a project in 1998 to lower the level of the lake through drainage. An expert group recommended that, to reduce the risk of a GLOF, the lake should be lowered three metres by cutting a channel in the moraine. A gate was constructed to allow for controlled release of water. Meanwhile, an early warning system was established in 19 villages downstream in case a Tsho Rolpa GLOF should occur despite these efforts. Local villagers were actively involved in the design of the system, and drills are carried out periodically. In 2002, the four-year construction project was completed at a cost of US\$ 3.2 million. Clearly, reducing GLOF risks involves substantial costs and is time consuming as complete prevention of a GLOF would require further drainage to lower the lake level.

Sources: Mool *et al.*, 2001; OECD, 2003b; Shrestha and Shrestha, 2004.

Recent observed weather extremes, particularly heat waves (e.g. 1995 heat wave in Chicago; the 1998 heat wave in Toronto; and the 2003 heat wave in Europe), have also provided the trigger for the design of hot weather alert plans. While such measures have been initiated primarily in response to current weather extremes, at times there is implicit or explicit recognition that 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; Mehdi, 2006; Ligeti, 2004), Shanghai (Sheridan and Kalkstein, 2004), several cities in Italy and France (ONERC, 2005). Weather and climate extremes have also led to a number of adaptation responses in the financial sector (see Box 17.2).

***Box 17.2: Adaptation practices in the financial sector***

Financial mechanisms can contribute to climate change adaptation. The insurance sector, especially property, health and crop insurance, can efficiently spread risks and reduce the financial hardships linked to extreme events. Financial markets can internalise information on climate risks and help transfer adaptation and risk reduction incentives to communities and individuals (ABI, 2004), while capital markets and transfer mechanisms can alleviate financial constraints to the implementation of adaptation measures. To date most adaptation practices have been observed in the insurance sector. As a result of climate change, demand for insurance products is expected to increase, while climate change impacts could also reduce insurability and threaten insurance schemes (ABI, 2004; Dlugolecki and Lafeld, 2005; Valverde and Andrews, 2006; Mills *et al.*, 2005). While these market signals can play a role in transferring adaptation incentives to individuals, reduced insurance coverage can, at the same time, impose significant economic and social costs. To increase their capacity in facing climate variability and change, insurers have developed more comprehensive or accessible information tools, e.g. risk assessment tools in the Czech Republic, France, Germany and the United Kingdom (CEA, 2006). They have also fostered risk prevention through: (i) implementing and strengthening building standards; (ii) planning risk prevention measures and developing best practices, and (iii) raising awareness of policyholders and public authorities (Mills and Lecomte, 2006; CEA, 2006; ABI, 2004). In the longer term, climate change may also induce insurers to adopt forward-looking pricing methods in order to maintain insurability (Loster, 2005; ABI, 2004).

There are now also examples of adaptation measures being put in place 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 in cases where business-as-usual activities would 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 50 metres (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). 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). To avoid such a future cost the designers decided to keep the treatment plant at a higher elevation, and the facility was completed in 1998. Other examples where ongoing planning is considering scenarios of climate

change in project design are the Konkan Railway in western India (Shukla *et al.*, 2004); a coastal highway in Micronesia (ADB, 2005); the Copenhagen Metro in Denmark (Fenger, 2000); and the Thames Barrier in the United Kingdom (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 Qinghai-Tibet Railway is an exception. The railway crosses the Tibetan Plateau with about a thousand kilometres of the railway at least 13,000 feet (4,000 metres) 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. The railway line would affect the permafrost layer, which will also be impacted by thawing as a result of rising temperatures, thus 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 minimise the amount of heat absorbed by the permafrost (Brown, 2005).

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. Efforts are underway to integrate adaptation to current and future climate within the Environmental Impact Assessment (EIA) procedures of several countries in the Caribbean (Vergara, 2006), as well as Canada (Lee, 2000). 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). In the Netherlands, for example, the *Technical Advisory Committee on Water Defence* recommended the design of new engineering works with a long lifetime, such as storm surge barriers and dams, to take a 50 cm sea level rise into account (Government of The Netherlands, 1997). Climate change is explicitly taken into consideration in the National Water Management Plan (NWMP) of Bangladesh, which was set up to guide the implementation of the National Water Policy. It recognises climate change as a determining factor for future water supply and demand, as well as coastal erosion due to sea level rise and increased tidal range (OECD, 2003a).

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, Finland and the United Kingdom have developed national strategies and frameworks to adapt to climate change (ONERC, 2005; MMM, 2005; DEFRA, 2006). 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 and 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). An eight step adaptation assessment procedure has now been developed (Rosenzweig *et al.*, *in press*). 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. 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. As an example 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. Also under examination are longer-term infrastructure adaptations such as 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

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). There is a small methodological literature on the assessment of costs and benefits in the context of climate change adaptation (Fankhauser, 1996; Smith, 1997; Fankhauser *et al.*, 1998; Callaway, 2004; Toman, 2006). In addition there are a number of case studies that look at adaptation options for particular sectors (e.g., Shaw *et al.*, 2000 for sea level rise); or particular countries (e.g., Smith *et al.*, 1998 for Bangladesh; World Bank, 2000 for Fiji and Kiribati; Dore and Burton, 2001 for Canada).

Much of the literature on adaptation costs and benefits is focused on sea level rise (e.g. Fankhauser, 1995a; Yohe and Schlesinger, 1998; Nicholls and Tol, 2006) and agriculture (e.g. Rosenzweig and Parry, 1994; Reilly *et al.*, 2003; Adams *et al.*, 2003). 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 focus on the United States and other OECD countries (e.g. Fankhauser, 1995a; Yohe *et al.*, 1996; Mansur *et al.*, 2005; Franco and Sanstad, 2006), although there is now a growing literature for developing countries also (e.g. Butt *et al.*, 2005; Nicholls and Tol, 2006; Callaway *et al.*, 2006).

#### 17.2.3.1 Sectoral and regional estimates

The literature on costs and benefits of adaptation to sea level rise is relatively extensive. Fankhauser (1995a) used 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 (1995a) 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%. Results of Yohe and Schlesinger (1998) show that total (adjustment and residual land loss) costs of sea level rise could be reduced by around 20 to 50% for the US coastline if the real estate market prices adjusted efficiently as land is submerged. Nicholls and Tol (2006) estimate optimal levels of coastal protection under IPCC SRES A1FI, A2, B1, and B2 scenarios. They 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 (Table 17.2).

**Table 17.2: Sea level rise protection costs in 2080 as a percentage of GDP for most affected countries under the four SRES worlds (A1FI, A2, B1, B2)**

| Protection Costs (%GDP) for the 2080s |      |      |     |      |
|---------------------------------------|------|------|-----|------|
| SRES scenarios                        | A1FI | A2   | B1  | B2   |
| Micronesia                            | 7.4  | 10.0 | 5.0 | 13.5 |
| Palau                                 | 6.1  | 7.0  | 3.9 | 9.1  |
| Tuvalu                                | 1.4  | 1.7  | 0.9 | 2.2  |
| Marshall Islands                      | 0.9  | 1.3  | 0.6 | 1.7  |
| Mozambique                            | 0.2  | 0.5  | 0.1 | 0.8  |
| French Polynesia                      | 0.6  | 0.8  | 0.4 | 1.0  |
| Guinea-Bissau                         | 0.1  | 0.3  | 0.0 | 0.6  |
| Nauru                                 | 0.3  | 0.4  | 0.2 | 0.6  |
| Guyana                                | 0.1  | 0.2  | 0.1 | 0.4  |
| New Caledonia                         | 0.4  | 0.3  | 0.2 | 0.4  |
| Papua New Guinea                      | 0.3  | 0.3  | 0.2 | 0.4  |
| Kiribati                              | 1.2  | 0.0  | 0.3 | 0.0  |
| Maldives                              | 0.0  | 0.2  | 0.0 | 0.2  |
| Viet Nam                              | 0.1  | 0.1  | 0.0 | 0.2  |
| Cambodia                              | 0.0  | 0.1  | 0.0 | 0.1  |

Source: Adapted from Nicholls and Tol (*in press*).

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 over the period 2000-2100, the present value of coastal protection costs for Singapore would be between US\$ 1 and 3.08 million (a very small share of the GDP), for a 0.49 and 0.86-metre 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 coastal 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 under 60-cm sea level rise “floodproofing” measures (such as elevation of living spaces) were superior to coastal protection measures (such as seawalls, bulkheads, and revetments). Meanwhile, coastal protection was found to be optimal under one-metre sea level rise. Another limitation of sea level rise costing studies is their sensitivity to (land and structural) endowment 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”. A further factor increasing uncertainty in costs is the social and political acceptability of adaptation options. Tol *et al.* (2003) show that the benefits of adaptation options for ameliorating increased river flood risk in the Netherlands could be up to US\$ 20 million per year in 2050. But they conclude that implementation of these options requires significant institutional reform and political, representing a significant barrier to implanting least cost solutions.

Adaptation studies looking at the agricultural sector 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.*, 2003; Butt *et al.*, 2005). The literature mainly reports on adaptation benefits, usually expressed in terms of increases in yield or welfare, or decrease in the number of people at risk of hunger. Adaptation costs, meanwhile, were generally not considered in early studies (Rosenzweig and Parry, 1994; Yates and Strzepek, 1998), but are usually included in recent studies (Mizina *et al.*, 1999; Adams *et al.*, 2003; Reilly *et al.*, 2003; Njie *et al.*, 2006). Darwin *et al.* (1995) and Rosenzweig and Parry (1994) estimated residual climate change impacts to be minimal at the global level mainly due to the significant benefits from adaptation. However, large inter and intra-regional variations were reported. In particular, for many countries located in tropical regions, the potential benefits of low cost adaptation measures such as changes in planting dates, crop mixes, and cultivars are not expected to be sufficient to offset the significant climate change damages (Rosenzweig and Parry, 1994; Butt *et al.*, 2005).

More extensive adaptation measures have been evaluated in some developing countries (see, for example, Box 17.3). For the 2030 horizon in Mali, Butt *et al.*, (2005) estimate that adaptation through trade, changes in crop mix, and the development and adoption of heat resistant cultivars could offset 90 to 107% of welfare losses induced by climate change impacts on agriculture.

**Box 17.3: Adaptation costs and benefits for agriculture in The Gambia**

Njie *et al.* (2006) investigated climate change impacts and adaptation cost and benefits for cereal production in the Gambia. Under IPCC SRES A2 scenario the study estimated that for the period 2010-2039, millet yield would increase by 2 to 13%. For the period 2070-2099 the outcome is highly dependent on projected changes in precipitation as it could range from a 43% increase to a 78% decrease in millet yield. Adaptation measures such as the adoption of improved cultivars, irrigation, and improved crop fertilisation were assessed in a framework accounting for projections of population growth, water demand and availability. These measures were estimated to increase millet yield by 13 to 43%, while reducing interannual variability by 84 to 200% in the near term (2010-2039). However, net adaptation benefits (value of higher production – cost of implementation) were not necessarily positive for all adaptation strategies. In the near term, net adaptation benefits were estimated at US\$ 22.3 to 31.5 million for crop fertilisation and US\$ -81.1 to -88.0 million for irrigation. The authors conclude that irrigation is more effective to improve crop productivity under climate change conditions but the adoption of improved crop fertilisation is more cost efficient. Meanwhile, much uncertainty remains on the cost of developing improved cultivars. In the distant future, potential precipitation decrease would make irrigation an imperative measure.

In addition to their effect on average yield, adaptation measures can also smooth out fluctuations in yields (and consequently social welfare) as a result of climate variability. Adams *et al.* (2003) found that adaptation welfare benefits for the American economy increased from 3.29 billion (2000 US\$) to 4.70 billion (2000 US\$) when their effect on yield variability is included. In the case of Mali, Butt *et al.* (2005) show that adaptation measures could reduce the variability in welfare by up to 84%.

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 make the unrealistic assumption of perfect adaptation by individual farmers. 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. Recent studies for US agriculture found that frictions in the adaptation process could reduce the adaptation potential (Schneider *et al.*, 2000a; Easterling *et al.*, 2003; Kelly *et al.*, 2005).

With regard to adaptation costs and benefits in the energy sector, there is some literature – almost entirely on the United States – on changes in energy expenditures for cooling and heating as a result of climate change. 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 (as a result of increased cooling and reduced heating) for the US economy ranging from US\$ 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 US\$ 2.98 billion to US\$ 11.5 billion. Mansur *et al.* (2005) meanwhile estimate increased energy expenditures for the United States ranging from US\$ 4 to 9 billion for 2050, and between US\$ 16 and 39.8 billion for 2100.

Besides sea level rise, agriculture, and energy demand, there are a few studies related to adaptation costs and benefits in water resource management (see Box 17.4), and transportation infrastructure. Kirshen *et al.* (2004) assessed the reliability of water supply in the Boston metropolitan region under climate change scenarios. Even under a stable climate, the authors project the reliability of water supply to be 93% by 2100 on account of the expected growth in water demand. Factoring in climate change reduces the reliability of water supply to 82%. Demand side management measures could increase the reliability slightly (to 83%), while connecting the local systems to the main state water system would increase reliability to 97%. The study, however, does not assess the costs of such adaptation measures.

#### **Box 17.4: Adaptation costs and benefits in water management sector of South Africa**

Callaway *et al.* (2006) provide estimates of water management adaptation costs and benefits in a case study of the Berg River basin in South Africa. Adaptation measures investigated include the establishment 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, the welfare related to water use (value for urban and farm use minus storage and transport cost) were estimated for the SRES B2 climate change scenario and the assumption of a 3% increase in urban water demand. Under these conditions and the current water allocation system, the discounted impact of climate change over the next 30 years was estimated to vary between 13.5 and 27.7 billion Rand. The net welfare benefits of adapting water storage capacity under current allocation rights were estimated at about 0.2 billion Rand, while adding water storage capacity in presence of efficient water markets would yield adaptation benefits between 5.8 and 7 billion Rand. The authors also show that under efficient water markets, the cost of not adapting to climate change that does occur outweigh the costs of adapting to climate change that does not occur.

N.B.: All monetary estimates are expressed in present values for constant Rand for the year 2000, discounting over 30 years at a real discount rate of 6%

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 for maintaining 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 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 CAN\$ 9,400 million for a city like Toronto if extreme events are considered. For the transportation sector, Dore and Burton (2001) also estimate that replacing all ice roads in Canada would cost around CAN\$ 908 million. However, the study also points out that retreat of permafrost would reduce road building costs. Also, costs of winter control, such as snow clearance, sanding, and salting, are generally expected to decrease as temperature rises.

### 17.2.3.2 Global estimates

Some adaptation costs are implicitly included in estimates of global impacts of climate change. Tol *et al.* (1998) estimate that between 7% and 25% of total climate damage costs included in earlier studies such as Fankhauser (1995b), Tol (1995), and Cline (1992) could be classified as adaptation costs. In addition, recent studies, including Nordhaus and Boyer (2000), Mendelsohn *et al.* (2000) and Tol (2002), incorporate 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 are often extrapolated from a limited number of regional studies. Furthermore, the source studies which form the basis for the climate damage functions do not always reflect the most recent findings. 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.

Mendelsohn *et al.* (2000) estimate that global energy cost related to heating and cooling would increase by 2 to 10 billion (1990 US\$) for a 2 °C increase in temperature by 2100 and by 51 to 89 billion (1990 US\$) for a 3.5 °C increase. For a 1 °C increase, Tol (2002) estimates global benefits from reduced heating at around US\$ 120 billion, and global costs resulting from increased cooling at around US\$ 75 billion. The same study estimates the global protection costs at US\$ 1055 billion for a 1-metre sea level rise. There are preliminary estimates of the global costs of “climate proofing” development (World Bank 2006), but the current literature does not provide comprehensive multi-sectoral estimates of global adaptation costs and benefits. The broader macroeconomic and economy-wide implications of adaptations on economic growth and employment remain largely unknown (Aaheim and Schjolden, 2004).

## 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, and includes adjustments in both behaviour and in resources and technologies. The presence of adaptive capacity has been shown to be a necessary condition for the design and implementation of effective adaptation strategies so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change (Brooks and Adger, 2005). Adaptive capacity also enables sectors and institutions to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism.

Much of the current understanding of adaptive capacity comes from vulnerability assessments. 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, 2006). 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; Tol and Yohe, *in press*).

Technology can potentially play an important role in adapting to climate change. Efficient 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 provisions to anticipated extreme events (Ebi *et al.*, 2005). Often, technological adaptations and innovations are developed through research programmes undertaken by governments and by the private sector (Smit and Skinner, 2002). 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. Although technological capacity can be considered a key aspect of adaptive capacity, many technological responses to climate change are closely associated with a specific type of impact, such as higher temperatures, or decreased rainfall.

New studies carried out since the TAR show that adaptive capacity is influenced not only by economic development and technology, but also by social factors such as human capital and governance structures (Brooks and Adger 2005; Klein and Smith, 2003; Berkhout *et al.*, 2006; Eriksen and Kelly, 2006; Næss *et al.*, 2005; Tompkins, 2005). Furthermore, recent analysis argues that adaptive capacity is not a concern unique to regions with low levels of economic activity. Although economic development may provide greater access to technology and resources to invest in adaptation, 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). Tol and Yohe (*in press*) show that some elements of adaptive capacity are not substitutable: an economy will be as vulnerable as the ‘weakest link’ in its resources and adaptive capacity (for example with respect to natural disasters). Within both developed and developing countries, some regions, localities, or social groups have a lower adaptive capacity (O’Brien *et al.*, 2006).

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, for example, 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, Adger, 2001, Sutherland *et al.*, 2005). Similarly, strong local and international support networks enable communities in the Cayman Islands to recover from and prepare for tropical storms (Tompkins 2005). Community organisation is an important factor in adaptive strategies to build resilience among hillside communities in Bolivia (Robledo *et al.*, 2004). Recovery from hazards in Cuba is helped by a sense of communal responsibility (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 (Ford *et al.*, 2006). The role of food-sharing as a part of a community’s capacity to adapt risks in resource provisioning is also evident among Alaska Natives (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).

### 17.3.2. Differential adaptive capacity

The capacity to adapt to climate change is unequal across and within societies. There are individuals and groups within all societies that have insufficient capacity to adapt to climate change. As described above, there has been a convergence of findings in the literature showing that human and social capital are key determinants of adaptive capacity at all scales, and that they are as important as levels of income and technological capacity. However, most of this literature also argues that there is limited usefulness in looking at only one level or scale, and that exploring the regional and local context for adaptive capacity can provide insights into both constraints and opportunities.

#### 17.3.2.1 Adaptive capacity is uneven across societies

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 the literature is contested on the usefulness of indicators of generic adaptive capacity and the robustness of the results (Downing *et al.*, 2001; Moss *et al.*, 2001; Yohe and Tol, 2002; Brooks *et al.*, 2005; Haddad, 2005). 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). 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 maximise the welfare of citizens, to maintain control of citizens, or to reduce the vulnerability of the most vulnerable groups) lead to different weightings of the elements of adaptive capacity,

and hence to different rankings of the actual capacity of countries to adapt. It has been argued that national indicators fail to capture many of the processes and contextual factors that influence adaptive capacity, and thus provide little insight on adaptive capacity at the level where most adaptations will take place (Eriksen and Kelly, 2006).

The specific determinants of adaptive capacity at the national level thus represent an area of contested knowledge. Some studies relate adaptive capacity to levels of national development, including political stability, economic well-being, human and social capital, and institutions (AfDB *et al.*, 2003). National-level adaptive capacity has also been represented by proxy indicators for economic capacity, human and civic resources, and environmental capacity (Moss *et al.*, 2001). 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 capita 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.

#### *17.3.2.2 Adaptive capacity is uneven within nations due to multiple stresses*

The capacity to adapt to climate change is not evenly distributed within nations. Adaptive capacity is highly differentiated within countries, where multiple processes of change interact to influence vulnerability and shape outcomes from climate change (Leichenko and O'Brien, 2002; Smit and Wandel, 2006; Ziervogel *et al.*, 2006; Dow *et al.*, 2006). In India, for example, both climate change and market liberalisation for agricultural commodities are changing the context for agricultural production. Some farmers may be able to adapt to these changing conditions, including discrete events such as drought and rapid changes in commodity prices, while other farmers may experience predominately negative outcomes. Mapping vulnerability of the agricultural sector to both climate change and trade liberalisation 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 are most and least able to adapt to drier conditions and variability in the Indian monsoons, as well as respond to import competition resulting from liberalised agricultural trade. The results of this vulnerability mapping show the districts that have “double exposure” to both processes. It is notable that districts located along the Indo-Gangetic Plains are less vulnerable to both processes, relative to the interior parts of the country (see Figure 17.1).

**Figure 17.1: Districts in India that rank highest in terms vulnerability to climate change and import competition associated with economic globalisation are considered to be double exposed (depicted with hatching).**

[Figure (B) to be inserted (see separate WORD file).]

Source: Adapted from O'Brien *et al.* (2004).

### 17.3.2.3 Social and economic processes determine the distribution of adaptive capacity

A significant body of new research focuses on specific contextual factors that shape vulnerability and adaptive capacity, influencing how they may evolve over time. These place-based studies provide insights on the conditions that constrain or enhance adaptive capacity at the continental, regional or local scales (Schröter *et al.*, 2005; Allison *et al.*, 2006; Leichenko and O'Brien, 2002; Belliveau *et al.*, 2006). These studies differ from the regional and global indicator studies assessed above both in approach and methods, yet come to complementary conclusions on the state and distribution of adaptive capacity.

The lessons from studies of local-level adaptive capacity are context-specific, but the weight of studies establishes broad lessons on adaptive capacity of individuals and communities. The nature of the relationships between community members is critical, as is access to and participation in 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. A series of studies has shown that successful community-based resource management, for example, can potentially enhance the resilience of communities as well as maintain ecosystem services and ecosystem resilience (Ford *et al.*, 2006; Tompkins and Adger, 2004; Manuta and Lebel, 2005; Ouwuor *et al.*, 2005) and that this constitutes a major priority for the management of ecosystems under stress (such as coral reefs) (Hughes *et al.*, 2003, 2005).

Much new research emphasises that adaptive capacity is also highly heterogeneous within a society or locality, and for human populations it is differentiated by age, class, gender, health, and social status. 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 17.5 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 (see also Box 8.1).

#### **Box 17.5: Gender aspects of vulnerability and adaptive capacity**

Empirical research has shown that entitlements to elements of adaptive capacity are socially differentiated along the lines of age, ethnicity, class, religion and gender (Cutter, 1995; Enarson,

2002; Denton, 2002). Climate change therefore has gender-specific implications in terms of both vulnerability and adaptive capacity (Dankelman, 2002). 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), 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 to weather-related disasters. The impacts of past weather-related hazards have been disaggregated to determine the differential effects on women and men. Such studies have been done, for example, for hurricane Mitch in 1998 (Bradshaw, 2004) and for natural disasters more generally (Fordham, 2003). These differential impacts include numbers of deaths, and well-being 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 elderly persons 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.

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. Gender differences in vulnerability and adaptive capacity reflect wider patterns of structural gender inequality. One lesson that can be drawn from the gender and development literature is that climate interventions that ignore gender concerns reinforce the differential gender dimensions of vulnerability (Denton, 2004). It has also become clear that a shift in policy focus away from reactive disaster management to more proactive capacity building can reduce gender inequality (Mirza, 2003).

### 17.3.3 *Changes in adaptive capacity over time*

Adaptive capacity at any one scale may be facilitated or 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 that 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 (Turner *et al.*, 2003; Luers, 2005; O'Brien and Leichenko, 2000). Violent conflict and the spread of infectious diseases, for example, have been shown to erode adaptive capacity (Barnett, 2006; Woodward, 2002). Social trends such as urbanisation or economic consequences of trade liberalisation are likely to have both positive and negative consequences for overall adaptive capacity of cities and regions (Pelling, 2003). For example, trade liberalisation policies associated with globalisation may facilitate climate change adaptation for some, but constrain it for others. In the case of India, many farmers no longer plant traditional, drought-tolerant oilseed crops because there are no markets due to an influx of cheap imports from abroad (O'Brien *et al.*, 2004). The globalisation of fisheries has decreased the resilience of marine ecosystems (Berkes *et al.*, 2006). Exploitation of sea urchins and herbivorous reef fish species in the past three decades in particular have been shown to make reefs more vulnerable to recurrent disturbances such as hurricanes and to coral bleaching and mortality due to increased sea surface temperatures (Berkes *et al.*, 2006; Hughes *et al.*, 2003).

In the Canadian Arctic, experienced Inuit hunters, dealing with changing ice and wildlife conditions, adapt by drawing on traditional knowledge to alter the timing and location of harvesting, and ensure personal survival (Berkes and Jolly, 2001). Young Inuit, however, do not have the same adaptive capacity. Ford *et al.* (2006) attribute this to the imposition of western education by the Canadian Federal Government in the 1970s and 1980s which resulted in less participation in hunting among youth and consequent reduced transmission 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 of living. This further eroded traditional knowledge by reducing inter-generational 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, 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 to changing economic conditions can increase 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 of switching varieties to increase economic competitiveness changed the nature of the system to make it more vulnerable to climatic stresses, to which it was previously less sensitive. To minimise 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 decreasing market competitiveness.

The vulnerability of one region is often '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), interactions with weather-related risks (coffee plant diseases and frosts) and the collapse of the International Coffee Agreement in 1989. In Mexico, Guatemala and Honduras, the capacity of smallholder coffee farmers to deal with severe droughts in 1997-1998 and 1999-2002 was complicated by low international coffee prices, reflecting changes in international institutions and national policies (Eakin *et al.*, 2005). Concurrently, market liberalisation in Mexico, Guatemala and Honduras reduced state intervention in commodity production, markets and prices in the region. There were also constraints to adaptation related to a contraction of rural finance, coupled with a strong cultural significance attached to traditional crops. Since coffee production is already at the upper limit of the ideal temperature range in this region, it is likely that climate change will reduce yields, challenging farmers to switch to alternative crops, which currently have poorly developed marketing mechanisms.

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 specialise 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). Eriksen *et al.* (2005) conclude that the determinants of adaptive capacity of smallholder farmers in Kenya and Tanzania are multiple and inter-related.

In summary, empirical research carried out since the TAR has shown that there are rarely simple cause-effect relationships between climate change risks and the capacity to adapt. Adaptive capacity can vary over time and is affected by multiple processes of change. In general, the emerging literature shows that the distribution of adaptive capacity within and across societies represents a major challenge for development and a major constraint to the effectiveness of any adaptation strategy. Some adaptations that address changing economic and social conditions may increase vulnerability to climate change, just as adaptations to climate change may increase vulnerability to other changes.

## **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 an important role for public policy in facilitating adaptation to climate change. This includes reducing vulnerability of people and infrastructure, providing information on risks for private and public investments and decision-making, and protecting public goods such as habitats, species and culturally important resources (Haddad *et al.*, 2003; Callaway, 2004; Tompkins and Adger, 2005;

Haddad, 2005). In addition, a further literature sets out the case for international financial and technology transfers from countries with high greenhouse gas emissions to countries that are most vulnerable to present and future impacts, for use in adapting to the impacts of climate change (Simms *et al.*, 2004; Burton *et al.*, 2002; Baer, 2006; Paavola and Adger, 2006; Dow *et al.*, 2006). Baer (2006) calculates the scale of these transfers from polluting countries based on aggregate damage estimates (at US\$ 50 billion).

Considerable progress has also been made in terms of funding adaptation within the United Nations Framework Convention on Climate Change (UNFCCC). Least Developed Countries have been identified as being particularly vulnerable to climate change, and planning for their adaptation has been facilitated through development of National Adaptation Programmes of Action (NAPAs). 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). Although only six countries had completed their national NAPA reports as of mid-2006, a number of specific projects were identified in these reports for priority action. Since the implementation of NAPAs had not commenced at the time of this assessment, their outcomes in terms of increased adaptive capacity or reduced vulnerability to climate change risks could not be evaluated. The process of developing NAPAs is, however, being monitored. Box 17.6 discusses some emerging lessons from Bangladesh. Early evidence suggests that NAPAs face the same constraints on effectiveness and legitimacy as other national planning processes (e.g. National Adaptation Plans under the Convention to Combat Desertification), including narrow and unrepresentative consultation processes (Thomas and Twyman, 2005).

***Box 17.6: Early lessons on effectiveness and legitimacy of National Adaptation Programmes of Action***

At present there is sparse documentary evidence on outcomes of NAPA planning processes or implementation. One case that has been examined is that of the Bangladesh NAPA (Huq and Khan 2006). The authors recommend 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-mobilisation (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 organisations in ensuring the sustainability and success of adaptation planning is likely to become evident over the incoming period of NAPA development and implementation.



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

11  
12 Mainstreaming initiatives have been classified in the development planning literature at four  
13 levels. At the international level, mainstreaming of climate change can occur through policy  
14 formulation, project approval, and country-level implementation of projects funded by  
15 international organisations. For example, the International Federation of Red Cross and Red  
16 Crescent (IFRC) is working to facilitate a link between local and global responses through its  
17 Climate Change Center (Van Aalst and Helmer, 2003). An example of an initiative at the regional  
18 level is the MACC (Mainstreaming Adaptation to Climate Change in the Caribbean) project. It  
19 assesses the likely impacts of climate change on key economic sectors (i.e., water, agriculture and  
20 human health) while also defining responses at community, national and regional levels. Various  
21 multi-lateral and bi-lateral development agencies, such as the Asian Development Bank, are  
22 attempting to integrate climate change adaptation into their grant and loan activities (Perez and  
23 Yohe, 2005; ADB, 2005). Other aid agencies have sought to screen out those loans and grants  
24 which are mal-adaptations and create new vulnerabilities, to ascertain the extent to which existing  
25 development projects already consider climate risks or address vulnerability to climate variability  
26 and change, and to identify opportunities for incorporating climate change explicitly into future  
27 projects. Klein *et al.* (2006) examine the activities of several major development agencies over the  
28 past five years and found that while most agencies already consider climate change as a real but  
29 uncertain threat to future development, they have not explicitly examined how their activities  
30 affect vulnerability to climate change. They conclude that mainstreaming needs to encompass a  
31 broader set of measures to reduce vulnerability that has thus far been the case.

32  
33 Much of the adaptation planning literature emphasises the role of governments, but also  
34 recognises the constraints that they face in implementing adaptation actions at other scales (Few *et al.*, 2006). There are few examples of successful mainstreaming of climate change risk into  
35 development planning. Agrawala and van Aalst (2005) identified following five major constraints:  
36 (1) Relevance of climate information for development-related decisions; (2) Uncertainty of  
37 climate information; (3) Compartmentalisation with governments; (4) Segmentation and other  
38 barriers within development-cooperation agencies; and (5) Trade-offs between climate and  
39 development objectives. The Adaptation Policy Framework (APF) (Lim *et al.*, 2005) developed to  
40 support national planning for adaptation by UNDP provides guidance on how these obstacles and  
41 barriers to mainstreaming can be overcome. Mirza and Burton (2005) found that the application of  
42 APF was feasible when they applied it for urban flooding and droughts in Bangladesh and India,  
43 respectively. However, they concluded that application of the APF could encounter problems  
44 related to a lack of micro-level socio-economic information and gaps in stakeholder participation  
45 in the planning, design, implementation and monitoring of projects.

In summary, the opportunities for implementing adaptation as part of government planning are dependent on effective, equitable and legitimate actions to overcome barriers and limits to adaptation (Agrawala and van Aalst, 2005; Lim *et al.*, 2005; ADB, 2005). Initial signals of impacts have been hypothesised to create the demand and political space for implementing adaptation, the so-called policy windows hypothesis. Box 17.7, however reveals that evidence is contested on whether individual weather-related catastrophic events can facilitate adaptation action or act as a barrier to long-term adaptation.

#### **Box 17.7: Is adaptation constrained or facilitated by individual extreme events?**

The policy window hypothesis refers to the phenomenon whereby adaptation actions such as policy and regulatory change are facilitated and occur directly in response to disasters, such as those associated with weather-related extreme events (Kingdon, 1995). According to this hypothesis, immediately following a disaster, the political climate may be conducive to legal, economic and social change which can begin to reduce structural vulnerabilities, for example in such areas as mainstreaming gender issues, land reform, skills development, employment, housing and social solidarity. The assumptions behind the policy windows hypothesis are that (1) new awareness of risks after a disaster leads to broad consensus, (2) development and humanitarian agencies are ‘reminded’ of disaster risks, and (3) enhanced political will and resources become available. Contrary evidence on policy windows, however, suggests that during the post-recovery phase, reconstruction requires weighing, prioritising and sequencing of policy programming and there is the pressure to quickly return to conditions prior to the event rather than incorporate longer term development policies (Christoplos, 2006). In addition, while institutions clearly matter they are often rendered ineffective in the aftermath of a disaster. As shown in diverse contexts such as ENSO-related impacts in Latin America, induced development below dams or levees in the U.S., and flooding in the United Kingdom, the end result is that short-term risk reduction can actually produce greater vulnerability to future events (Pulwarty *et al.*, 2003; Berube and Katz, 2005; Penning-Rowsell *et al.*, 2006).

#### **17.4.2 Limits and barriers to adaptation**

Most studies of specific adaptation plans and actions argue that there are likely to be both limits and barriers to adaptation as a response to climate change. US National Assessment (2001), for example, maintain that adaptation will not necessarily make the aggregate impacts of climate change negligible or beneficial, nor can it be assumed that all available adaptation measures will actually be taken. Further evidence from Europe and other parts of the globe suggests that high adaptive capacity may not automatically translate into successful adaptations to climate change (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 their feasibility, costs, effectiveness, and the likely extent of their actual implementation (US National Assessment, 2001). Despite high adaptive capacity and significant investment in planning, extreme heat wave events continue to result in high levels of mortality and disruption to infrastructure and electricity supplies in European, North American and East

Asian cities (Klinenberg, 2003; Poumadère *et al.*, 2005; Lagadec, 2004, Mohanty and Panda, 2003).

This section assesses 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 and are largely insurmountable. These limits are necessarily subjective and dependent upon the values of diverse groups. 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. 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 *et al.* (2000b)—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. But emerging literature on adaptation processes also identifies significant barriers to action in financial, cultural, and policy realms that 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 instance, find thresholds in the resilience of kelp forest ecosystems, coral reefs, rangelands and lakes affected both by climate change and 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; Tol *et al.*, 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). Tol *et al.* (2006) argue that it is technically possible to adapt to 5 metres of sea level rise but that the resources required are so unevenly distributed that in reality this risk is outside the scope of adaptation. In the Sudano-Sahel region of Africa, persistent below average rainfall and recurrent droughts in the late 20<sup>th</sup> century have constricted physical and ecological limits by contributing to land degradation, diminished livelihood opportunities, food insecurity, internal displacement of people, cross-border migrations, and civil strife (Leary *et al.*, 2006, Osman-Elasha *et al.*, 2006; Mortimore and Adams, 2001). The loss of Arctic sea ice threatens the survival of polar bears, even if management adaptations are taken to minimise 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, regulating, cultural, and supporting services (MEA, 2006).

The ecological literature has documented regime shifts in ecosystems associated with climatic changes and other drivers (Scheffer *et al.*, 2001; Noss, 2001). These regime shifts are argued to impose limits on economic and social adaptation (van Vliet and Leemans, 2006). Economies and communities that are directly dependent on ecosystems such as fisheries and agricultural systems are likely to be more affected by sudden and dramatic switches and flips in ecosystems. 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 loss of local knowledge associated with thresholds in ecological systems is a limit to 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 (Tol *et al.*, 2006). 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.*, 2006).

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 *et al.*, 2003; Scott *et al.*, *in press*). 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 barriers

The implementation of adaptation measures faces a number of financial barriers. At the international level, preliminary estimates from the World Bank indicate that the total costs of “climate proofing” development could be as high as US\$ 10 billion to US\$ 40 billion per year (World Bank, 2006). While the analysis notes that such numbers are only rough estimates, the scale of investment implied constitutes a significant financial barrier. At a more local level, individuals and communities can be similarly constrained by the lack of adequate financial resources. Deep financial poverty is a factor that constrains the use of seemingly inexpensive health measures, such as insecticide-treated bed nets, while limited public finances contribute to

choices by public health agencies to give low priority to measures that would reduce vulnerability to climate-related health risks (Yanda *et al.*, 2006 and Taylor *et al.*, 2006). Farmers often cite the lack of adequate financial resources in field surveys and focus groups as an important factor that constrains their use of adaptation measures which entail significant investment, such as irrigation systems, improved or new crop varieties, and diversification of farm operations (Smit and Skinner 2002).

Lack of resources may also limit the ability of low-income groups to afford proposed adaptation mechanisms such as climate-risk insurance. In the case of Mexico, a restructuring of public agricultural institutions paralleled market liberalisation, reducing the availability of publicly subsidised credit, insurance, and technical assistance for smallholders (Appendini, 2001). Even where both crop insurance and contract farming are being actively promoted by the state and federal government to help farmers address climatic contingencies and price volatility, very few of the surveyed farmers, however, had crop insurance (Wehbe *et al.*, 2006). In addition, individuals often fail to purchase insurance against low-probability high-loss events even when it is offered at favourable premiums. While this may occur because of the relative benefits and costs of alternatives, the trade-offs may not be explicit. Kunreuther *et al.* (2001) show that the search costs involved in collecting and analysing relevant information to clarify trade-offs can be enough to discourage individuals from undertaking such assessments, and thus from purchasing coverage even when the premium is affordable. Climate change is also likely to raise the actuarial uncertainty in catastrophe risk assessment, placing upward pressure on insurance premiums and possibly leading to reductions in risk coverage (Mills, 2005).

#### 17.4.2.4 Informational and cognitive barriers

Extensive evidence from psychological research indicates that uncertainty about future climate change combines with individual and social perceptions of risk, opinions and values to influence judgment and decision-making concerning climate change (Oppenheimer and Todorov, 2006). It is increasingly clear that interpretations of danger and risk associated with climate change are context specific (Lorenzoni *et al.*, 2005) and that adaptation responses to climate change can be limited by human cognition (Grothmann and Patt, 2005; Moser, 2005). Four main perspectives on informational and cognitive constraints on individual responses (including adaptation) to climate change emerge from the literature.

1. *Knowledge of climate change causes, impacts and possible solutions does not necessarily lead to adaptation.* Well established evidence from the risk, cognitive and behavioural psychology literatures points to the inadequacy of the "deficit model" of public understanding of science, which assumes that providing individuals with scientifically sound information will result in information assimilation, increased knowledge, action and support for policies based on this information (Eden, 1998; Sturgis and Allum, 2004; Lorenzoni *et al.*, 2005). Individuals' interpretation of information is mediated by personal and societal values and priorities, personal experience, and other contextual factors (Irwin and Wynne, 1996). As a consequence, an individual's awareness and concern either do not necessarily translate into action, or translate into limited action (Baron, 2006; Weber, 2006). This is also known as the "value-action" or "attitude-behaviour" gap (Blake, 1999) and has been shown in a small number of studies to be a significant barrier to adaptation action (e.g. Patt and Gwata, 2002).

2. *Perceptions of the climate change risks are differing.* A small but growing literature addresses the psychological dimensions of evaluating long-term risk; most focuses on behavior changes in relation to climate change mitigation policies. However, some studies have explored the behavioral foundations of adaptive responses, including the identification of thresholds, or points at which adaptive behavior begins (e.g. 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 of rapid climate change may induce different individual responses influenced by trust in others (e.g. institutions, collective action, etc.), 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 may overshadow considerations about the impacts of climate change and adaptation. This work also indicates, consistently with findings in the wider climate change risk literature (e.g. Moser and Dilling, 2004), that individuals tend to prioritise the risks they face, focusing on those they consider – rightly or wrongly- to be the most significant to them at that particular point in time. Furthermore, a lack of experience of climate-related events may inhibit adequate responses. It has been shown, for instance, that the capacity to adapt among resource-dependent societies in Southern Africa is high if based on adaptations to previous changes (Thomas *et al.*, 2005). Although concern about climate change is widespread and high amongst publics in Western societies, it is not ‘here and now’ or a pressing personal priority for most people (Lorenzoni and Pidgeon, 2006). Weber (2006) found that strong visceral reactions towards the risk of climate change are needed to provoke adaptive behavioral changes.

3. *Perceptions of vulnerability and adaptive capacity are important.* 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). Furthermore, perceptions by the vulnerable of barriers to actually adapting 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 action was determined by both perceived abilities to adapt and observable capacities to adapt. They conclude that a divergence between perceived and actual adaptive capacity is a real barrier to adaptive action. Moser (2005) also similarly finds that perceived barriers to action are a major constraint in coastal planning for sea level rise in the United States.

4. *Appealing to fear and guilt does not motivate appropriate adaptive behaviour.* In fact, communications research has shown that appealing to fear and guilt does not succeed in fostering sustained engagement with the issue of climate change (Moser and Dilling, 2004). Analysis of print media portrayal of climate change demonstrates public confusion when scientific arguments are contrasted in a black-and-white, for-and-against manner (Boykoff and Boykoff, 2004; Ereaut and Segnit, 2006; Carvalho and Burgess, 2005). Calls for effective climate change communication have focused on conveying a consistent, sound message, with the reality of anthropogenic climate change at its core. This, coupled with making climate change personally relevant through messages of practical advice on individual actions, helps to embed responses in people’s locality. Visualisation imagery is being increasingly explored as a useful contribution to increasing the

effectiveness of communication about climate change risks (e.g. Nicholson-Cole, 2005; Sheppard, 2005).

Overall, the psychological research reviewed here indicates that an individual's awareness of an issue, knowledge, personal experience, and a sense of urgency of being personally affected, constitute necessary but insufficient conditions for behaviour or policy change. Perceptions of risk, of vulnerability, motivation and capacity to adapt will also affect behavioural change. These vary among individuals and groups within populations. Some of these perceptions can act as barriers to adapting to climate change. Policy makers need to be aware of these barriers, provide structural support to overcome them, and concurrently work towards fostering individual agency.

#### *17.4.2.5 Social and cultural barriers*

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 prioritisations of climate change issues across different social and cultural groups can limit adaptive responses (Ford and Smit, 2004).

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 17.8 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 17.8: Do voluntary or displacement migration represent failures to adapt?***

Migration by individuals or relocation of settlements have been discussed in various studies as a potential 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 due to climate change impacts. There has been, for example, 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 for people of Tuvalu, a nation consisting of low-lying atolls in the western Pacific. Patel (2006) and Barnett (2005) argue 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. Sea level rise impacts on Pacific Island atoll states of Kiribati, Tuvalu, Tokelau, and Marshall Islands 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 that the possibility of relocation represents a limit of adaptation.

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). Studies in Asia and North America (Adger *et al.*, 2002; Winkels, 2004; McLeman and Smit, 2006) 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 United States 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. Mendelsohn *et al.* (2006) therefore argue that climate change impacts in rural economies may make migration and relocation a necessary but undesirable adaptation. Finan and Nelson (2001), however, suggest that government policies in Brazil such as rural retirement policies have actually augmented household adaptive capacity and attracted young migrants back from cities. Thus migration can be influenced by government intervention. In the case of island states, Barnett (2005) argues that adaptation should already be deemed as unsuccessful if it has limited development opportunities.

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).

Anthropological research suggests that 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 organisations to reflect on and adapt their behaviour); and framing (legitimately diverse views about the state of the world) (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 internalisation of traditional practices; and the development of appropriate world views and cultural values (Pretty, 2003).

The social and cultural limits to adaptation are not well researched: Jamieson (2006) notes that a large segment of the U.S. population think of themselves as environmentalists but often vote for environmentally negative candidates. 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 globalisation (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. Also memories and hunting narratives are appearing unreliable because of rapid change. 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).

## 17.5 Conclusions

Adaptation has the potential to alleviate adverse impacts, as well as to capitalise on new opportunities posed by climate change. Since the TAR there has been significant documentation and analysis of emerging adaptation practices. Adaptation is occurring in both the developed and developing world, both to climate variability and in a limited number of cases to observed or anticipated climate change. Adaptation to climate change is seldom undertaken in a stand-alone fashion, but as part of broader social and development initiatives. Adaptation also has limits, some posed by the magnitude and rate of climate change, and others that relate to financial, institutional, technological, cultural and cognitive barriers. The capacities for adaptation and the processes by which it occurs vary greatly within and across regions, countries, sectors, and communities. Policy and planning processes need to take these aspects into account in the design and implementation of adaptation. The review in this chapter suggests that a high priority should be given to increasing the capacity of countries, regions, communities and social groups to adapt to climate change in ways that are synergistic with wider societal goals of sustainable development.

There are significant outstanding research challenges in understanding the processes by which adaptation is occurring and will occur in the future, and in identifying areas for leverage and action by government. Many initiatives on adaptation to climate change are too recent at the time of this assessment to evaluate their impact on reducing societal vulnerability. Further research is

1 therefore needed to monitor progress on adaptation, and to assess the direct as well as ancillary  
2 effects of such measures. In this connection there is also a need for research on the synergies and  
3 trade-offs between various adaptation measures, and between adaptation and other development  
4 priorities. Human intervention to manage the process of adaptation in biological systems is also  
5 not well understood and the goals of conservation are contested. Hence research is also required  
6 on the resilience of socio-ecological systems to climate change. Another key area where  
7 information is currently very limited is on the economic and social costs and benefits of  
8 adaptation measures. In particular, the non-market costs and benefits of adaptation measures  
9 involving ecosystem protection, health interventions, and alterations to land-use are under-  
10 researched. Information is also lacking on the economy-wide implications of particular  
11 adaptations on economic growth and employment.  
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