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

# Chapter 20 - Perspectives on Climate Change and Sustainability

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## Executive Summary

**The impacts of climate change are, with high confidence, expected to be most significant when and where they occur in the context of multiple stresses from other sources such as poverty, unequal access to resources, food insecurity, and environmental degradation.** The intensities of these interactions vary from place to place and over time along specific development pathways [20.3.1, 20.4 & 20.3.3].

**Efforts to cope with the impacts of climate change and attempts to promote sustainable development share common goals and determinants including, for example, access to resources, equity in the distribution of resources, stocks of human and social capital, access to risk spreading mechanisms, abilities of decision-support mechanisms to cope with uncertainty [20.2 & 20.3.2].**

**Sustainable development can encourage adaptation to climate change, increase adaptive capacity, and vice versa [20.3.3].** However, some development activities can exacerbate climate-related vulnerabilities [20.3.3, 20.7.1 and 20.8.3].

**Discussions about promoting development and improving environmental quality have seldom explicitly included adapting to climate impacts and/or promoting adaptive capacity. [20.4 & 20.8.3]**

**Reducing vulnerability to the hazards of current climate variability, through specific programs, individual initiatives, participatory planning processes and other community approaches can reduce vulnerability to climate change, *per se.* [20.5, 20.8.1, and 20.8.2].** These opportunities will not be sufficient to eliminate damages associated with climate change, and they can be counterproductive if the signal drawn from variability produces false impressions of long-term trends.

**Medium confidence global estimates of the number of people adversely affected by climate change are now available [20.6].** By 2080 1.1 to 3.2 billions could be experiencing water scarcity (depending on SRES scenario); 200 to 600 millions, hunger; 2 to 7 millions more, coastal flooding.

**The aggregate global impacts of climate change are expected to be negative even though specific estimates are uncertain and should therefore be interpreted very carefully [(high confidence) 20.6].** The SAR reported that the net cost of a doubling of greenhouse gas concentrations would be about 1.5% to 3.5% of gross global product; corresponding estimates of (marginal) social cost of carbon ranged from $5 to $125 per tonne of carbon (in 1990 prices). The TAR reported comparable estimates. Across more than 100 estimates from 28 studies now available, the 5% to 95% range of estimates runs from -$10 to $350 per tonne of carbon; the median estimate is $14 per tonne and the mean is $93 per tonne. Climate sensitivity, the discount rate, the treatment of equity, and estimates of economic and non-economic damages explain much of this variation.

**The social cost of carbon and all greenhouse gases will rise over time; with medium confidence, the social cost of carbon will rise at 2% to 3% per year [(high confidence) 20.6].**

**With high confidence, the global distribution of climate impacts will show varying degrees of vulnerability according to nations' exposures and capacities to adapt [20.7].**

Increased vulnerability to climate change will impede nations' abilities to achieve sustainable development pathways, as measured for example as progress toward Millennium Development Goals. Climate change, *per se*, will not be a serious impediment to reaching the 2015 targets in most cases [(high confidence) 20.7.1].

Through 2050, developing countries would experience significant increases in vulnerability even if climate sensitivity turns out to be low. The adaptive capacities of most developing countries would be overwhelmed if climate sensitivity is high, and some developed countries would be significantly vulnerable in that case[(medium confidence) 20.7.2].

Through 2100, developed and developing countries could be extremely vulnerable even if climate sensitivity turns out to be low, but developing countries would feel the largest stress. If climate sensitivity is high, inequity across this distribution would disappear before 2100 because adaptive capacity would be overwhelmed almost everywhere [(medium confidence) 20.7.3].

Through 2050 with low climate sensitivity, global mitigation efforts would benefit developing countries (in terms of reducing an aggregate vulnerability index) more than developed countries. By 2100, or earlier if climate sensitivity is high, unfettered climate change would overwhelm adaptive capacity nearly everywhere and mitigation would benefit developed countries more than developing countries [(medium confidence) 20.7.4].

Through 2050, global mitigation efforts designed to cap effective greenhouse gas concentrations at 550 ppm, especially when combined with enhanced adaptation, would benefit developing countries (in terms of reducing a vulnerability index calibrated to aggregate impacts) more than developed countries. For an index calibrated to urgent impacts, however, the entire globe would confront moderate to significant vulnerabilities, and mitigation would benefit developed countries more. By 2100, climate change would produce significant net effects everywhere even if a 550 ppm concentration cap were implemented in combination with enhanced adaptive capacity [(medium confidence) 20.7.4].

The longer-term impacts of climate change (particularly abrupt climate change) significantly threaten regional and global sustainability and development [(medium confidence) 20.7.5].

**Significant synergies could be exploited if progress were made in bringing climate change to the development community and critical development issues to the climate change community [(high confidence) 20.3.3, 20.8.2 & 20.8.3].** Dialogue processes in assessment, appraisal and action are becoming important tools both in participatory governance and in identifying productive areas for shared learning initiatives.

## 20.1 Introduction — Setting the Context

Consistent with the Bruntland Commission (WCED, 1987), the IPCC TAR (2001a) defined sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". There are many alternative definitions, of course, and none is universally accepted. Nonetheless, they all typically emphasize one or more of the following critical elements: (a) identifying what to develop, (b) identifying what to sustain, (c) characterizing links between entities to be sustained and entities to be developed and (d) envisioning future contexts for these links (National Research Council, 1999). Goals, indicators, values and practices can also frame examinations of sustainable development (Kates *et al.*, 2005). In every case, the essence of sustainable development is meeting fundamental human needs while preserving the life support systems of the planet (Kates *et al.*, 2000), and its strength lies in reconciling real conflicts between economy and environment and between the present and the future (National Research Council, 1999). In the last two decades, the concept of sustainable development has permeated mainstream thinking, especially after the 1992 Earth Summit where 178 governments adopted Agenda 21. Ten years later, the 2002 World Summit on Sustainable Development (WSSD) made it clear that sustainable development had become a widely held social and political goal.

More recently, authors have emphasized the economic, ecological and human/social dimensions that under gird sustainable development (Kates *et al.*, 2005; Munasinghe et al, 2003; Robinson and Herbert, 2001). The economic dimension aims at improving human welfare. The ecological dimension seeks to protect the integrity and resilience of ecological systems and the services they provide. The social dimension focuses on enriching human relationships and attaining individual and group aspirations (Munasinghe, 2001). There is broad international agreement that global development programs should work to foster transitions toward paths that meet human needs while preserving the earth's life support systems and alleviating hunger and poverty (Mexico City Workshop, 2002) by integrating these three dimensions – the pillars of sustainable development. Emerging fields of science, such as "sustainability science" (Kates *et al.*, 2000) and "sustainomics" (Munasinghe, *et al.*, 2003), seek to increase our understanding on how societies can develop sustainably.

Climate change adds to the list of stressors that challenge our ability to achieve the ecologic, economic and social objectives that define sustainable development; indeed, earlier chapters of this report have assessed the state of our current understanding of how and when. Chapter 20 builds on those assessments to note the potential for climate change to affect development paths themselves. Figure 20.1 locates its key topics schematically in the context of the three pillars of sustainable development. Topics shown at the centre of the triangle (the three-legged stool of sustainable development) are linked with all three pillars. Other topics are located closer to one leg or another. The arrows leading from the centre indicate that adaptation to climate change adaptation can influence the processes that join the pillars rather than the individual pillars themselves. For example, the technical and economic aspects of renewable resource management could illustrate efforts to support sustainable development by working with the economy-ecology connection.

Section 20.2 briefly reviews current knowledge relating to impacts and adaptation drawn from other chapters of this report. Section 20.3 assesses impacts and adaptation in the context of multiple stresses. Section 20.4 focuses on links to environmental quality and explores the notion of adding climate change impacts and adaptation to the list of components of environmental impact assessments. Section 20.5 addresses implications for risk, hazards and disaster

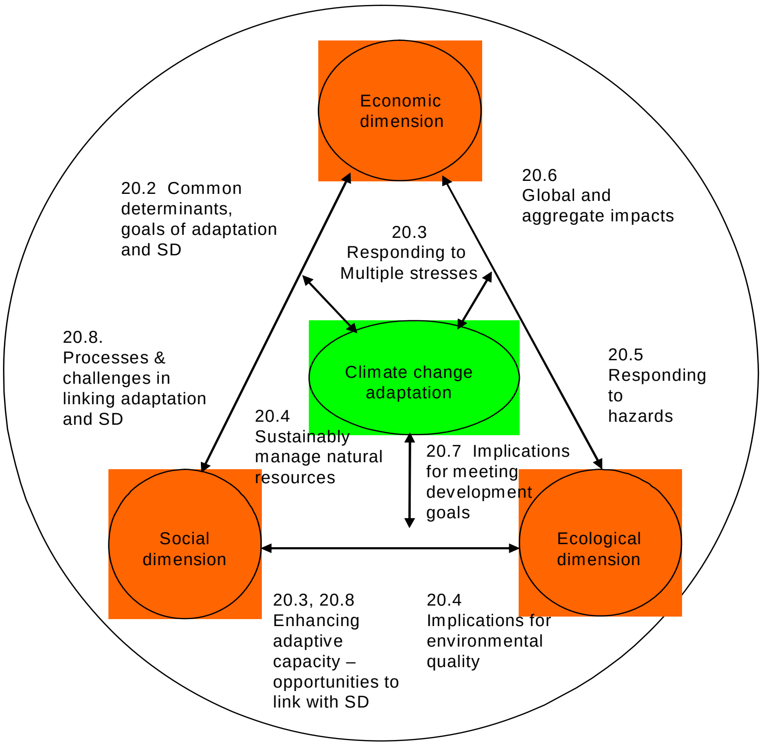



***Figure 20.1:*** *Sustainable development and climate change adaptation. Outline of Chapter 20 mapped against the pillars of sustainable development; base figure adapted from Munasinghe and Swart (2005).*

management, including the challenge of reducing vulnerability to current climate variability and adapting to long term climate change. Section 20.6 reviews global and regionally aggregated estimates of economic impacts. Section 20.7 assesses the implications for achieving sustainable development across various time scales. Section 20.8 considers opportunities, co-benefits and challenges for climate change adaptation, and for linking (or mainstreaming) adaptation into national and regional development planning processes. Section 20.9 finally identifies research priorities. While links between sustainable development and mitigation are mentioned throughout, more systematic explorations of these links is the province of Working Group III (Chapter 12, in particular).

## 20.2 A synthesis of new knowledge relating to impacts and adaptation.

IPCC (2001a), as well as the authors of Chapter 17 of this report, have concluded that *exposure to the impacts of climate and its baseline sensitivity to those impacts* initially defines the context of any system's vulnerability to climate change and climate variability. They have observed that a system's *adaptive capacity and derived ability to cope* with this sensitivity ultimately defines its vulnerability; and they have noted that all of these factors (but perhaps most fundamentally adaptive capacity) depend on development paths and local, site-specific conditions. To sort through the implications of the diversity implied by this insight, Yohe and Tol (2001) suggested an organizing list of fundamental determinants of adaptive capacity that included:

1. the range of available technological options for adaptation,
2. the availability of resources and their distribution across the population,

3. the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed,
4. the stock of human capital including education and personal security,
5. the stock of social capital including the definition of property rights,
6. the system's access to risk spreading processes,
7. the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers, themselves, and
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

Brooks and Adger (2005) addressed the same need for organization by listing at least eight questions that must be answered to understand the degree to which adaptive capacity exits and might be exercised; they included:

1. What is the nature of the system/population to be assessed?
2. What are the principal hazards faced by this system/population?
3. What are the major impacts of these hazards and which elements/groups of the system/population are most vulnerable to these hazards?
4. Why are these elements/groups particularly vulnerable?
5. What measures would reduce the vulnerability of these elements/groups?
6. What are the factors that determine whether these measures are taken?
7. Can we assess these factors in order to measure the capacity of the system/population to implement these measures?
8. What are the external and internal barriers to the implementation of these measures?

The last four questions focus attention on the underlying determinants of the capacity of a system to adapt within the specific path-dependent and site-specific context described in the answers to the first four. Given the likelihood that no two contexts will ever be identical, Chapter 17 argues that future research has a long way to go if it is to come to grips with the wide ranges of sensitivities and enormous variances in adaptive capacity within which researchers and planning practitioners will assess relative vulnerability to climate change. Perhaps more importantly, strength across the determinants of adaptive capacity does not necessarily mean high adaptive capacity. A society, be it developed or developing, can have everything in place and still be vulnerable unless whatever level of decision-making is most appropriate utilizes its capacity to respond to external stress.

Adger and Vincent (2004) confronted the implications of this geographically and temporally driven diversity directly. They observe that uncertainty is pervasive and argue that adaptive capacity essentially describes the space within which decision-makers might find feasible adaptation options. For them, diversity means that it is easier to anticipate changes in generic adaptive capacity than it is to predict changes in adaptation, *per se*. It follows that linking the determinants of adaptive capacity to the drivers of development and to the set of available policy levers can help explain why certain responses work sometimes in some places, but not at other times in other places.

## 20.3 Impacts and adaptation in the context of multiple stresses.

### *20.3.1 A catalogue of multiple stresses*

The current literature shows a growing appreciation of the multiple stresses that ecological systems face, how those stresses are likely to change over the next several decades, and what some of the net environmental consequences are likely to be. The Pilot Analysis of Global Ecosystems prepared by the World Resources Institute (2000) conducted literature reviews to document the state and condition of forests, agro-ecosystems, freshwater ecosystems, and marine systems. The Millennium Ecosystem Assessment (MEA, 2005) comprehensively documented the condition and recent trends of ecosystems and the services they provide, and provided several scenarios of possible future conditions. For reference, the MEA offered some startling statistics. Cultivated systems covered 25% of Earth's terrestrial surface in 2000. On the way there, global agricultural enterprises converted more area to cropland between 1950 and 1980 than in the 150 years between 1700 and 1850. As of the turn of the century, 20% of the world's coral reefs had been lost (with another 20% having been degraded significantly) and 35% of mangrove areas had been lost. Since 1960, withdrawals from rivers and lakes have doubled, flows of biologically available nitrogen in terrestrial ecosystems have doubled, and flows of phosphorus have tripled. At least 25% of major marine fish stocks have been over-fished, and global fish yields have actually begun to decline. Major changes in land-cover have been identified in the MEA (2005), and the consequences of rapid land-cover change explored by Foley *et al.* (2005).

The MEA (2005) recognizes two different categories of drivers of change. Direct drivers of ecosystem change affect ecosystem characteristics in specific, quantifiable ways; examples include land-cover and land-use change, climate change, and species introductions. Indirect drivers affect ecosystems in a more diffuse way, generally by affecting one or more direct drivers; here, examples are demographic changes, socio-political changes, and economic changes. Both types of drivers have changed substantially in the past few decades, and will continue to do so. Among direct drivers, for example, food production has increased 2 ½ times, water use has doubled, wood harvests for pulp and paper have tripled, timber production has doubled, and installed hydropower capacity has doubled. On the indirect side, global population has doubled to reach 6 billion people while the global economy has increased more than six fold.

Table 20.1, taken from the MEA (2006), documents expectations for how several of the direct drivers of ecosystem change are likely to change in magnitude and importance over the next several decades. With the exception of polar regions, coastal ecosystems, some dry land systems, and montane regions, climate change is not today a major source of stress. However, climate change is the only direct driver whose magnitude and importance to a series of regions, ecosystems, and resources are likely to continue to grow over the next several decades. Table 20.1 does illustrate, however, the degree to which these ecosystems are currently experiencing stresses from several direct drivers of change simultaneously. It also shows that any potential interactions with climate change are likely to grow over the next few decades, as the magnitude of climate change itself continues to grow.

### *20.3.2 Factors that support sustainable development*

This section offers a brief excursion into some recent literature on economic development to support the fundamental observation that the factors that determine a country's ability to promote (sustainable) development coincide with the factors that influence adaptive capacity relative to climate change, climate variability and climatic extremes. Much of the recent literature continues to cite Lucas (1988) who concluded that human capital externalities are large enough to explain differences between the long-run growth rates of poor and rich countries. Moretti (2004), for example, showed that plants located in cities where the fraction of college graduates grew faster experienced larger increases in productivity. Guiso, *et al.* (2004) explored the role of social capital in supporting successful application of financial structures; they found that social capital matters

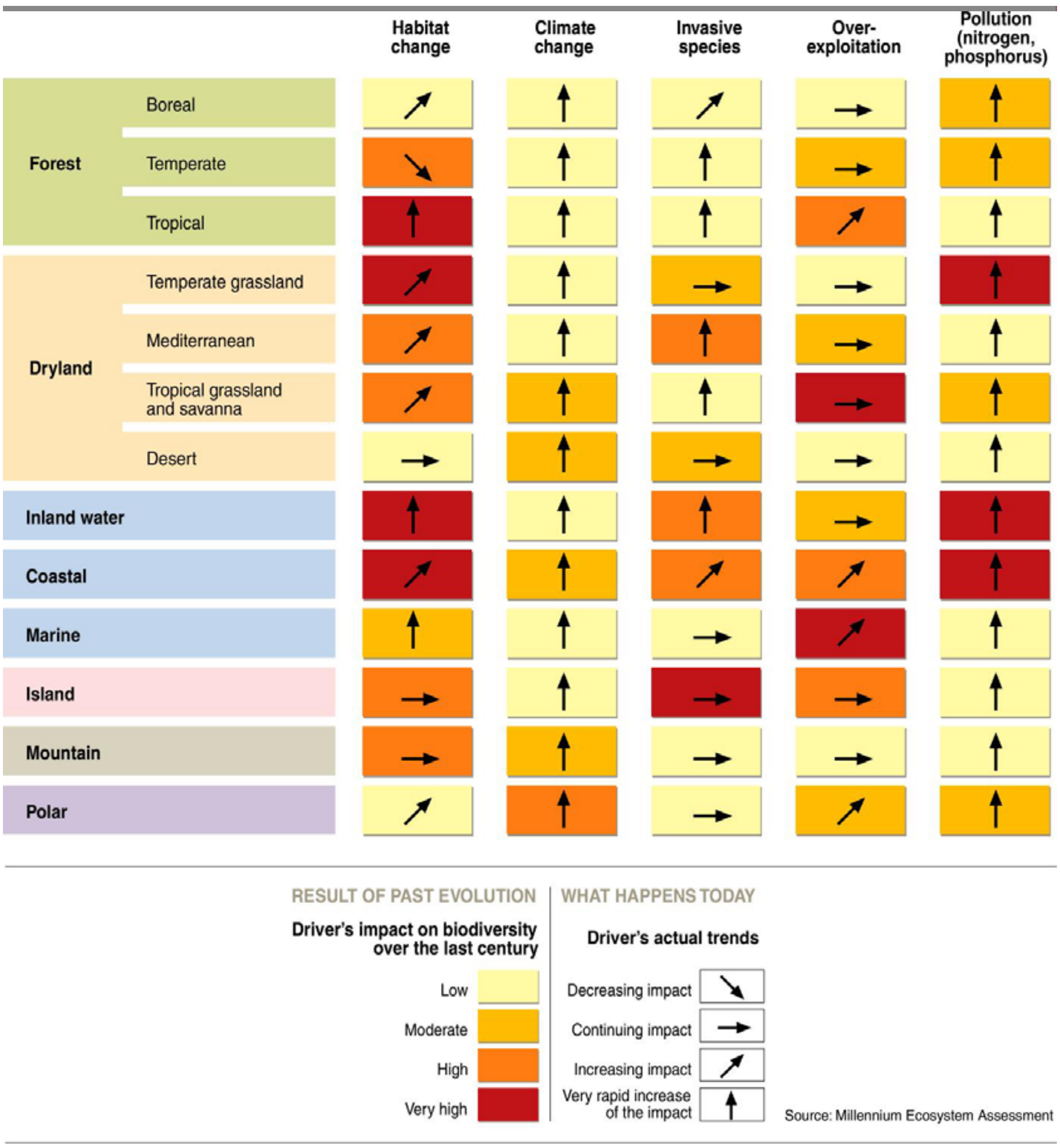



***Table 20.1:*** *Drivers of Change in Ecosystem Services [Source: MEA (2005)]*

most when education levels are low and law enforcement is weak. Rozelle and Swinnen (2004) looked across transition countries across central Europe and the former Soviet Union and observed that countries that grew steadily a decade or more after their reforms had accomplished a common set of intermediate goals: achieving macroeconomic stability, reforming property rights, and creating institutions to facilitate exchange. Order and timing did not matter; success depended, instead, upon on meeting all of these underlying objectives. Winters, *et al.* (2004) reviewed a long literature that looks at the links between trade liberalization and poverty reduction. They concluded that a favourable relationship depends on the existence and stability of markets, the ability of economic actors to handle changes in risk, access to technology, resources, competent and honest government, *and* policies that promote conflict resolution and human capital accumulation. Shortfalls in any of these underpinnings make it extremely difficult for the gains to trade to reach the most disadvantaged citizens. Finally, Sala-i-Martin, *et al.* (2004) explained economic growth by variation in national participation in primary school education (human capital), other measures of human capital (e.g., health measures), access to affordable investment goods, and the initial level of per capita income (access to resources).

### *20.3.3 Two-way causality between sustainable development and adaptive capacity*

It has become increasingly evident, especially since the publication of IPCC (2001a), that the pace and character of development influences adaptive capacity and that adaptive capacity influences the pace and character of development. It follows that development paths, and the choices that define them, affect the impacts of climate change not only through changes in exposure and sensitivity, but also through changes in the capacities of systems to adapt.

Swart *et al.* (2003) and Munasinghe and Swart (2005) argued that sustainable development measures and climate change policies, including adaptation, can reinforce each other; Figure 20.2 suggest some of the texture in the interaction that they envisioned. Until recently, however, linkages between sustainable development and climate change policies have been defined primarily in terms of mitigation. For example, there is no mention within the Millennium Development Goals (MDGs) of potential changes in climate-related disasters or of the need for including climate change adaptation within development programs; indeed, only carbon dioxide emissions are the only reference to climate change (Reid and Alam, 2005). Klein, *et al.* (2005) suggest that adaptation has not been seen as a viable option in part because of the belief that market forces on their own would create the necessary conditions for adaptation without an explicit climate change adaptation policy, and in part because of limited understanding of how climate change adaptation could differ from historic experience.

Promoting alternative development pathways as a means of achieving sustainable development could include measures to reduce non-renewable energy consumption, for example, or shifting construction of residential or industrial infrastructure to avoid high-risk areas (e.g. areas prone to flooding). MEA (2005) attempted to describe a global portrait of such a pathway in its "Techno Garden" scenario. In this future, an inter-connected world promotes expanded use of innovative technology, but its creators included a warning that technology may not solve all problems and could lead to the loss of - cultures. Climate change measures could also encounter such limitations. Gupta and Tol (2003) describe various climate policy dilemmas including competition between human rights and property rights.

Adaptation measures within climate change policies could, by design, try to reduce vulnerabilities by enhancing the adaptive capacity of communities and economies. This would be consistent with sustainability goals. However, just as researchers and practitioners should not equate vulnerability to poverty, they should not contemplate adaptation and adaptive capacity in isolation. More specifically, Brooks *et al.* (2005) conclude that efforts to promote adaptive capacity need to incorporate aspects of education, health and governance; i.e., they should extend the context beyond a particular stress (such as climate change) to include factors that critical in a broader development context. Haddad (2005) extends this idea of capacity to include general rankings of not only economic development performance, but also national goals and aspirations because variation across these factors can lead different nations to adopt different development paths based on the same information and from the same set of choices.

Past adaptation and development experience displays mixed results, however. Kates (2000) described several historic climate adaptations (e.g., drought in the Sahel) and development measures (e.g., the Green Revolution). He argued that development measures that were arguably consistent with climate adaptation often provided benefits to some groups (e.g. people with access to resources) while harming others (e.g. poor populations, indigenous peoples). Ford, *et al.* (2006) showed that unequal acquisition of new technologies can weakening social networks by altering adaptive capacity within communities and between generations; the result can be increased vulnerability to a myriad of external stresses. Belliveau (in press) makes the link to climate explicit in observing that adaptation to non-climatic forces (e.g., changing markets) without explicitly considering climate can lead to increased vulnerability to climate because it costs to adapt to previous adaptations.

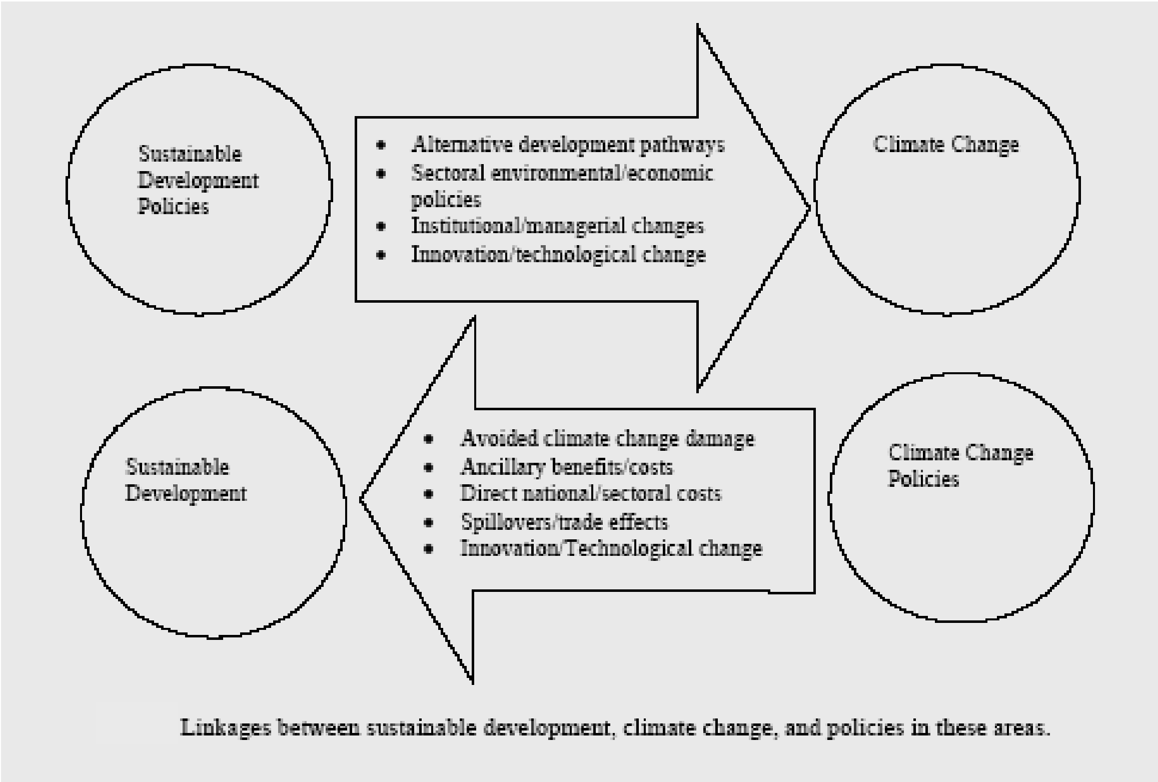



***Figure 20.2:*** *Two-way Linkages between Climate and Sustainable Development. [Source: Swart, et al. (2003)].*

Future linkages between sustainable development and climate change will evolve from current development frameworks. This means that recognizing the exposure of places and peoples to multiple stresses and accepting the challenge of mainstreaming adaptation into development planning will be critical in understanding what policies will work where and when. For example, in the Sudan, there is a risk that development efforts that focus on short-term relief may undermine rather than enforce community coping capacity (Elasha, 2005). An example from climate change is the negative effect that carbon sequestration incentives pose for biodiversity (Caparrós and Jacquemont, 2003). This interaction also adds complexity to the analysis of the causes of recent climate-related disasters. As noted in Chapter 7, for example, are observed trends in injuries/fatalities and property losses (Mileti, 1999; Mirza, 2003; MunichRe, 2005; MEA, 2005) due to unsustainable development policies, climate change, or a mixture of different factors? Could policy interventions reduce these losses in ways that would still meet broader objectives of sustainable development?

Globalization also adds complexity to the management of common-pool resources because increased interdependence makes it more difficult to find equitable solutions to development problems (Ostrom *et al.*, 1999). Increases in costs of hazards and the prospects of cumulative environmental/economic threats have been described as syndromes that are manifest along non-sustainable trajectories of development. Schellnhuber, *et al.* (1997) identified three significant categories: i) (over) utilization (e.g., over-cultivation of marginal land in the Sahel), ii) inconsistent development (e.g., urban sprawl and associated destruction of landscapes), and iii) hazardous sinkage (e.g., large-scale diffusion of long-lived substances). Schellnhuber, *et al.* (2002) and Lüdeke, *et al.* (2004) describe possible future distributions of some of these syndromes, suggesting how mechanisms of mutual reinforcement, including climate change and development drivers, can help to identify regions where syndromes may expand and others where they might be contracted. Examples of development decisions resulting in cumulative threats include extensive water resource development in the Columbia River Basin (Hamlet, 2003) and potential implications for achievement of basin management objectives within scenarios of climate change (Payne, *et al.*, 2004). There, climate change influences on stream-flow cause policy dilemmas when decision-makers must balance of hydroelectricity production and fisheries protection. Restoring in-stream flow to current flow deficit levels (i.e., protecting fisheries) would lead to reduced hydroelectricity production; and that, in turn, could lead ultimately to increased demand for electricity from fossil fuel sources.

## 20.4 Implications for environmental quality

The inseparability of environment and development has been widely recognized ever since the Brundtland Commission [Kates, et. al. (2005) and WCED (1987)]. In the United Nations' Millennium Development Goals (MDGs), for example, environmental considerations are reflected in the 7the goal and the operative target, among others, is to reverse loss of environmental resources by 2015. Overall, how to meet the target of integrating the principles of sustainable development in national policy and reversing the loss of environmental resources remains a partially answered question for most countries [Lee and Ghamine (2005)].

There has been increased interest and work over the past few years on the use of environmental indicators/performance indices to monitor change. The matrix compilation of different sustainable development indicators by Kates, *et al*. (2005) showed that most of them implicitly or explicitly build from reflections of the health of environmental and ecological resources and/or the quality of environmental and ecological services. This is relevant in both developed and developing countries, although arguably the drivers encouraging sustainable management are currently greatest in the developed world (e.g., development agencies for provinces and states in Canada and the US). Huq and Reid (2004) and Agrawala (2004) have noted that climate change is being increasingly recognized as a key factor that could affect the development (sustainable development) of developed and developing countries alike. For example, the Philippine Country Report (1999) identified 153 sustainable development indicators of which a number pertain to climate change such as level of GHG emissions.

Promoting environmental quality is about more than encouraging sustainable development. It is also about adjusting existing environmental management and resource use practices to manage and sustain environmental resources. . In many countries managers of activities which use natural resources and are susceptible to variations in resource availability and hazard over time are currently seeking to revise practices and procedures to make their actions more sustainable. These managers include individual farmers, small businesses and major international corporations. Hilson (2001), for example, points to the mineral extraction industry) as well as public agencies from local to national and international scales. Definitions of sustainable vary across managers, but their common theme is to change the way resources are exploited or hazards managed in order to lessen adverse impacts downstream or for subsequent generations. However, climate change is seldom included in the list of stressors that might influence sustainability. Arnell and Delaney (2006) do note, though, that the water management industry in the United Kingdom is an exception; climate change is seen there as one of the reasons for increasing the sustainability of water abstractions.

The published literature on the links between sustainable management of natural resources and the impacts of and adaptation to climate change is extremely sparse, and in most cases is conceptual rather than specific. Most of this literature focuses on engineering and management techniques which achieve management objectives, such as degree of protection against flood hazard or volume of crop production, whilst having smaller impacts on the environment. Harman, *et al.* (2002) and Turner (2004) speak to this point, but very few of the studies of engineering methods consider explicitly how the performance of these measures is affected by climate change or how suitable they would be in the face of a changing climate. Kundzewicz (2002), however, demonstrates how non-structural flood management measures can be sustainable adaptations to climate change because they are relatively robust to uncertainty. On the other hand, as shown in Clark (2002) and Kashyap (2004), much of the literature on integrated water management in the broadest sense emphasizes adaptation to climatic variability and change through the adoption of sustainable and integrated approaches.

Several studies have demonstrated the benefits to an organization of adopting more sustainable practices, in terms of reduced costs, increased efficiency, or financial performance more broadly interpreted. Johnson & Walck (2004) offer an example from forestry while Epstein and Roy (2003) is illustrative of the more expansive context; but none of these studies explicitly consider the effects of climate change on the benefits of adopting more sustainable practices. Also, none of the literature on mechanisms for incorporating sustainable behaviour into organizational practice and monitoring its implementation (e.g., Jasch (2003) and Figge and Hahn (2004)) consider how to incorporate the effects of climate change into mechanisms or monitoring procedures.

For the purposes of elaborating sustainability criteria for environmental impact assessment, Gibson (2000) listed seven key changes to assess, laid out in the form of principles. Clark (2002) and Bansal (2005) have identified several drivers behind moves to become more sustainable. First, altered legal or regulatory requirements may have an effect. Many governments have adopted legislation aimed at encouraging the sustainable use of the natural environment, but these rarely explicitly include reference to climate change. Heiskanen, *et al.* (2004) report how the European Union's Water Framework Directive, for example, requires agencies responsible for managing water resources across the EU to reduce the environmental impacts of their actions, but the Directive does not explicitly require agencies to adapt to climate change. Secondly, as highlighted by Ramus (2002) and Thomas, *et al.* (2004), internally-generated desires to do things better, either following an ethical position held by an influential champion or in order to reduce costs or risk and enhance attractiveness to potential employees, can push systems toward sustainability.
Finally, stakeholder expectations may change. While these drivers may encourage a shift towards sustainable management, they may not in themselves be directly related to concerns over the impacts of and adaptation to climate change. As Kates, *et al.* (2005) noted, these principles, goals or practices of sustainability are not fixed and immutable but are works in progress. The original focus on economic development versus environmental protection has now become more open to reinterpretation to different social and ecological perspectives.

## 20.5 Implications for risk, hazard and disaster management

The management of the risk from "natural" hazards and disasters is a special case of environmental management. In the most general terms, it has two components. The first is preparing for and reducing exposure to potentially hazardous events (such as floods, droughts, hurricanes or earthquakes), and the second is developing mechanisms to aid recovery after an event strikes. The literature on hazard and disaster management is huge. Some focus attention on the mechanisms that generate hazards. Others examine engineering and management responses. Still others explore the factors that determine vulnerability. There is also a large and expanding literature on hazards and climate change (e.g. for droughts (Richter & Semenov, 2005), landslides (Schmidt & Glade, 2003), avalanches (Stethem *et al.*, 2003), storm surges (Danard *et al.* (2003), and floods (Mirza *et al.*, 2003, Hunt, 2002; Bronstert, 2003)) and a growing literature on the linkages between hazard management and sustainable development (see below). The literature linking hazard management with sustainable development *and* climate change, however, is small.

### *20.5.1 Hazard management and sustainability*

"Pre-event measures" include actions designed to alter the physical manifestations of the hazard event, reduce exposure to loss and facilitate subsequent recovery from loss. They include engineering works to, for example, alter river channels, building works to reduce susceptibility to damage, encouraging wise use of hazard-prone areas, developing early-warning and forecasting systems, and creating insurance mechanisms to cover losses. "Sustainable" pre-event measures would (i) not lead to an increase in exposure (e.g. by encouraging development in risk zones), (ii) not differentially benefit or harm particular sectors of the community, (iii) not increase exposure to other hazards and threats, and (iv) not increase exposure to "downstream" communities. Examples of reviews of sustainable hazard-focused management include Hooijer *et al.* (2004), Harman *et al.* (2002), Yin (2001) and Penrose & Fry (2000). All of these examine how different measures can reduce the impact of flooding whilst maintaining and enhancing the physical environment. A different perspective is taken by those following a vulnerability approach to hazard management, who examine how enhancing adaptive capacity [e.g. Tompkins & Adger (2004); Ford & Smit (2004); Liverman & Meredith (2002) Finan *et al.*, (2002)] can reduce the impacts of hazardous events.

"Emergency measures" are those actions taken immediately after onset of a disaster, and include the provision of disaster relief and assistance. "Sustainable" disaster relief should not increase vulnerability to subsequent events or other hazards, and should be implemented equitably. Wisner *et al.* (2004) give examples of disaster relief which sought to increase resilience to drought in Orissa, India. However, inappropriately targeted disaster relief can enhance inequalities in an impacted society [by concentrating effort on relatively wealthy victims, for example; see Morris & Wodon (2003)], and can encourage a cycle of dependency [Wisner *et al.* (2004)]. Reconstruction of damaged property in the same exposed locations will also, obviously, maintain and possibly enhance exposure to subsequent hazards.

For example, if tropical cyclones increase in intensity, as suggested by many AOGCMs and by recent empirical evidence (Chapter 6.4.1), the sustainability of some of the worlds' most heavily populated cities could reach a threshold that would necessitate massive relocation. Even if tropical cyclones do not increase in intensity, sea level rise will increase the propensity for storm surge flooding in deltas, atolls, small islands, and other highly vulnerable coastal areas. Large investments in flood control works and societal wealth do not necessarily confer greater adaptive ability or resilience, as revealed along the Gulf Coast of the Southern United States in the aftermath of Hurricanes Katrina and Rita in the late summer of 2005. The flooding impacts of these two hurricanes, which claimed approximately 1400 lives and over $110 billion in property damages [NOAA (2005 and 2006)] in south Louisiana and Mississippi, also demonstrated the differential vulnerability of people based on their socio-economic status. About 40% of the housing units destroyed Louisiana were rental properties; a substantial portion of these were occupied by low-income households [State of Louisiana (2006)]. The hurricanes displaced about 50,000 households that had been receiving federal housing aid, and 70% of the rental properties destroyed was affordable to low-income renters who earn 80% or less of the area's median income [National Low

Income Housing Coalition (2005)]. As a result, low-income homeowners were also impacted disproportionately because their property losses were more likely to be uninsured.

Climate change is just one (but not necessarily the most important) of the drivers behind an increasing interest in "sustainable" hazard management approaches, but including it on the list does affect the performance and benefits of sustainable measures. Few studies have explicitly addressed this issue, although O'Hare (2002) suggested that incorporating climate change and its uncertainty into measures to reduce vulnerability to hazard was essential in order for them to be truly sustainable. Kundzewicz (2002) also showed how non-structural flood management measures, such as flood forecasting and warning, land use planning, and property-scale flood proofing, were not only more sustainable than traditional measures such as structural works but were also more robust to climate change uncertainty.

### *20.5.2 Reducing vulnerability to current climatic variability and adapting to climate change*

Reducing vulnerability to current climatic variability can go a long way towards reducing vulnerability to increased hazard risk associated with climate change (e.g. Burton, *et al.* (2002), Davidson, *et al*. (2003), Kashyap (2004), Goklany, 2003); Robledo, *et al*. (2004)) emphasized the extra value to be gleaned if measures designed to reduce vulnerability are also sustainable. To a large extent, adaptation measures for climate variability and extremes already exist. Measures to reduce current vulnerability by capacity building rather than distribution of disaster relief, for example, will increase resilience to changes in hazard caused by climate change [Mirza (2003)]. Similarly, the implementation of improved warning and forecasting methods and the adoption of some land use planning measures would reduce both current and future vulnerability. However, many responses to current climatic variability would not in and of themselves be a sufficient response to climate change. For example, a changing climate would alter the design standard of a physical defence, such as a realigned channel or a defence wall. It could alter the effectiveness of building codes based on designing against specified return period events (such as the 10 year return period gust). Finally, it could alter the area exposed to a potential hazard, meaning that development previously assumed to be "safe" was now located in a risk area. Burton and van Aalst (1999) in their assessment of the World Bank Country Strategic Programs and project cycle identify the need to assess the success of current adaptation to present day climate risks and climate variability, especially as they may change with climate change.

Coping with current changes in climatic variability and extremes will build learning in dealing with future climate changes and will enhance coping abilities of communities. Since climate change will likely manifest itself through changes in variability as well as in overall trend, methods used to cope with past and emerging patterns in climatic variability will be a useful starting point for the design of future adaptations. In the National Adaptation Plans (NAPAs) of many developing countries, there is emphasis on enhancing local coping mechanisms and indigenous knowledge systems, where necessary, as a way to build adaptive capacity at the community level. This can be accomplished in several ways. Approaches used to deal with emerging shifts in growing season conditions (such as shifts in start of rains, length and quality of growing season) include diversifying the selection of crops that they plant, staggered planting dates, and increasing water harvesting techniques (see Desanker and Mushove (2005)) will increase community resilience and enhance their coping abilities to future changes in climate. Areas that are facing new or increased climatic threats, such as drought or floods, can learn from areas that have traditionally been exposed to frequent droughts and floods. This is translation of knowledge was highlighted in the NAPA Primer (Desanker 2004) as an important area for regional synergies in adaptation planning.

## 20.6 Global and aggregate impacts

### *20.6.1 Spatially-explicit methods*

As shown in the reviews of Hitz and Smith (2004) and Warren (2006), the vast majority of impact assessments are made at the local scale, and use a wide variety of methods and scenarios. It is therefore extremely difficult to estimate impacts across the global domain from these localised studies (although some of the damage functions used in Integrated Assessment Models (section 20.6.3) are based on results of such studies. A small number of studies, however, have used geographically-distributed impacts models to estimate the impacts of climate change across the global domain. The Defra "Fast Track" studies (Arnell, 2004; Arnell *et al.*, 2002; Levy *et al.*. 2004; Nicholls, 2004; Parry *et al.*, 2004; Van Lieshout *et al.*, 2004) used a consistent set of scenarios and assumptions to estimate the effects of HadCM-based scenarios on water resource availability, food security, coastal flood risk, ecosystem change and exposure to malaria. Schroeter *et al.* (2005) used a similar approach in the ATEAM project, with scenarios constructed from a larger number of climate models, and tabulated impacts across Europe. Both these sets of studies used a wide range of metrics, varying between sectors. Table 20.2 summarises some of the global scale impacts of defined climate change scenarios. Although the precise numbers depend on the climate model used to create the climate change scenarios, it is clear that the future impacts of climate change are dependent not only on the rate of climate change, but also on the future social and economic state of the world. Impacts are greatest under an A2 world, for example, not because the climate change is greatest but because there are more people to be impacted. Impacts also vary regionally, and Table 20.3 summarises impacts by major world region.

A key problem with such geographically-distributed impact assessments, however, lies in the aggregation of impacts to the regional and global scales. Tables 20.2 through 20.4, for example, show people living in watersheds with an increase in stress – but many people live in watersheds where climate change increases runoff and therefore apparently *decreases* stress. Simply calculating the "net" impact of climate change, however, is misleading where "winners" and "losers" are in different geographic regions. Watersheds with an increase in runoff, for example, are concentrated in east Asia, whilst watersheds with reduced runoff are much more widely distributed.

***Table 20.2:*** *Global scale impacts of climate change by 2080.*

| | Climate and socio-economic scenario | | | |
|---|---|---|---|---|
| | A1FI | A2 | B1 | B2 |
| Global temperature change ($^{o}$C difference from 1961-1990) | 3.97 | 3.21-3.32 | 2.06 | 2.34-2.4 |
| Millions of people at increased risk of hunger (Parry *et al.*, 2004) | 290 | 550-580 | 50 | 150-170 |
| Millions of people exposed to increased water resources stress (Arnell, 2004) | 1260 | 2600-3210 | 1140 | 1200-1535 |
| Additional numbers of people (millions) flooded in coastal floods each year, with lagged evolving protection (Nicholls, 2004) | 7 | 29 | 2 | 16 |

Note: Change in climate derived from the HadCM3 climate model. Impacts are compared to the situation in 2080 with no climate change. The range in impacts under the A2 and B2 scenarios represents the range between different climate simulations. The figures for additional millions of people flooded in coastal floods assumes a low rate of subsidence, and a low rate of population concentration in the coastal zone

***Table 20.3:*** *Regional-scale impacts of climate change by 2080.*

| | Population living in watersheds with an increase in water-resources stress (Arnell, 2004) | | | | Increase in average annual number of coastal flood victims (Nicholls, 2004) | | | | Additional population at risk of hunger (Parry *et al.*, 2004) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A1 | A2 | B1 | B2 | A1 | A2 | B1 | B2 | A1 | A2 | B1 | B2 |
| Europe | 270 | 380-490 | 230 | 170-180 | 1.6 | 0.3 | 0.2 | 0.3 | 0 | 0 | 0 | 0 |
| Asia | 290 | 810-1200 | 300 | 330-600 | 1.3 | 14.7 | 0.5 | 1.4 | 78 | 266 | 7 | 53 |
| North America | 130 | 110-145 | 110 | 10-65 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| South America | 160 | 430-470 | 100 | 130-190 | 0.6 | 0.4 | 0 | 0.1 | 27 | 85 | 5 | 15 |
| Africa | 410 | 690-910 | 400 | 490-560 | 2.8 | 12.8 | 0.6 | 13.6 | 157 | 200 | 23 | 89 |
| Australasia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note: change in climate derived from the HadCM3 climate model. Impacts are compared to the situation in 2080 with no climate change. The range in impacts under the A2 and B2 scenarios represents the range between different climate simulations. The figures for additional millions of people flooded in coastal floods assumes a low rate of subsidence, and a low rate of population concentration in the coastal zone. The figures for additional populations at risk of hunger assume no beneficial effects of $CO_2$ fertilisation.

The Defra Fast Track and ATEAM studies both describe the impacts of defined scenarios: it is difficult to infer from these the effects of different rates or degrees of climate change. A more generalised approach uses a wide range of scenarios representing different rates of change to estimate impacts at different temperature levels. Leemans & Eickhout (2004), for example, show that most species, ecosystems and landscapes would be impacted with increases of global temperature between 1 and 2$^{o}$C above 2000 levels. Arnell (2006) showed that an increase in temperature of 2$^{o}$C above the 1961-1990 mean by 2050 would result in between 550 and 900 million people suffering an increase in water resources stress under the SRES A1 and B1 world. In this case, the range represents the effect of different spatial patterns of rainfall change associated with a 2$^{o}$C rise in global temperature.

### *20.6.2 History and present state of aggregate impact estimates*

Three types of aggregate impacts are commonly reported. In the first, impacts are computed as a percent of GDP for a specified rise in global mean temperature. In the second, impacts are aggregated over time and discounted back to the present day along specified emission scenarios such as those documented in IPCC (2002). A third type of estimate has attracted the most attention, recently. It computes the economic value of the extra (or marginal) impact caused by the emission of one more tonne of carbon (in the form of carbon dioxide) at any point in time. Researchers calculate this marginal cost by summing the extra impacts for as long as the extra tonne remains in the atmosphere and discounting them back to the year of emission. It is also an estimate of the marginal benefit of reducing carbon emissions by one tonne; it is, therefore, often called the social cost of carbon (denoted here as SCC).

Table 20.4 compares the global impacts of a 1% annual increase in CO2 concentrations (the IS92a scenario) with the impacts of emissions trajectories stabilising at 750 and 550ppmv (Arnell *et al.*, 2002). The results are not directly comparable to those in Table 20.2; different population assumptions and methodologies were employed in their preparation. Nevertheless, the results indicate that aiming for stabilisation at 750 ppmv has a relatively little effect on impacts, in most sectors, whilst aiming for stabilisation at 550 ppmv has a much clearer effect. The S550 pathway has a greater apparent impact on exposure to hunger than the S750 pathway, and this is because the beneficial effect of $CO_2$ enrichment on crop productivity is less.

***Table 20.4:*** *Global-scale impacts under unmitigated and stabilisation pathways (Arnell et al., 2002).*

| | Unmitigated | S750 | S550 |
|---|---|---|---|
| 2050s | | | |
| Approximate equivalent $CO_2$ concentration (ppmv) | 520 | 485 | 458 |
| Approximate global temperature change ($^oC$ difference from 1961-1990) | 2.0 | 1.3 | 1.1 |
| Area potentially experiencing vegetation dieback (million $km^2$) | 1.5-2.7 | 2 | 0.7 |
| Millions of people exposed to increased water stress | 2200-3200 | 2100 | 1700 |
| Additional people flooded in coastal floods (millions/year) | 20 | 13 | 10 |
| Population at increased risk of hunger (millions) | -3 to 9 | 7 | 5 |
| 2080s | | | |
| Approximate equivalent $CO_2$ concentration (ppmv) | 630 | 565 | 493 |
| Approximate global temperature change ($^oC$ difference from 1961-1990) | 2.9 | 1.7 | 1.2 |
| Area potentially experiencing vegetation dieback (million $km^2$) | 6.2-8 | 3.5 | 1.3 |
| Millions of people exposed to increased water stress | 2830-3440 | 2920 | 760 |
| Additional people flooded in coastal floods (millions/year) | 79-81 | 21 | 5 |
| Population at increased risk of hunger (millions) | 69-91 | 16 | 43 |

Note: climate scenarios based on HadCM2 simulations: the range with unmitigated emissions reflects variation between ensemble simulations.

Most of the aggregate impacts reported in the IPCC (1995) were of the first type; i.e., they monetize the likely damage that would be caused by a doubling of CO2 concentration. For developed countries, the results were of the order of 1% of GDP. Developing countries suffered larger percentage damages so that a mean global loss of 1.5 to 3.5% of world GDP was reported from different studies. Clearly, the uncertainty range is enormous. Corresponding estimates of the SCC varied from $5 to $125 (in 1990 prices); they were particularly sensitive to the discount rate. IPCC (1995) suggested that the SCC would run from $5 to $12 for a 5% discount rate. IPCC (2001a) arrived at essentially the same range. In the complex dynamics that determine marginal damage costs, the more optimistic estimates of market damages at the end of the last century were balanced by other factors such as higher non-market impacts and a better capture of uncertainties [IPCC (2001)].

Since IPCC (2001a), interest in the social cost of carbon has been stimulated by a recent rise in interest in the economic benefits of climate change policy, as part of wider post-Kyoto considerations [Watkiss, *et al.*, (2005)]. After surveying the literature, Clarkson and Deyes (2002) proposed a value of $105 per tonne of carbon (in year 2000 prices) for the SCC, with upper and lower values of $50 and $210 per tonne. Pearce (2003) argued that 3% is a reasonable representation of a social discount rate, and so the probable range of the SCC is in the region of $4-9 tC for emissions today. Tol (2005) gathered over 100 estimates of the SCC from 28 published studies and combined them to form a probability density function, with a mode of $2/tC, a median of $14/tC, a mean of $93/tC, and a 95 percentile estimate equal to $350/tC. Studies that were peer-reviewed generally had lower estimates and smaller uncertainties; their mean was $43/tC, with a standard deviation of $83/tC. Figure 20.3 shows the cumulative density function for all the studies and at different pure rates of time preference. There is about a 10% chance that the SCC is negative; this could occur if the climate sensitivity were low and if small rises in global mean temperature brought benefits rather than costs to some. The effect of the discount rate is striking. The 90-percentile SCC, for instance, is $62/tC for a 3% pure rate of time preference, $165/tC for 1%, and $1610/tC for 0%.

Other estimates of the SCC span at least three orders of magnitude, from less than $1 per tonne to over $1500 per tonne of carbon. Downing, *et al.* (2005) argued that this range reflects uncertainties in climate and impacts, coverage of sectors and extremes, and choices of decision variables. Tol (2005) concludes that using standard assumptions about discounting and aggregation, the SCC is unlikely to exceed $50/tC, and is probably much smaller. In contrast, Downing, *et al*. (2005) concludes that a lower benchmark of $50/tC is reasonable for a global decision context committed to reducing the threat of dangerous climate change and including a modest level of aversion to extreme risks, relatively low discount rates and equity weighting. An upper benchmark of the SCC for global policy contexts is more difficult to deduce from the present state-of-the-art, but the risk of higher values for the social cost of carbon is significant.

Climate change is caused by a range of greenhouse gases, not just carbon dioxide, and integrated assessment models can calculate the social cost of each of them. The mean estimate from the PAGE2002 model for the social cost of methane is $280 per tonne emitted in 2001, in year 2000 dollars, with a 5-95% range of $80 to $750. The estimate for the social cost of SF6 is $800 000 per tonne emitted in 2001, in year 2000 dollars, with a 5-95% range of $160,000 to more than $2 million per tonne (Hope, forthcoming).

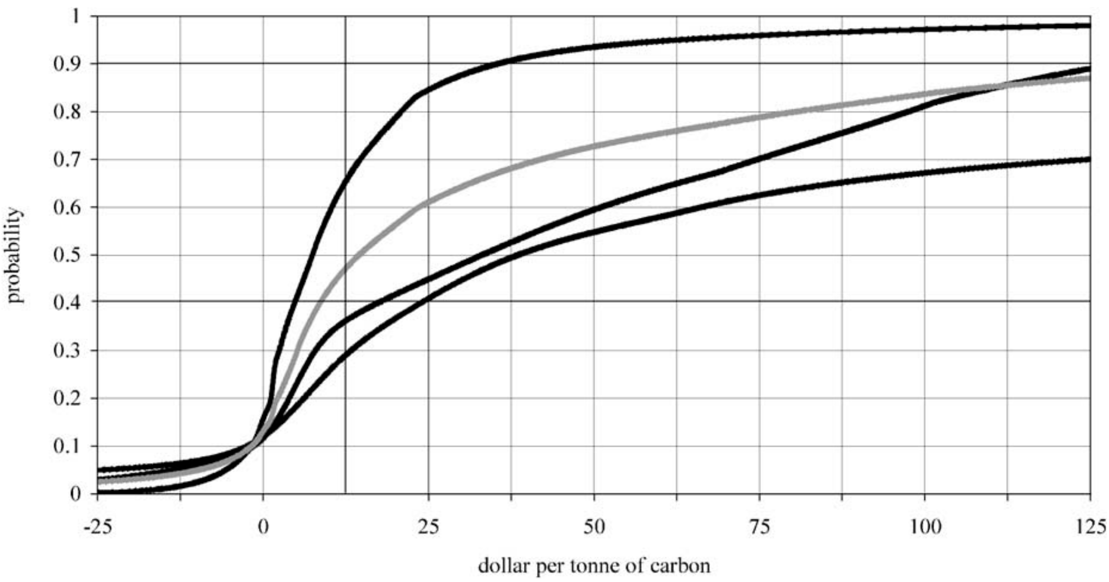



***Figure 20.3:*** *Cumulative Density Function for the Social Cost of Carbon The distribution is shown for all studies in gray and for studies that use pure rates of time preference equal to 3%, 1%, and 0% in black from top to bottom, respectively. [Source: Tol (2005)]*

*20.6.2.1 Variation of social costs with date of emission*

That the SCC will rise over time has been known since the SAR [IPCC (1995)]. Figure 20.4 shows that the mean estimate of the SCC from one integrated assessment model increases by about 2.4% per year; by 2060 the mean estimate has risen to $265 per tonne of carbon. It also shows that the mean estimate of the social cost of methane increases faster than carbon dioxide, by 3.6% per year. This is because of the short atmospheric lifetime of methane; any extra methane emitted today will have disappeared from the atmosphere before the most severe climate change impacts occur, but emissions that occur later will not (Watkiss, 2005).

The social cost of carbon appears to be insensitive to the exact emissions scenario on which it is superimposed, within quite a wide range. The reason for this lies in the interplay between the logarithmic relationship between radiative forcing and concentration (which will tend to make one extra tonne under a high emission scenario cause less impacts), the non-linear relationship of impacts to temperature (which will tend to make one extra tonne under a high emission scenario cause more impacts), and discounting (which will tend to make early impacts more costly than late impacts). The insensitivity of the social cost to the emission path is rather counter-intuitive; it is strong evidence in support of using integrated assessment approaches to explore climate issues, since neither a scientific nor an economic model would capture all of the underlying and critical complexity [Hope (2005b)].

*20.6.2.2 Sources of uncertainty*

Tol (2005) finds that much of the uncertainty in the estimates of the social cost of carbon can be traced to two assumptions: one on the discount rate and the other on the equity weights that are used to aggregate the monetized impacts over countries. In most other policy areas, the rich do not reveal as much concern for the poor as is implied by the equity weights used in many models. Downing, *et al.* (2005) state that the extreme tails of the estimates depend as much on decision values (such as discounting and equity weighting) as on the climate forcing and uncertainty in the underlying impact models.

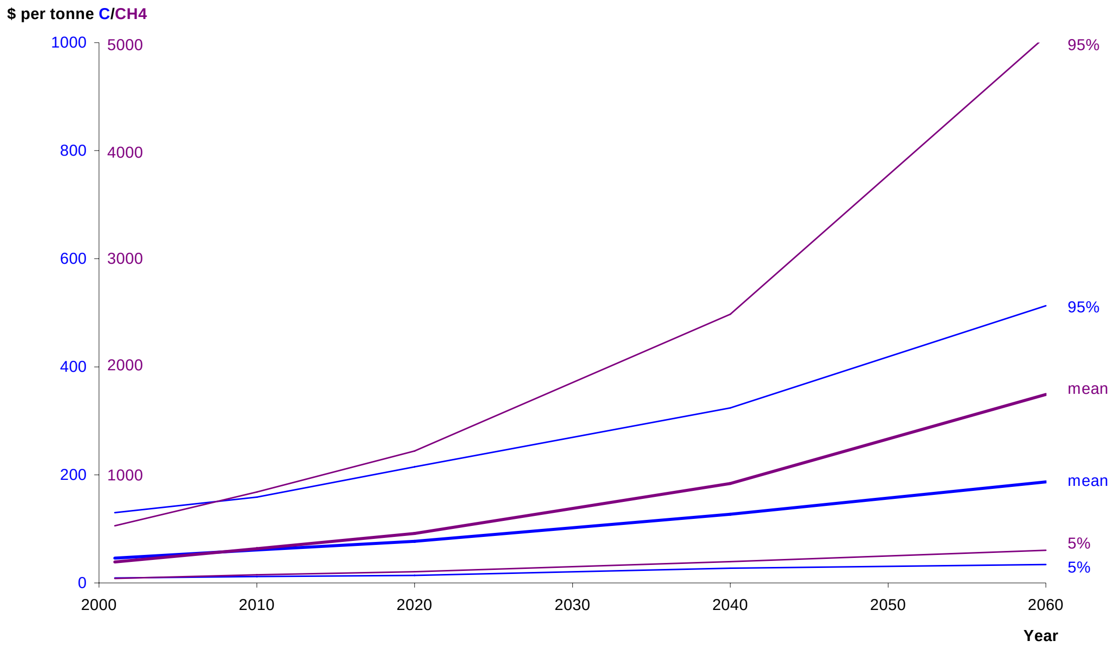



***Figure 20.4:*** *The Social Cost of Carbon and Methane by Date of Emission. The range of the social cost of carbon over time is portrayed in blue; the social cost of methane, in purple. [Source: Watkiss (2005)]*

Table 20.5 shows the six major influences calculated by PAGE2002 and reported in Hope (2005b); that they divide into two scientific and four economic parameters is another strong argument for the building of integrated assessment models. Models that are exclusively scientific, or exclusively economic, would omit parts of the climate change problem which still contain profound uncertainties. The two top influences are the climate sensitivity, which is the temperature rise that would occur for a doubling of carbon dioxide concentration, and the pure time preference rate. The climate sensitivity is positively correlated with the SCC, so a rise leads to a higher SCC; the pure time preference rate is negatively correlated with the SCC, so a rise leads to a lower SCC. Notice that non-economic impact ranks third and that economic impact ranks $6^{th}$ (a far below climate sensitivity as a source of uncertainty).

*20.6.2.3 Limitations of IAM estimates*

A few models have existed for long enough to trace the changes in their estimates of the SCC over time. Table 20.6 shows how the results from three integrated assessment models have evolved over the last 15 years. The DICE and PAGE estimates have not changed greatly over the years. But this gives rather a misleading impression of stability and precision. In fact the values from PAGE have changed little because several quite significant changes have approximately cancelled each other out. In the later studies, lower estimates for the impact on market sectors in developed countries are offset by higher non-market impacts, equity weights and the inclusion of initial estimates of the possible impact of large-scale discontinuities (Tol, 2005).

***Table 20.5:*** *Major Factors Causing Uncertainty in the Social Cost of Carbon. Relative importance is measured by the magnitude of the partial rank correlation coefficient between the parameter and the SCC, with the most important indexed to 100. Source: Hope (2005b).*

| Parameter | Definition | Sign | Range | Importance |
|---|---|---|---|---|
| **Climate sensitivity** | Equilibrium temperature rise for a doubling of CO2 concentration | + | 1.5 – 5 deg C | 100 |
| **PTP rate** | Pure time preference for consumption now rather than in 1 year's time | - | 1 – 3% per year | 66 |
| **Non-economic impact** | Valuation of non-economic impact for a 2.5 deg C temperature rise | + | 0 – 1.5 % of GDP | 57 |
| **Equity weight** | Negative of the elasticity of marginal utility with respect to income | - | 0.5 – 1.5 | 50 |
| **Climate change Half-life** | Half life in years of global response to an increase in radiative forcing | - | 25 – 75 years | 35 |
| **Economic impact** | Valuation of economic impact for a 2.5 deg C temperature rise | + | -0.1 – 1.0 % of GDP | 32 |

***Table 20.6:*** *Estimates of the Social Cost of Carbon over Time from Three Models (in constant 2000 dollars.) Source: DICE best guesses of Nordhaus and Boyer (2001) are from Pearce (2003). FUND estimates are from Tol (1999), and 25 to 75% range with green book discounting and equity weights from Downing et al. (2005). PAGE fifth and ninety-fifth percentile ranges from Plambeck and Hope (1996) rebased to year 2000, and Hope (2006).*

| Date of estimate | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|
| **DICE** | $10 | $7 | $6 | |
| **FUND** | | | $9 to $23 | -$15 to $110 |
| **PAGE** | | $12 to $60 | | $4 to $51 |

Hitz and Smith(2004) found that the relationships between global mean temperature and impacts are not consistent across sectors. One consistent pattern is that beyond an approximate 3–4 deg C increase in global mean temperature, all sectors, with the possible exception of forestry, show increasing adverse impacts. Tol (2005) found that few studies cover non-market damages, the risk of potential extreme weather, socially contingent effects, or the potential for longer-term catastrophic events. Therefore, the uncertainty in the SCC value concerns not only the ‘true’ value of impacts that are covered by the models, but also uncertainty about impacts that have not yet been quantified and valued. Perhaps most importantly, as argued in Watkiss, *et al.*(2005) and displayed in Figure 20.5, SCC estimates in the literature are products of work that spans only a sub-set of impacts from which complete estimates might be calculated. Nonetheless, current estimates do provide enough information to start a rational discussion about sensible cutbacks of the emissions of $CO_2$, methane and other greenhouse gases, and the appropriate trade-off between gases.

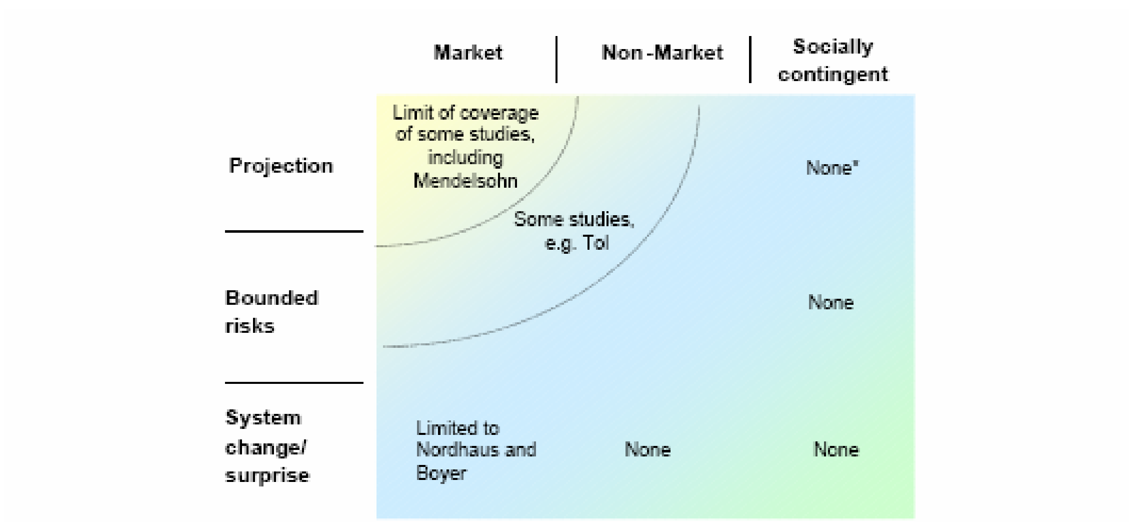



***Figure 20.5:*** *Coverage of Studies that Compute Estimates of the Social Cost of Carbon against sources of Climate Related Risk. Coverage of most studies is limited to market-based sectors, and few of them move beyond the upper left corner to include bounded risks and abrupt system change. [Source: Watkiss, et al.(2005)]*

The estimates are worth having because, if the social cost calculations are complete and markets are perfect, efforts to cut back the emissions of greenhouse gases should continue as long as the marginal cost of the cutbacks is lower than the social cost of the impacts they cause. Moreover, as emphasized by Morimoto and Hope (2004), even current estimates of SCC offer a consistent way to internalize the impacts of climate change into development, mitigation, and/or adaptation decisions that the private and public sector will be making over the near term. If taxes are used, they should be set at the social cost. If tradable permits are used, their price should be the same as the social cost; if their price turns out to be lower than the social cost, the total allocation of permits is too large and vice versa. In any comparison between greenhouse gases, according to Pearce (2003), the ratio of the social costs is the correct figure to use. For reference, spot prices for permits in the European Carbon Trading Scheme since its inception early in 2005 started out towards the bottom end of the range of social cost estimates, but they rose quickly and plateaued at around $100 per tonne of carbon.

## 20.7 Implications for regional, sub-regional, local and sectoral development; access to resources and technology; equity

IPCC (2001) concluded "developing countries will be more vulnerable to climate change than developed countries (pg. 916)". The TAR attached "high confidence" to this statement despite concerns raised elsewhere that "current knowledge of adaptation and adaptive capacity is insufficient for reliable prediction of adaptations (pg. 880)" because "the capacity to adapt varies considerably among regions, countries and socioeconomic groups and will vary over time (pg. 879). This section explores this apparent contradiction by examining what current knowledge can say about the geographical distribution of vulnerability. To that end, this section offers portraits of the implications of climate change at three points in the future. The first, the relatively near term, speaks to the interactions between climate change and our abilities to meet the first thresholds of the Millennium Development Goals. The second looks at the middle of the century in terms of the geographical distribution of vulnerability across a sample of countries within which more than 80% of the world's population reside. The final portrait offers a comparable look at vulnerability across the globe at the end of the century. A fourth section illustrates the geographic texture of the complementary roles of adaptation and mitigation.

### *20.7.1 Millennium Development Goals – A 2015 time slice*

The Millennium Development Goals (MDG's) represent an international consensus on a framework by which countries can assess tangible progress towards sustainable development; they are enumerated in Table 20.7. The Millennium Development Goals Report [UN (2005)] provides the most up to date official documentation of the 8 MDG's, the 11 specific targets for progress by 2015 (or 2020 in some cases), and the 32 quantitative indicators that are being used as metrics. Goal 7, "to ensure environmental sustainability" is the most immediately relevant of the MDG's to climate change. Climate change and its drivers, *per se*, affect MDG indicators directly in only two ways: in terms of energy use per dollar GDP and CO2 emissions per capita.

***Table 20.7*** *The Millennium Development Goals.*

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Source: http://www.un.org/millenniumgoals/documents.html

Current literature provides little guidance as to whether climate change, itself, will affect progress towards any of the MDG's in the near term, i.e. by 2015. The short-term targets of the MDG's will be difficult to reach in any case. While current climate impacts have now been documented with some levels of confidence, it will be difficult to blame climate change for our limited progress towards the MDG's in this short time-frame.

Climate change impacts enter the MDG's in no direct way, although they could conceivably affect several indicators in Goal 7, and possibly one indicator in Goal 6 ("prevalence and death rates associated with malaria), over the medium-term. For example, climate change impacts on the timing, flow, and amount of available freshwater resources could affect the ability of developing countries to increase access to potable water [Goal 7, Target 10, Indicator 30 from UN (2005)]. Climate change impacts could also affect the proportion of land area covered by forest. It is also conceivable that climate change could have measurable consequences, in some parts of the world at least, on the indicators of progress on food security [Goal 1, Target 2, Indicators 4 and 5, from UN (2005)].

In the longer-term, Arrow *et al.* (2004) argue that adaptation decisions can reduce the effective investment available to reach the MDG's, raising the possibility that there are opportunity costs from climate adaptation that could slow down efforts to achieve sustainable development. However, because the determinants of adaptive capacity and of sustainable development overlap significantly (see section 20.2), it is equally possible that a dollar spent on climate adaptation could also strengthen progress towards sustainable development, i.e. be a synergy rather than a cost.

Determining whether synergistic effects or opportunity costs dominate the interaction between climate impacts, adaptation decisions, and sustainable development decisions depends at least in part on the particular decisions that are made. Decisions about how countries will acquire sufficient energy to sustain growing demand will, for example, play crucial roles in determining the sustainability of economic development. If those demands were met exclusively through the combustion of fossil fuels, there are likely to be positive feedbacks to climate change itself through higher emissions of greenhouse gases. There are some indications of this even in recent data – per capita emissions of CO2 in developing countries rose between 1990 and 2002 [1.7 mt CO2 per capita to 2.1 mt per capita; see UN (2005)], although they still were not close to values in developed countries (12.6 mt CO2 per capita). Resources devoted to expanding fossil fuel generation could, in principle, therefore be thought of as having resulted in expanded climate change impacts compared to what otherwise might occur. On the other hand, investments in forestry and agricultural sectors that would preserve and enhance soil fertility and productivity to reach food security MDG's (e.g. Goal 1) might also have synergies for climate mitigation through sequestration of carbon and for adaptation if they also result in greater economic return for local communities that could then be devoted to coping strategies.

We do not know, *a priori*, which effects will predominate. Each situation must be analyzed quantitatively. But we can say with certainty that not all development paths will necessarily be equal with respect to their consequences for climate change itself, or with respect to their consequences for adaptive capacity.

The Millennium Ecosystem Assessment (2005) and others [e.g., African Development Bank (2005)] argue that, over the longer term, climate change will indeed prove to be a significant hindrance to meeting the MDG's. There is no discrepancy here. Stresses from climate change will continue to grow. Some regions and countries are already known to be lagging in their progress towards the MDG's, and these tend to be in regions where vulnerabilities to climate change over the 21$^{st}$ century are likely to be high. For example, the proportion of land area covered by forests fell between 1990 and 2000 in Sub-Saharan Africa, Southeast Asia, and Latin America and the Caribbean, while it appeared to stabilize in developed countries [UN (2005)]. Energy use per unit of GDP fell between 1990 and 2002 in both developed and developing regions, but developed regions remained approximately 10% more efficient than developing regions [UN (2005)]. Regions and ecosystems that are already under significant multiple stresses that are eroding ecosystem services and their contributions to human well-being are more likely to have low adaptive capacity.

### *20.7.2 Our Common Future – A 2050 time slice*

IPCC (2001) argued in Chapter 18 that vulnerability is a function of exposure, sensitivity and adaptive capacity; Sections 20.1 and 20.3 make it clear that many researchers continue to favour this type of approach as they organize their analyses. Yohe, *et al.* (2006), for example, used this approach to construct global portraits of vulnerability for more than 100 nations scattered across the globe. Their index of vulnerability reflects exposure to climate change (represented by changes in local annual mean temperatures drawn from a small ensemble of global circulation model results) and subjective judgments of national capacities to adapt drawn from Brenkert and Malone (2005). They portrayed their results on maps with a time-dependent vulnerability index denoted $V_i(t)$ [equal to national temperature change in year t divided by an index of adaptive capacity normalized to unity for the current global mean*)*.

Figures 20.6 through 20.8 display four-colour versions of their maps. In each map, assigning light green to a country means that it would face little or modest vulnerability at time t because $V_i(t) < 1$. Assigning yellow means moderate vulnerability for $1 < V_i(t) < 2$, orange means significant vulnerability for $2 < V_i(t) < 3$, and red identifies countries for which adaptive capacity is overwhelmed by exposure to climate change with $V_i(t) > 3$. These interpretations reflect vulnerability for a hypothetical country with an adaptive capacity index equal to the global average that experienced increases in annual mean temperature that matched changes in the global mean. In Figure TS-12 of IPCC (2001a), such a country would, against the “Aggregate Impacts” metric, face low risk of climate impacts from another 1 degree of warming (pale green), moderate risk from a second degree of additional warming (yellow), significant risk for the next degree of warming (orange), and overwhelming risk for warming that exceeds $3^oC$ (red). Of course, this calibration automatically assigns different colours at lower thresholds for countries with lower adaptive capacities; and visa versa.

Figure 20.6 portrays vulnerability in 2050 along two different development scenarios for adaptive capacity and two different climate sensitivities. For the left-hand panels, adaptation was completely static so that future temperature increases produce vulnerabilities under the limiting assumption that the current adaptive capacities of all nations would not change over time. For the right-hand panels, the capacities of all countries increased either to the current global mean or to 125% of their current values (whichever value was larger). The top two panels, meanwhile, show that only a few developing countries would experience moderate vulnerability through 2050 along low climate sensitivity futures (a sensitivity equal to $1.5^oC$). If climate sensitivity turns out to be high, however, the bottom two panels suggest that all countries would moderate or significant vulnerability. Developing countries would be more at risk in these cases, and enhanced adaptive capacity would be most effective in the developed world.

### *20.7.3 Fundamental Transition – A Slice of Time from 2080 through 2100*

Figure 20.7 shows the results of extending the exercise described in Section 20.7.2 to the year 2100.

In the low sensitivity scenario, the global patterns show the largest vulnerabilities among the developing countries, but developed countries are not immune to climate stress. Moreover, scenarios with high climate sensitivity (equal to 5.5°C) produce so much exposure to higher temperatures that climate change overwhelms adaptive capacity (even enhanced adaptive capacity) nearly everywhere. As a result, differences in relative vulnerability disappear for all practical purposes before 2100.

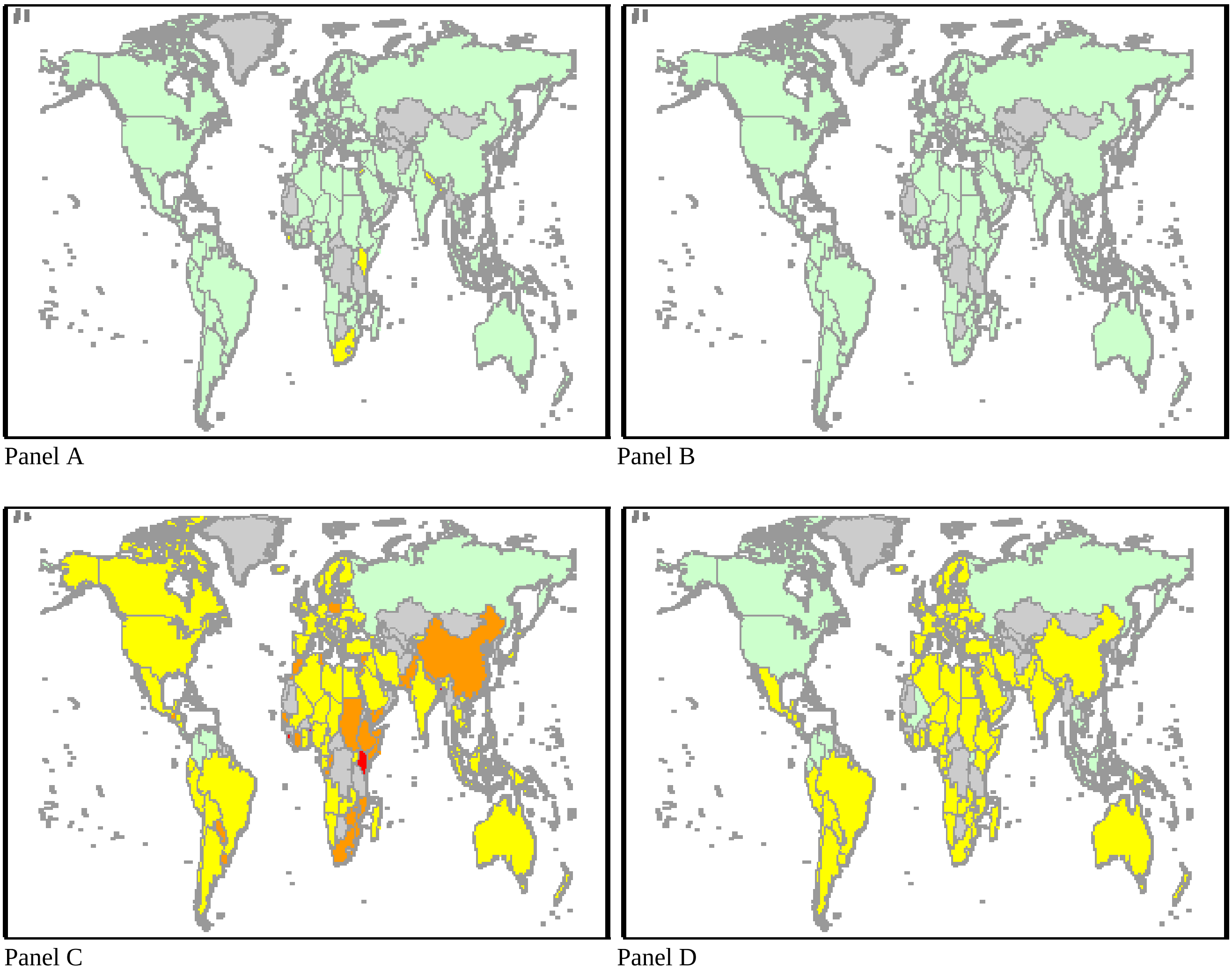
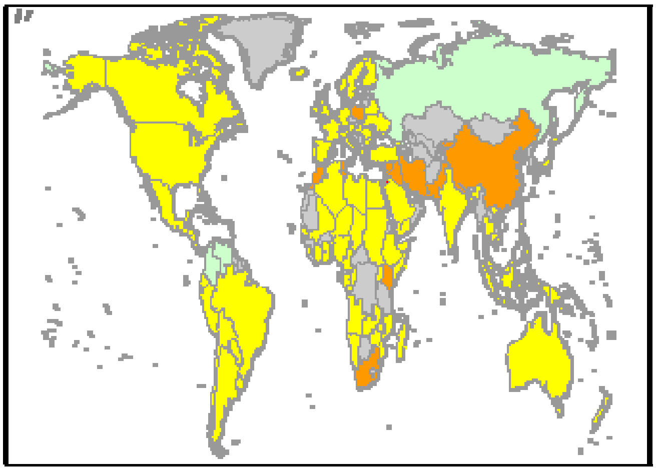



***Figure 20.6:*** *Global Distributions of Vulnerability in 2050 along the A2 Emissions Scenario.* ***.*** *Panels A and B show vulnerability in 2050 without and with enhanced adaptive capacity, respectively, along an A2 emissions scenario with the climate sensitivity equal to 1.5°C; panels C and D show the analogous portraits for A2 with a climate sensitivity equal to 5.5°C. Light green indicates little or modest vulnerability. Yellow designates moderate vulnerability. Orange signifies significant vulnerability, and red identifies nations where adaptive capacity would be overwhelmed by exposure. Light gray shading indicates countries for which insufficient data were available. Low climate sensitivity produces limited vulnerability in 2050, but significant vulnerabilities would develop before 2050 even with enhanced adaptive capacity in the developing countries of Africa and China if climate sensitivity were high. Even enhanced adaptive capacity could not prevent moderate vulnerability in most developing and many developed countries.*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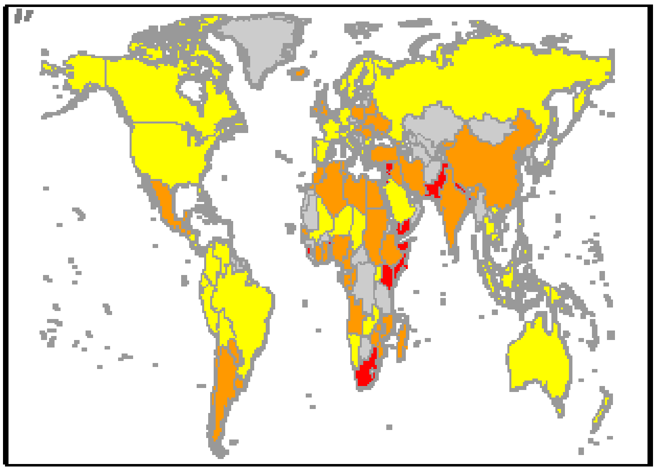
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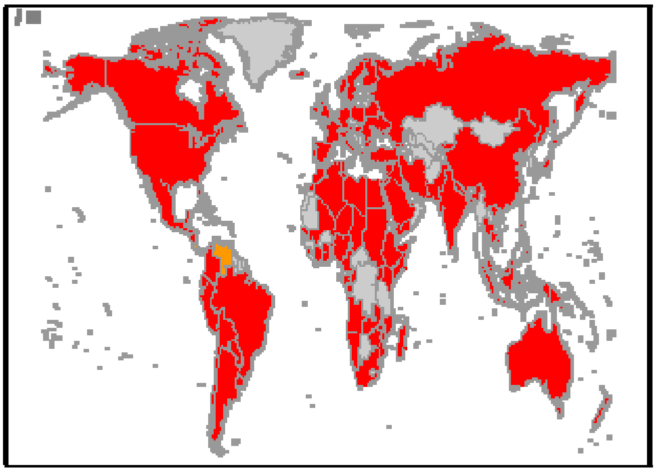
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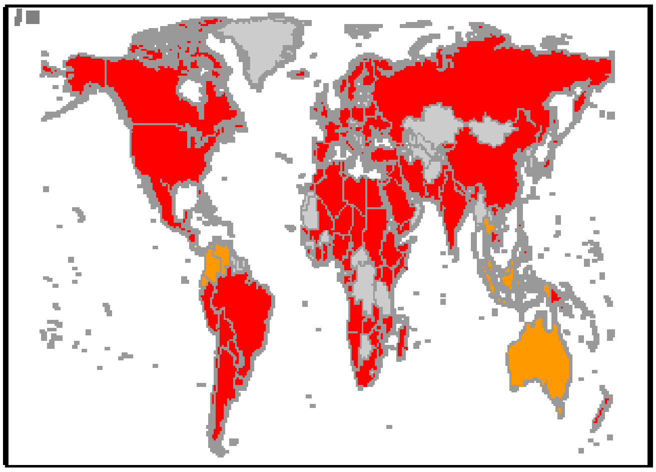

Panel D

***Figure 20.7:****Global Distributions of Vulnerability in 2100 along the A2 Scenario. Panels A and B show vulnerability in 2100 without and with enhanced adaptive capacity, respectively, along an A2 emissions scenario with the climate sensitivity equal to 1.5$^{o}$C; panels C and D show the analogous portraits for A2 with a climate sensitivity equal to 5.5$^{o}$C. Light green indicates little or modest vulnerability. Yellow designates moderate vulnerability. Orange signifies significant vulnerability, and red identifies nations where adaptive capacity would be overwhelmed by exposure. Light gray shading indicates countries for which insufficient data were available. Even enhanced adaptive capacity could not prevent moderate vulnerability in most developing and many developed countries – even for a low climate sensitivity future. Comparing the bottom panels of Figure 20.6 with the top panels here, it is clear that higher climate sensitivity essentially moves this future forward. In both cases, global distributions show at least moderate vulnerability nearly everywhere even with enhanced adaptive capacity; and developing countries and China face significant risk by 2100 even with a climate sensitivity equal to 1.5$^{o}$C. By 2100, even enhanced adaptive capacity is overwhelmed by exposure to climate change nearly everywhere.*

### *20.7.4 The complementarity roles of mitigation and enhanced adaptive capacity*

IPCC (2001) focused some attention on the co-benefits of mitigation, broadly defined to included environmental improvement in non-climate areas, improved human health, and the like. This fourth assessment has refocused attention on the potentially complementary roles that mitigation and adaptation can play in a comprehensive climate policy. The emphasis emerging from Chapter 18 is one of constructing a “portfolio of adaptation and mitigation actions” where the capacity to respond in either dimension is supported by a “similar set of factors” that are themselves determined by “underlying socio-economic and technological development paths.”

The various panels of Figures 20.8 and 20.9 plot global distributions of the vulnerability index described above with and without mitigation by 2050 and 2100, respectively, when climate sensitivity equals 5.5$^{o}$C. Left hand panels present distributions under the limiting assumption that adaptive capacities are fixed at current levels; right hand panels allow enhanced capacity as described above. The upper two panels portray distributions with temperature change driven by an unfettered A2 emissions scenario; the lower two panels do the same for an emissions scenario that restricts effective greenhouse gas concentrations to 550 ppm. The various panels of the two figures therefore show the relative efficacy of this level of mitigation with and without enhanced adaptive capacity. Through 2050, global mitigation efforts would benefit developing countries more than developed countries when combined with enhanced adaptation. By 2100, climate change would produce significant vulnerabilities ubiquitously according to either metric even if a 550 ppm concentration cap were implemented in combination with enhanced adaptive capacity.

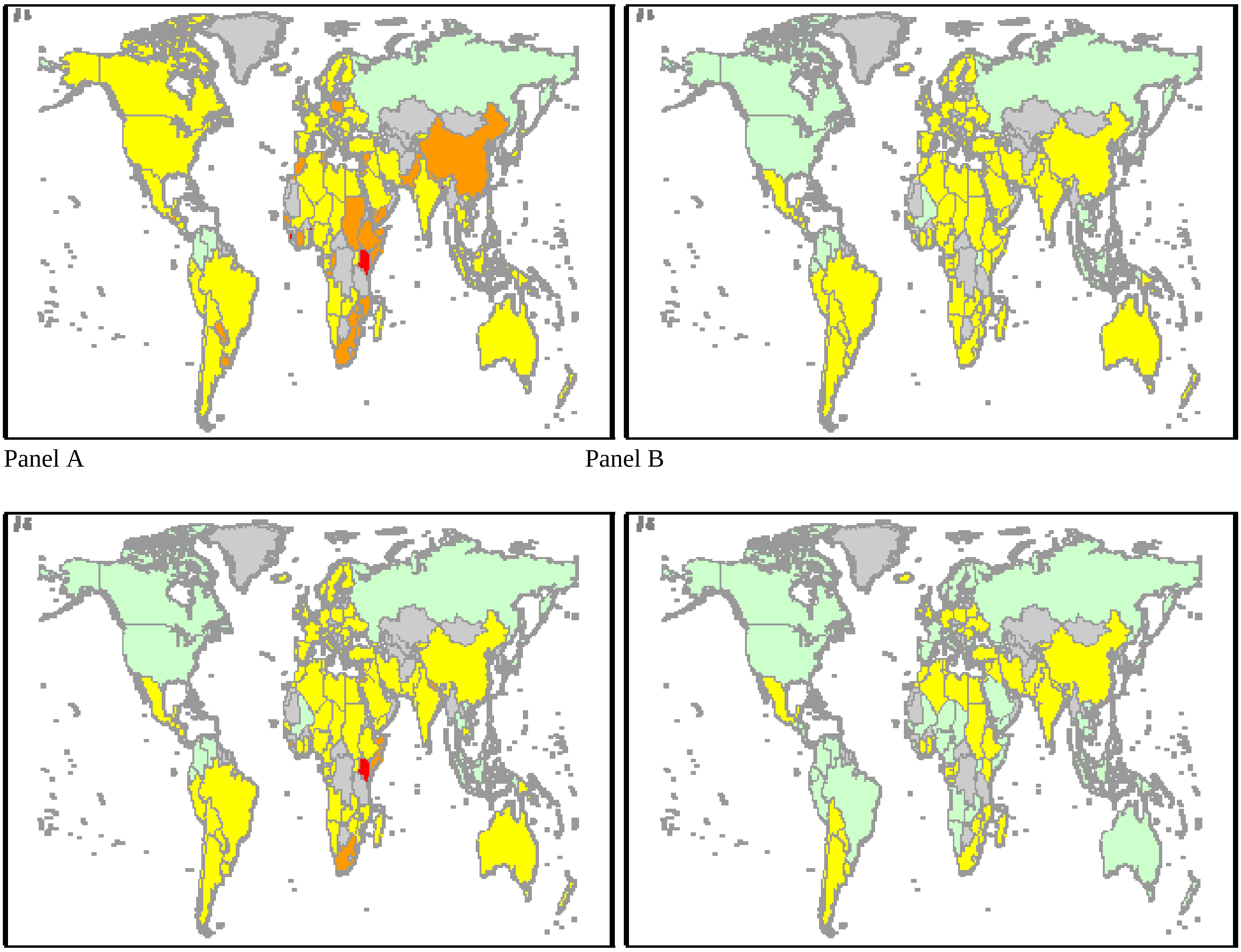
## 20.8 Opportunities, co-benefits and challenges for adaptation

This section is devoted to a discussion of some of the opportunities and challenges that can be gleaned from the current state of knowledge on linking adaptation with sustainable development. Discussions focus on the challenges involved in mainstreaming climate change adaptation into planning and development decisions, particularly with respect to participatory processes.

### *20.8.1 Challenges and opportunities for mainstreaming adaptation into national/regional/local development processes*

A synergy between the three processes (i.e. economic, social, and environmental) is key to overall sustainability, as outlined in Agenda 21, and noted in Section 20.1. Opportunities, therefore, are ample when these realities are taken into consideration with a view to developing concomitant processes to enhance economic capacity, social capital, and environmental sustainability. A synergy between national policies and community empowerment for locality-based improved disaster risk assessment and management, can lead to significant minimization of adverse consequences of natural disasters at local spaces. This can also lead to the best possible mobilization of local resources, promotion of local economic growth, and participation of local people in various processes of social transformation.

An international opportunity for adaptation to be mainstreamed into the national, regional and local development processes has recently emerged with the community approach to disaster management adopted by World Conference on Disaster Reduction (WCDR) held in Kobe, Hyogo, Japan in January 2005. (Hyogo Declaration). An empirical support for this approach is available from the results of an action research and pilot activity undertaken during 2002-2004, *albeit* on a limited scale in Bangladesh, India, and Nepal, with support from World Meteorological Organization



Panel A Panel B

Panel C Panel D

***Figure 20.8:*** *Global Distributions of Vulnerability in 2050 along the A2 Scenario with and without Mitigation. Panels A and B show vulnerability in 2050 without and with enhanced adaptive capacity, respectively, along an A2 emissions scenario with the climate sensitivity equal to $5.5^{o}C$; panels C and D show the analogous portraits for along an emissions scenario that deviates from A2 to limit atmospheric concentrations of greenhouse gases at least cost to 550 ppm. Light green indicates little or modest vulnerability. Yellow designates moderate vulnerability. Orange signifies significant vulnerability, and red identifies nations where adaptive capacity would be overwhelmed by exposure. Light gray shading indicates countries for which insufficient data were available. Mitigation or enhanced adaptive capacity can reduce vulnerability in developed countries and developing countries facing the largest risk. Combining the two brings all countries to at most moderate levels of vulnerability.*

(WMO) and Global Water Partnership (GWP). This activity focused on community approach to flood management and found that a community flood management committee formed in a local area, working in cooperation with the relevant local government and supported by national government policy, can significantly minimize the adverse consequences of floods (APJED 2004).

However, there are many challenges. The foremost challenges are the persistence of thinking among the policy-makers of compartmentalizing the three key aspects of sustainable development, with two of them (social and environmental) being given grossly inadequate attention and lack of awareness and extremely limited capacity at the community level . Economic growth is pursued through unfettered market principles, usually without regard to adverse social and environmental consequences. With the pursuit of economic growth taking precedence, the social and environmental/climate change issues are often left resource-constrained and without proper institutional support (UN Inequality Report; Ahmad and Ahmed, 2002).

It is also recognized that communities must participate in order to build resilient and effective capacity at the grassroots for sustainable development, but not generally acted upon. Also, the climate change issues still remain neglected, because of powerful oil, technology, and other lobbies internationally; lack of knowledge among policy-makers and policy advisers, particularly in the developing world; and the still persisting view that climate change is a thing of the future and, therefore, need not feature prominently in the present day policy and action regimes. The last named challenge has a political aspect to it, which is that an incumbent government's mandate is for four or five years, so that its emphasis is more on what can be achieved quickly to strengthen its immediate political capital. Therefore, adaptation to climate change is not taken as seriously as necessary.

Many countries have of course signed up to various international protocols and conventions relating to climate change and sustainable development and have adopted national environmental conservation and natural disaster management policies. But, these usually remain on the fringes of government's mainstream policy goals and processes. Suggestions for improving the mainstreaming process for multilateral environmental agreements have been offered by Watson International Scholars of the Environment (2006).

The other challenges in mainstreaming adaptation in the developing world include lack of access to adequate resources, lack of capacity for assessing the needs and developing responses, and lack of appropriate technologies, despite commitments made by the developed countries in, for example, Rio, Monterrey, and Johannesburg.

### *20.8.2 Participatory processes in research and practice*

Knowledge about climate change adaptation and sustainable development can be translated into public policy through processes that generate usable knowledge. The idea of usable knowledge stems from the experiences of national and international bodies (academies, boards, committees, panels, etc.) that offer credible and legitimate information to policy-makers through transparent multi-disciplinary processes. This requires the inclusion of local knowledge [(e.g. see Johnson (1992)] complementing more formal technical understanding generated through scientific research.

Ultimately, social learning emerges through consensus that includes both scientific discourse and policy debate. In this case, the learning process will have to include participation of local practitioners in climate-sensitive endeavours (water management, land use planning, etc.) so that past experiences can be included in the study of, and the planning for, future climate change and development pressures. There needs to be a process of integration of various dimensions of knowledge about how regional resource systems operate, how they are affected by biophysical and socioeconomic forces, and how they might be affected by future changes of various kinds. This has led to increased interest in participatory integrated assessment (PIA) as a methodology for using dialogue to facilitate the development of integrated models [e.g. Turnpenny, *et al.*(2004)] and for models to be used to facilitate policy dialogue [e.g. van de Kerkhof (2004)].

PIA is an umbrella term describing approaches in which non-researchers play an active role in integrated assessment [Rotmans and van Asselt (2002)]. Participatory processes can be used to facilitate the integration of biophysical and socio-economic aspects of climate change adaptation and development by creating opportunities for shared experiences in learning, problem definition, and design of potential solutions [Hisschemöller, *et al.*(2001)]. Van Asselt and Rijkens-Klomp (2002) identify several approaches, including methods for mapping out diversity of opinion (e.g. focus groups, participatory modelling), and reaching consensus (e.g. citizens' juries, participatory planning). Huitema, *et al.* (2004) report on a recent exercise on water policy that employed citizen's juries.

The long-term sustainability of dialogue processes is critical to the success of participatory approaches. For PIA and similar processes to be successful as shared learning experiences, they have to be inclusive and transparent. Haas (2004) describes examples of experiences in social learning on sustainable development and climate change, noting the importance of sustaining the learning process over the long term, and maintaining distance between science and policy while still promoting focused science-policy interactions. However, within the rural development literature, there has been particular concern regarding its application within development processes in poor countries. The methodology often employed is Participatory Rural Appraisal. Cooke and Kothari (2001) and Garande and Dagg (2005) document some problems, including hindering empowerment of local scale interests, reinforcing existing power structures and constraining how local knowledge is expressed. However, Hickey and Mohan (2004) offer several examples of the convergence of participatory development and participatory governance, with empowerment for marginalized communities.

Participatory governance is part of a growing global movement to decentralize many aspects of natural resources management. This is meant to improve access to resources and enhance social capital [Larson and Ribot (2004a and 2004b)]. Unfortunately, this broadening of decision making may also exacerbate vulnerabilities. For example, there have been cases emerging from Latin America describing difficulties in building national adaptive capacity as national and local institutions change their roles in governance. Although the language of sustainability and shared governance is widely accepted in this region, the benefits of globalization for adaptive capacity are unlikely to be easily obtained [Eakin and Lemos (2006)].

In order to support the growing interest in participatory governance, dialogue processes in assessment and appraisal are becoming important tools. Although they may be seen as relatively similar activities, PIA and Participatory Rural Appraisal have different mandates. The latter is directly within a policy process (selecting among development options), while the former is a research method that assesses complex problems (e.g. environmental impact of development, climate change impacts/adaptation), producing results that can have policy implications. This chapter's discussion on PIA is offered as a complement to integrated modelling results (see 20.6, 20.7), and may assist in providing regional scale technical support to match the scale of information needs of decentralized governance.

One example of a PIA of climate change adaptation is an agriculture case from the eastern United Kingdom (Lorenzoni, *et al.* (2001). Adaptation options are identified (e.g. shifting cultivation times, modifying soil management to improve water retention and avoid compaction), but there are also questions on how a climate component can be built into the way non-climate issues are currently addressed. Long-term strategies may have to include regional acceptance of greater fluctuations in crop yields than is currently the case, and to diversify operations in order to maintain farm incomes and employment. The compartmentalization of regional decision-making is seen as a barrier to encouraging more sustainable land management over the periods in which climate change evolves.

An example from Canada (Cohen, *et al.*, 2004) illustrates the linkages between water management, population growth and climate change in the Okanagan region. Planners are including consideration on how to incorporate climate change adaptation into long term water plans (Summit Environmental Consultants Ltd., 2004), but there are governance-related obstacles to proactive implementation (Shepherd, *et al.*, 2005).

Several examples illustrate the role of indigenous knowledge. Sutherland *et al.* (2005) describe a community-based vulnerability assessment in Samoa, addressing both future changes in climate-related exposure and future challenges for improving adaptive capacity. Twinomugisha (2005) describes the dangers of not considering local knowledge in dialogue on food security in Uganda. In Arctic Canada, traditional knowledge was used as part of an environmental assessment which recognized the implications of climate change on river flows and ice formation important for the ecological integrity of a large freshwater delta (NRBS Board, 1996). In another case from Arctic Canada, an environmental assessment of a proposed mine was produced through a partnership with governments and indigenous peoples. Knowledge to facilitate sustainable development was identified as an explicit goal of the assessment, and climate change impacts were listed as one of the long-term concerns for the region (WKSS Society, 2001). Additional Arctic examples are described in ACIA (2005).

A comprehensive understanding of the implications of extreme climate change requires an in-depth exploration of the perceptions and reactions of the affected stakeholder groups and the lay public. Toth and Hizsnyik (2005) describe how participatory techniques might be applied to inform decisions in the context of possible abrupt climate change. The project on "Atlantic sea level rise: Adaptation to imaginable worst-case climate change" (Atlantis) has studied one such case, the collapse of the West Antarctic Ice Sheet and a subsequent 5-6 meter sea-level rise. Possible methods for assessing the societal consequences of impacts and adaptation options in selected European regions include simulation-gaming techniques, a policy exercise approach, as well as directed focus group conversations. Each approach can be designed to explore adaptation as a local response to a global phenomenon. As a result, each sees adaptation being informed by a fusion of "top down" descriptions of impacts from global climate change and "bottom up" deliberations rooted in local, national and regional experiences.

### *20.8.3 Bringing climate change adaptation and development communities together to promote sustainable development*

The Millennium Development Goals (MDGs) are the latest international articulation of approaching poverty eradication and related goals in the developing world. At the same time, though, the on-going process of economic development through free market-based economic process continue to be pursued nationally and internationally. Indeed, economic growth is necessary for poverty reduction and promoting other millennium goals; but, unless the growth achieved is equitably distributed, the result is a lopsided development where inequality increases. In fact, many countries around the world face intensifying poverty and inequality predicament in the wake of free market policies undertaken by them (UNDP 2003; UN Inequality Predicament, 200x).

The United Nations (2004) review of progress toward attaining the eight MDGs notes that climate change is identified as a fundamental stressor only within Goal 7: "Ensure Environmental Sustainability". The climate change component is represented solely by indicators of changes in energy use per unit of GDP, and by total and per capita emissions of $CO_2$. Tracking indicators of protected areas for biological diversity, changes in forests and access to water all appear in the Goals, but they are not linked to climate change impacts or adaptation; nor are they identified as part of a country's capacity to adapt to climate change.

In addition to the MDGs, the other issues of particular concern include ensuring energy services, promoting agriculture and industrialization, promoting trade, and upgrading technologies. But, a key to sustained economic growth and poverty reduction is sustainable natural resource management that calls for clean energy sources and the nature and pattern of agriculture, industry and trade to be such as would not unduly impinge on the ecological health and resilience ; otherwise, the very basis of economic growth will be shattered through environmental degradation, more so as a consequence of climate change as a result of which both the natural and human systems are subject to ever increasing threats. A key to sustainable management of resources, while increasing productivities and production, is to develop (based on an integration of traditional and frontier technologies including bio-technologies, renewable energy, and modern management techniques) and employ "eco-technologies, rooted in the principles of economics, gender, social equity, and employment generation" (Swaminathan 2005, p.55), with due emphasis given to climate change.

For environmentally sustainable economic growth and social progress, therefore, the development policy issues must inform the work of the climate change community such that the two communities bring their respective perspectives to bear on the formulation and implementation of integrated approaches and processes. The key message is, therefore, to link up human needs keeping in sharp view the persisting debilitating poverty and environmental needs keeping in sharp view the adverse consequences of climate change. In this process, science has a critical rule to play in assessing the prevailing realities and likely future scenarios and identifying policies and cost effective methods to address various aspects of development and climate change. In order to go down this road, a strong political will and public commitment to promoting sustainable development is needed, focusing simultaneously on economic growth, social progress, environmental conservation, and adaptation to climate change. (World Bank, 1998). It is also important that private and public sectors work together within a framework of identified roles of each, with growth, social, and climate change perspectives built into the process. Also, there has to be coordination among national development and climate change communities as well as coordination among appropriate national and international institutions.

This raises an important question regarding the process for bringing climate change and sustainable development together. Growing interest in these linkages is evident in a series of recent publications, including Collier and Löfstedt (1997), Cohen *et al.* (1998), Jepma and Munasinghe (1998), Toth (1999), Munasinghe and Swart (2000, 2005), Abaza and Baranzini (2002), Markandya and Halsnaes (2002), Kok *et al.* (2002), Swart *et al.* (2003), and Yamin (2004). A number of themes recur in this literature that are of particular relevance to adaptation, such as the need for equity between developed and developing countries in the delineation of rights and responsibilities within any climate change response framework. Gardiner (2004) identifies some examples from economics (such as discounting) which raise concerns for intergenerational ethics—the interests of future generations are given relatively lower weighting in favour of short-term concerns. Beg *et al.* (2002) outlines such challenges as well, but also identifies potential synergies between climate change and other policies that could facilitate adaptation such as those that address desertification and biodiversity. Masika (2002) specifically outlines gender aspects of differential vulnerabilities. Swart *et al.* (2003) identify the need to describe potential changes in vulnerability and adaptive capacity within the SRES storylines.

Although these linkages should appear to be self evident, it has been difficult to act on them in practice. Burton and May (2004) have described the "adaptation deficit" as the gap between sustainable and observed patterns of resource use, and that climate change will lead to an increased future adaptation deficit. While mitigation within the UNFCCC includes clearly defined objectives, measures, costs, and instruments, this is not the case for adaptation. Agrawala (2005) indicates that much less attention has been paid to how development could be made more resilient to climate change impacts, and identifies a number of barriers to mainstreaming climate change adaptation within development activity. These barriers are outlined in detail in Chapter 17.

This does not mean that the linkage between development and climate change adaptation remains unrecognized within the development community. Climate change is identified as a serious risk to poverty reduction in developing countries, particularly because these countries have a limited capacity to cope with climate variability and extremes. Projected climate change impacts on human health and access to natural resources has implications for the attainment of the MDGs, including food security in Africa (AfDB *et al.*, 2003). Adaptation measures will need to be integrated into strategies of poverty reduction to ensure sustainable development, and this will require improved governance, mainstreaming of climate change measures, and the integration of climate change impacts information into national economic projections (AfDB *et al.*, 2003). Brooks *et al.* (2005) offer an extensive list of potential proxy indicators for national-level vulnerability to climate change, including health, governance and technology indicators. Agrawala (2005) describes case studies of natural resources management in Nepal, Bangladesh, Egypt, Fiji, Uruguay and Tanzania, and recommends several priority actions for overcoming barriers to mainstreaming, including project screening for climate-related risk, inclusion of climate impacts in EIAs, and shifting emphasis from creating new plans to better implementation of existing measures. The Commission for Africa (2005) explicitly links the need to address climate change risks with achievement of poverty reduction and sustainable growth.

Recent negotiations within the Conference of the Parties of the Framework Convention (the COP) have led to the establishment of new mechanisms to support adaptation including the Lesser Developed Countries (LDC) Fund, Special Climate Change Fund, and the Adaptation Fund (Huq, 2002; Brander, 2003; Desanker 2004). This has provided visibility and opportunity to mainstream adaptation into local/regional development activities. However, there are technical challenges associated with defining adaptation benefits for particular actions within UNFCCC mechanisms such as the Global Environmental Facility (GEF). For example, Huq and Reid (2004) and Burton (2004) note that the calculation of costs of adapting to future climate change (as opposed to current climate variability) as well as the local nature of resulting benefits are both problematic *vis a vis* GEF requirements for defining global environmental benefits. On the other hand, Dang *et al.* (2003) illustrate how including “adaptation benefits of mitigation” in Viet Nam offers a way of linking both criteria in the analysis of potential projects for inclusion in the Clean Development Mechanism.

To avoid misunderstanding, statements about GEF funding requirements must be read carefully. As of the winter of 2006, the COP has not yet defined how funding of adaptation activities will be costed. The LDC Fund is currently the one adaptation fund that is operational in its support of National Adaptation Programs of Action (NAPAs) in LDCs; and the COP and GEF are in the process of defining how the implementation of adaptation activities defined in NAPAs will be funded (Huq, 2006).

Significant improvement in estimates of the SCC will require well-validated assessments at the regional scale of the dynamic processes of vulnerability and adaptation.

### *20.8.4 Improving understanding of the social cost of greenhouse gases*

Many potential impacts of climate change have yet to be included into the models used for estimating the marginal damage costs of carbon dioxide and other greenhouse gases. These include recreation, tourism, amenity, urban infrastructure, many diseases, river floods, storms as well as a suite of possible impacts of abrupt change. The reason for exclusion is that too little is known about these impacts to come up with a credible, global and regionally specific estimates of impacts. In some cases, this knowledge is now emerging, and the reason for exclusion is the time lag between primary impact study and comprehensive economic impact assessment. A high priority for these efforts is to conduct robust regional studies that can focus on multiple stresses and socially contingent effects. Expanding research in this arena will require international collaboration, not least to validate regional and sectoral results at a higher resolution than captured by global models. Partnerships among researchers and stakeholders in developing countries will be essential (Downing et al, 2005).

## 20.9 Uncertainties, unknowns, and priorities for research

Synergies exist between practitioners and researchers in the sustainable development and climate change communities, but there is a need is to develop means by these communities can integrate their efforts more productively. The relative efficacies of dialogue processes and new tools required to promote this integration, as well as the various participatory and/or model based approaches required to support their efforts, must be assessed. Moreover, engaged stakeholders can inform both communities.

Significant uncertainties in estimating the social cost of greenhouse gases exist, and many of their sources have been identified. It would be good to progress in reducing these uncertainties, but coincident improvement in our ability to use existing decision support tools and design new approaches to cope with uncertainties and associated risks that will persist over the foreseeable future is even more essential.

The current state of the art in casting adaptive capacity and vulnerability into the future is primitive. We need to develop more thorough understandings of the process by which adaptive capacity and vulnerability evolve over time along specific development pathways.

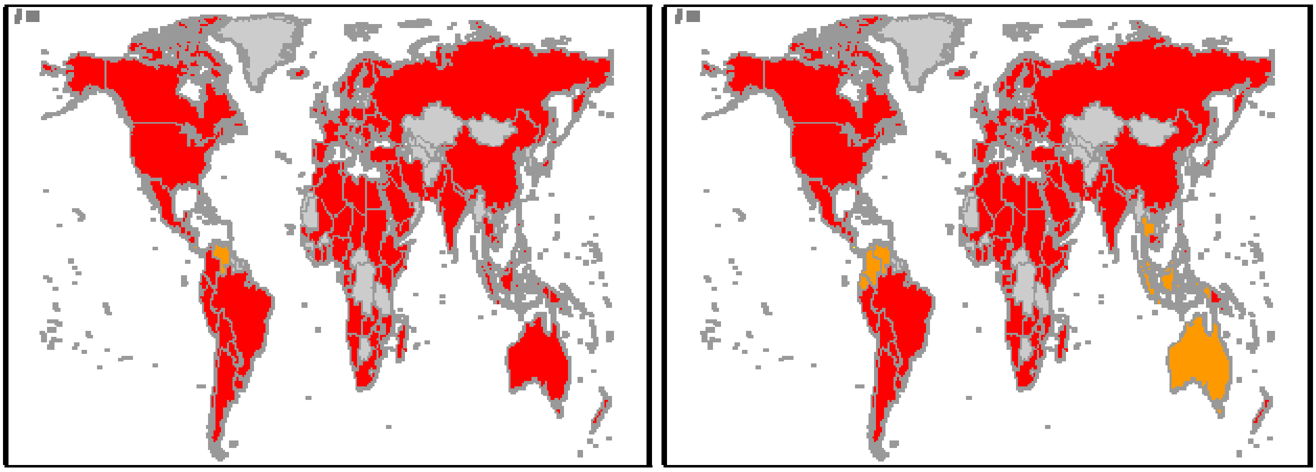
Geographical and temporal scales of development and climate initiatives vary widely. New tools are required if we are to cope effectively with these differences, particularly, for example, between the local and national, short-to-medium term scales of adaptation and development programs and projects, on the one hand, and the global, medium-to-long term scale of mitigation, on the other.

Commonalities exist across the determinants of adaptive capacity and the factors that support sustainable development, but our current ability to understand how they can be recognized and exploited is minimal.

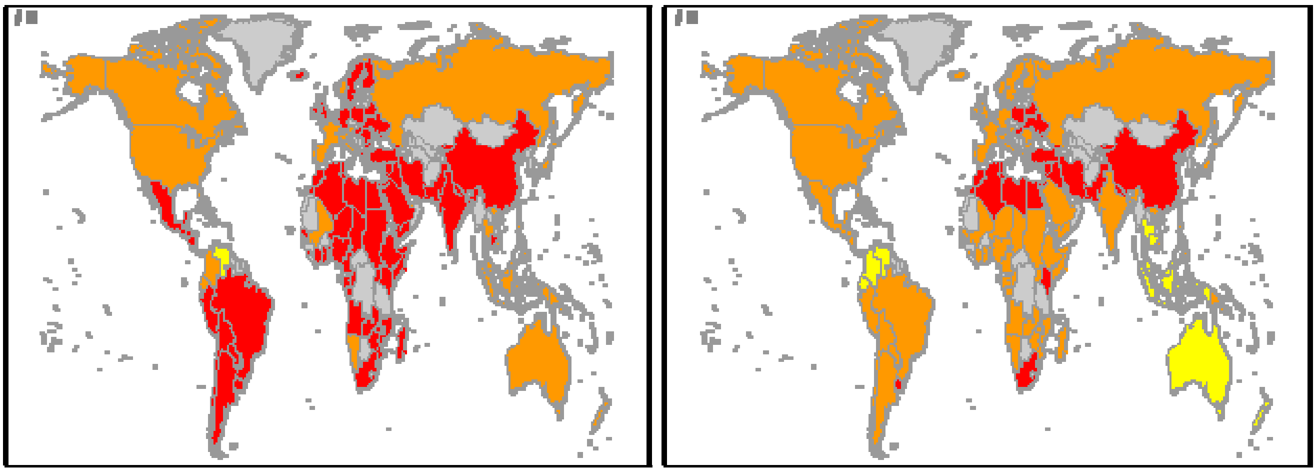
The interaction and intersection between spatially explicit and aggregate integrated assessment models is virtually a null set at the moment. For example, representations of adaptive capacities and resulting vulnerabilities in aggregate integrated assessment models are still rudimentary. As progress is encouraged in improving their abilities to depict reality, we also need to recognize difficulties in matching the scales at which models are constructed and exercised with the scales at which decisions are made. Opportunities for shared learning between practitioners and researchers should be identified, explored, and exploited.

## 20.10 Concluding Thoughts

Estimates of the aggregate effects of climate change at global and regional levels have been available for nearly two decades. They have been the stock and trade of the integrated assessment, and they have served as the foundation of the benefit-cost approach to climate change decision-making. Across more than 100 estimates from 28 studies now available, the 5% to 95% range of estimates runs from -$10 to $350 per tonne of carbon; the median estimate is $14 per tonne and the mean is $93 per tonne. Climate sensitivity, the discount rate, the treatment of global equity, and estimates of economic and non-economic damages explain much of the variation across this range. In addition, since none of the estimates takes explicit account of the local conditions where climate impacts will be felt, this range of estimates cannot possibly reflect the implications of geographically driven diversity in these conditions. Clearly, uncertainty persists.



Panel A Panel B



Panel C Panel D

***Figure 20.9:*** *Global Distributions of Vulnerability in 2100 along the A2 Scenario with and without Mitigation. Panels A and B show vulnerability in 2100 without and with enhanced adaptive capacity, respectively, along an A2 emissions scenario with the climate sensitivity equal to $5.5^{o}C$; panels C and D show the analogous portraits for along an emissions scenario that deviates from A2 to limit atmospheric concentrations of greenhouse gases at least cost to 550 ppm. Light green indicates little or modest vulnerability. Yellow designates moderate vulnerability. Orange signifies significant vulnerability, and red identifies nations where adaptive capacity would be overwhelmed by exposure. Light gray shading indicates countries for which insufficient data were available. Mitigation is more effective in reducing extreme vulnerability in developed countries; and it combines with enhanced adaptation to diminish the index across much of the developing world.*

When this uncertainty is factored into the climate equation, the answer to questions like "Who is most vulnerable?" or "Who benefits most from mitigation?" becomes "It depends." Current knowledge makes it possible to cast vulnerability to climate change in terms of adaptive capacity (indexed for specific nations according the relative strengths of underlying determinants) and exposure (reflected by changes in national annual mean temperatures). The "burning embers" of the TAR make it possible to calibrate that vulnerability qualitatively in terms of several alternative metrics: aggregate impacts, risk of extreme events, and so on. Doing so supports the long-held opinion that developing countries are generally more vulnerable than developed countries, but only if the effects of climate change on the chosen metric are not so severe that they overwhelm the capacities of even the most advanced economies to adapt. In terms of extreme events, for example, think about the 2003 European heat-wave or hurricane Katrina. Meanwhile, the converse of this conclusion also carries water. Through 2050 with low climate sensitivity, global mitigation efforts would benefit developing countries (in terms of reducing an aggregate vulnerability index) more than developed countries. By 2100, or earlier if climate sensitivity is high, unfettered climate change would overwhelm adaptive capacity nearly everywhere and mitigation would reduce the vulnerability of developed countries more than developing countries.

In the real world, of course, climate change is one of many sources of external stress. Systems that are vulnerable to climate change are usually vulnerable to a multiplicity of other non-climatic pressures like poverty, unequal access to resources, food insecurity, and environmental degradation. All of these external stressors interact in complex ways that vary from place to place and over time along specific development pathways. Indeed, development and adaptation choices directed at coping with any of these stresses can have significant (negative or positive) effects on future near-term and long-term climate change. Why? There are several aspects to the answer to this question. One is that perturbations in the climate system have long-lived effects. A second is that socio-political-economic systems can become extremely rigid and difficult (or expensive) to change after development or climate-policy decisions, like investment in energy or transportation infrastructures, have been taken. Still another is that coping with the complexity of climate-sensitive systems may create significant tradeoffs against competing social objectives or produce unanticipated and unintended consequences. It is therefore no surprise to conclude, with high confidence, that increased vulnerability to climate change can impede nations' abilities to move along sustainable development pathways; and vice versa.

It is important to see the opportunity hiding in this complexity. Efforts to cope with the impacts of climate change and attempts to promote sustainable development in the face of other stressors share common goals. Perhaps more importantly, sustainable development programs and interventions designed to improve a system's capacity to adapt to climate change both depend on strength across a common set of supporting factors. These commonalities include providing access to resources, promoting equity in their distribution, sustaining quality stocks of human and social capital, expanding access to efficient risk spreading mechanisms, and supporting the abilities of decision-support mechanisms to cope with uncertainty. As increasing attention is paid to coping with accelerating climate change to which we are already committed, it should be possible to take advantage of significant synergies across these commonalities. To do so will require bringing climate change to the development community and bringing development concerns to the attention of the climate change community – continuing the incremental learning evidenced by this chapter. Therein lies the next challenge, and therein may lie significant reward.

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