Chapter 20. Climate-Resilient Pathways: Adaptation, Mitigation, and Sustainable Development

Coordinating Lead Authors
Fatima Denton (Gambia), Thomas Wilbanks (USA)

Lead Authors
Ian Burton (Canada), Achala Chandani (Sri Lanka), Qingzhu Gao (China); Maria Carmen Lemos (USA), Toshihiko Masui (Japan), Karen O'Brien (Norway), Koko Warner (Germany)

Contributing Author
Thea Dickinson (Canada)

Review Editors
Suruchi Bhadwal (India), Walter Leal (Germany), Jean-Pascal van Ypersele (Belgium)

Contents

Executive Summary

Sustainable development within the context of climate change calls for new approaches to development that take into account complex interactions between climate and society. Climate-resilient pathways are not predetermined routes defined by a given set of practices. Rather, they are potential trajectories that link current decisions and actions with an emergent future – a future which recognizes that the consequences of climate change call for transformative planning and responses. These responses include both climate change risk reduction through mitigation and adaptation and also resilience in sustainable development pathways themselves.

This chapter integrates a variety of complex issues in assessing climate-resilient pathways in a variety of regions at a variety of scales: sustainable development as the ultimate aim, mitigation as the way to keep climate change impacts moderate rather than extreme, adaptation as a response strategy to cope with impacts that cannot be (or are not) avoided, and elements of sustainable development pathways that contribute to resilience. Climate-resilient pathways recognize that impacts are certain, because climate change can no longer be avoided. Ignoring this source of stress will endanger sustainable development. As a result, vulnerability assessments and risk management strategies are important, considering both possible/likely climate effects – extremes as well as average – and also development conditions such as demographic, economic, and land use patterns and trends; institutional structures; and technology development and use. In most cases, vulnerabilities and appropriate risk management approaches will differ from situation to situation, calling for a multi-scale perspective built solidly on fine-grained contextual realities. But most situations share at least one fundamental characteristic: threats to sustainable development are greater if climate change is substantial than if it is moderate.

This chapter's assessment findings are the following. Although they are based on a high level of consensus in source materials and in the expert communities, the amount of supporting evidence is usually limited by the fact that so many aspects of sustainable development and climate change mitigation and adaptation, considered together over periods many decades into the future, are surrounded by issues that are beyond past and current observation and experience.

Climate change is a significant threat to sustainable development, especially if climate change is substantial rather than moderate. (High confidence: high agreement, moderate evidence; see section 20.2.2). Climate change can no longer be avoided; and, added to other stresses on sustainable development, its effects will make sustainability more difficult to achieve for many locations, systems, and affected populations.

Reducing this threat will require <u>both</u> resilient sustainable development pathways and actions to reduce climate change and its impacts, including both mitigation and adaptation. (High confidence: high agreement, moderate evidence; see sections 20.2.3, 20.3, and 20.4) Adaptation and mitigation can both contribute to and impede sustainable development, and sustainable development strategies and choices can both contribute to and impede climate change responses.

Integrating these elements of climate-resilient pathways, often in place-based contexts, offers potentials for win-win consequences. (Moderately high confidence: moderately high agreement, moderately strong evidence: see sections 20.2.2, 20.3.3, 20.4, 20.3, and 20.5.4) Development pathways that are fully resilient from a sustainable development standpoint are also likely to be the pathways best-suited to be climate resilient; strategies to achieve each goal have the potential to reinforce each other.

With more substantial change, resilience will often require *transformational* adaptations: responses that change the nature, composition, and/or location of threatened systems in order to sustain development. (High confidence: high agreement, moderately strong evidence; see sections 20.2.2, and 20.4.2) Larger increases in climate extremes or climate-related severe weather events are less amenable to incremental adaptations to climate change.

At a global scale, climate-resilient pathways will include actions that promote both climate change adaptation and mitigation in a sustainable manner, while at sub-global scales climate-resilient pathways will involve a range of actions appropriate to differences in potentials for vulnerability and risk reduction. (High confidence: high agreement, moderately strong evidence; see section 20.5.3) Although at a global scale, both

mitigation and adaptation will be essential, relatively local scales in many developing regions have limited capacities to include mitigation in their climate-resilience strategies because they contribute very little to the causes of climate change.

Although payoffs from specific long-term pathways may be uncertain, strategies and actions can be pursued now that will reduce climate change risks, promote adaptive management, and contribute significantly to prospects for climate-resilient pathways while helping to improve human livelihoods and social and economic well-being. (High confidence: high agreement, moderate evidence; see section 20.5.4) Actions at the present time will emphasize co- benefits and iterative learning, with risk management strategies refined continually on the basis of growing bases of knowledge and experience.

20.1. Introduction

Following summaries of *what we know* about climate change impacts, vulnerabilities, and prospects for adaptation (Chapter 18) and of *what we should be most worried about* (Chapter 19), this concluding topical chapter of the Working Group II Fifth Assessment Report summarizes what is currently known about options regarding *what to do* in responding to these risks and concerns.

As evidence of climate change begins to emerge, the need to address both near-term and longer-term implications of climate change is increasing as an issue for policymaking and decision-making. This includes responses to *observed* impacts as well as managing risks of *projected* impacts, which in many cases converts "what to do" from prudent long-term contingency planning to planning for relatively near-term actions. Reconciling short-term and long-term goals is thus becoming an increasingly important dimension of sustainable development policies. This is important not only in response to climate variability and extreme events, as was highlighted in the SREX report (IPCC 2012), but also in response to the impacts of more gradual changes, which are becoming increasingly evident around the world (Chapter 19).

As a result, the big-picture, long-term consequences of climate change are now being seriously considered, along with the types of responses that can contribute to sustainable development. For example, UNFCCC negotiations have included attention to such questions as: What strategies and actions, on the part of all nations, can contribute to effective approaches to sustainable development, including appropriate climate change mitigation and adaptation commitments and actions? How should climate change policy be integrated into sustainable development? What are alternative pathways for developing countries to achieve sustainable development in the context of challenges from climate change? These questions derive from principles contained in Articles 2 and 3.4 of UNFCCC with the ultimate objective of stabilizing greenhouse gas concentrations in the atmosphere, as expanded by the Delhi Ministerial Declaration on Climate Change and Sustainable Development: Decision 1/CP.8 (see Box 20-1).

_____ START BOX 20-1 HERE _____

Box 20-1. UNFCCC Goals for Climate-Resilient Pathways

Climate resilient pathways are trajectories of combined mitigation and adaptation that are consistent with the aims of sustainable development and which do not traverse the threshold of "dangerous anthropogenic interference with the climate system" as specified in Article 2 of the Convention.

Article 2 of the United Nations Framework Convention on Climate Change presents the ultimate objective as the, '*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.'* According to the Convention, the climate system must not be dangerous in order to "allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". Article 3.4 recognizes that "Parties have a right to, and should promote sustainable development." The Copenhagen Accord of 2009 states, "To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change."

The Cancun Agreements Decision 1/CP.16 confirms this with a view that "… recognizes … deep cuts in global greenhouse gas emissions are required according to science, and as documented in the Fourth Assessment Report of the IPCC, with a view to reducing global greenhouse gas emissions so as to hold the increase in global average temperature below 2°C above preindustrial levels…consistent with science…[and] also recognizes the need to consider, in the context of the first review… strengthening the long-term global goal on the basis of the best available scientific knowledge.

The 2011 Conference of the Parties in a decision known as the Durban Platform increases the strength of the language in the decision -/CP.17 to conclude, "… climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires to be urgently addressed … with a view to accelerating the reduction of global greenhouse gas emissions.... Current UNFCCC negotiations have once again adopted +2°C as the desirable target upper limit and equated this with "dangerous" in Article 2.

_____ END BOX 20-1 HERE _____

In many cases, reducing the long-term impacts of climate change on nature and society will require transformational changes that address the drivers of both greenhouse gas emissions and social vulnerability to impacts. Limiting the rate and magnitude of climate change and its impacts on society is thus becoming a key dimension of sustainable development, and there is a growing recognition that transformation of behaviors, systems, cultures and institutions may be a prerequisite for avoiding dangerous climate change consequences (Raskin et al., 2011; Westley, et al. 2011; O'Brien, 2012).

Sustainable development within the context of climate change calls for new approaches to development that takes into account complex interactions between climate and society. Climate-resilient pathways are not predetermined routes defined by a given set of practices. Rather, they are potential trajectories that link current decisions and actions with an emergent future – in this case a normative, desirable future that recognizes that the consequences of climate change call for transformative planning and responses which include both mitigation and adaptation, carried out in a reflexive and ethical manner to promote equitable and sustainable development (Gallopin, 2006; Nelson, Adger, and Brown, 2007; Robinson et al., 2006; Miller, 2007).

Chapter 20 integrates a variety of complex issues in assessing climate-resilient pathways in a variety of regions at a variety of scales: sustainable development as the ultimate aim, mitigation as the way to keep climate change impacts moderate rather than extreme, adaptation as a response strategy to cope with impacts that cannot be (or are not) avoided, and development pathways as contexts that shape choices and actions. It is organized in five parts: sustainable development as a context for climate resiliency, posing challenges for both climate change responses and sustainable development pathways (20.2), contributions to resilience through climate change responses (20.3), contributions to resilience through sustainable development strategies and choices (20.4), perspectives on appropriate and effective pathways (20.5), and important gaps in existing knowledge for clarifying what to do (20.6). The chapter shows that adaptation and mitigation can both contribute to and impede sustainable development, and sustainable development strategies and choices can both contribute to and impede climate change responses. Climate resilient pathways can be considered those trajectories that not only recognize the relationship between mitigation, adaptation and sustainable development, but also invoke transformative actions to deliberately avoid dangerous climate change and its impacts (see Box 20-1).

Several of the terms that are central to this chapter have been defined earlier in the Working Group 2 Fifth Assessment Report, including climate, adaptation, and mitigation. In addition, by "resilient" we mean a system's capacity to anticipate and reduce, cope with, and respond to and recover from external disruptions (IPCC SREX, 2012). For literatures on "sustainable development," see section 20.2.1 below. A summary definition is development that achieves continuing human progress and assures a sustainable relationship with a physical environment that is already under stress, reconciling tradeoffs among economic, environmental, and other social goals through institutional approaches that are equitable and participative in order themselves to be sustainable.

The aim of the chapter is to consider the attributes and characteristics of pathways for sustainable development that are resilient to impacts of climate change, including potentials and possible limitations. The chapter considers pathways that can incorporate climate change as one of many issues for development in order to avoid serious disruptions, from both adaptation and mitigation perspectives (Figure 20-1). For instance, prospects for climate-resilient pathways are rooted in potentials for climate change adaptation in order to enhance coping capacities, but they are profoundly shaped by the rate and magnitude of climate change, which depend on potentials for climate change mitigation. Effects of climate change interact with other factors that shape development – economic, social, institutional, environmental, political, and technological – in an immense variety of development contexts: e.g., different threats, different locations, different time frames, different vulnerable systems/populations, different response capacities. Although this diversity complicates any attempt to offer broad generalizations that are of value, the chapter provides a framework for thinking about this problem and offers some examples of both challenges and possible response strategies.

[INSERT FIGURE 20-1 HERE
Figure 20-1: Sustainable development depends on effective responses to climate change and other stresses.]

20.2. Sustainable Development as a Context for Climate Resiliency

Climate-resilient pathways bring together (a) sustainable development as the larger context for societies, regions, nations, and the global community with (b) climate change effects as threats to (and possibly opportunities for) sustainable development and responses to reduce those effects that would undermine future development and even offset already achieved gains (Figure 20-1).

20.2.1. The Challenge of Sustainable Development

"Sustainable development" is a concept rooted in many decades of concerns about relationships between society and nature (e.g., Brown, 1981). These concerns grew during the 1960s and 1970s in connection with observations of a declining quality of the environment coupled with increasing needs for resources as populations expand and living standards rise. Early initiatives focused more on individual attributes of the environment, including water quality, air quality, management of hazardous substances and natural resources. Some of the outcomes from these initiatives included a complex array of regulations intended to manage and improve development, a movement toward recycling of consumable resources, and an emphasis on renewable energy as a substitute for energy production that consumed non-renewable fossil fuel resources (Frey and Linke, 2002). While the initiatives taken regionally had many positive effects, it soon became evident that there were global environmental issues that needed to be addressed as well.

The Brundtland Report defines sustainable development as that which meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The report also recognizes that poverty is one of the main causes of environmental degradation and that equitable economic development is key to addressing environmental problems both in developing and developed regions.(Halsnaes et al., 2008; Lafferty and Meadowcroft, 2010). From a practical perspective, sustainable development has been "operationalized" through Agenda 21, which is a comprehensive plan of action adopted at the 1992 Earth Summit by more than 178 governments (Sitarz, 1994), and "Rio+20" in June 2012 is expected to urge countries to renew their commitment to sustainable development. Meanwhile, although the existing global discourse and practice around sustainable development has helped to establish some commonly held principles, the concept itself remains elusive and contested (e.g., Hopwood, Mellow, and O'Brien, 2005; Jabareen, 2008). For example, sustainable development has been criticized as being vague and immeasurable; and its connections with continued economic growth have drawn suspicion from both those who believe sustainable development is a strategy to slow or limit development in the developing world and from those who think that continued growth is itself non-sustainable (e.g., Robinson, 2004). Whereas some authors equate sustainable development with equity and values through which climate policies can be implemented (Najam et al., 2006), in practice some national authorities tend to interpret sustainable development as economic development, perhaps in part because the term sustainable development has gained political currency, despite an apparent lack of attention to distributional impacts.

Conceptual understandings of sustainable development have developed considerably, particularly over the past two decades, as the short- and long-term implications of climate change and extreme events have become better understood, although empirical evidence of progress with sustainable development is often elusive. The discussion of sustainable development in the IPCC process has evolved since the First Assessment Report, which focused on the technology and cost-effectiveness of mitigation activities, and the Second Assessment Report (SAR), which included issues related to equity and to environmental and social considerations. The Third Assessment Report (TAR) further broadened the treatment of sustainable development by addressing issues related to global sustainability, and the Fourth Assessment (AR4) included chapters on sustainable development in both WG II and III reports, with a focus on both climate-first and development-first literatures.

20.2.2. Links between Sustainable Development and Climate Change

As the extent of implications of climate change become better-understood (Chapter 18) and as particular reasons for concern have begun to come into focus (Chapter 19), climate change has been increasingly seen as an issue for sustainable development – with the potential either to aid or impede its sustainability (e.g., Halsnaes, et al., 2008; Munasinghe, 2010). The links between sustainable development and climate adaptation and mitigation are cross-cutting and complex. First the effects of climate change may derail current sustainable development policy and potentially offset already achieved gains (see Boxes 20-2 and 20-3). Second, mitigation has the potential to keep these threats at a moderate rather than extreme level and adaptation will enhance the ability of different systems to cope with the remaining impact, therefore modulating negative effects on sustainable development. Third, many of the conditions that define vulnerability to climate impact and the ability to respond to them are firmly rooted in development processes (e.g., structural deficits and available assets and entitlements). Fourth, current levels of sustainable development intersect with many of the drivers of climate change, especially regarding energy production and consumption and ability to mitigate emissions. Fifth, because several of the conditions that predict success of mitigation and adaptation may overlap with those of sustainable development, systems where sustainable development has been effectively embraced may provide a more conducive context for the implementation of successful mitigation and adaptation. Finally, climate mitigation and adaptation, if planned and integrated well, have the potential to create opportunities to further fostering sustainable development (see section 20.3.3 below). Understanding how to enhance positive feedbacks while minimizing negative ones is an essential part of planning for and pursuing climate-resilient pathways. In the next paragraphs we discuss these links in light of empirical findings and specific examples (Boxes 20-2 and 20-3). While some of the links described above have been contemplated in the scholarly literature, there remain considerable gaps on our knowledge base to inform climate resilient pathways.

_____ START BOX 20-2 HERE _____

Box 20-2. Key Reasons for Concern about Climate Change Effects on Sustainable Development

Chapter 19 of IPCC's Fourth Assessment Report, Working Group 2, was concerned with "Addressing Key Vulnerabilities and the Risk from Climate Change" (IPCC, 2007). Changes in perceived risks compared with the Third Assessment Report were reviewed in Smith et al., 2009.

As reported in these sources, key vulnerabilities to climate change that might affect sustainable development include the following, recognizing that the distribution of such impacts can be uneven and variable across both space and time:

- Increases in the frequency and/or intensity of extreme events
- Loss of glaciation and sea-ice cover
- Loss of biodiversity: threats to unique and threatened systems
- Loss of coral reefs and some Arctic ecosystems
- Decreased agricultural productivity and food security in some areas

- Decreased water availability and increased drought in some areas
- Potentials for environmental migration
- Increases in human mortality

[to be updated from AR5 Chapter 19 FOD]

Especially at risk are Africa, small islands, dense concentrations of population in vulnerable coastal areas, and biological populations adapted to conditions in border zones between climatic regimes. Cross-cutting reasons for concern include possible limitations and/or costs of adaptation in some areas and the possibility of thresholds (e.g., TAR pointed to possibilities of "large-scale singularities": IPCC, 2001).

_____ END BOX 20-2 HERE _____

_____ START BOX 20-3 HERE _____

Box 20-3. Connecting Representative Concentration Pathways with Shared Socioeconomic Pathways

The climate change science community has developed a new set of visions of a range of climate futures, called "Representative Concentration Pathways" or RCPs, intended to replace the rich families of SRES scenarios (IPCC, 2000) that were used extensively by IPCC and others for a decade. As reported in Moss et al., 2010, the RCPs include four representative pathways to illustrate the range of possible climate futures, defined in terms of approximate radiative forcing levels. These scenarios represent a broad range of potential climate outcomes, both over the near term (to 2035) and longer term (2100 and beyond).

To accompany these RCPs and provide context for assessing impacts of such futures, the climate change science community is also developing a set of representative socioeconomic futures, reflecting different pathways of economic intensity, capacity for societal problem-solving, and other dimensions of socioeconomic futures, called Shared Socioeconomic Pathways (SSPs), each defined by a storyline and supported by qualitative and quantitative characterizations (Kriegler et al., 2011). In principle, it will be possible to compare socioeconomic conditions (SSPs) with climate forcings (RCPs) to evaluate such issues as differences in needs and challenges for mitigation or the feasibility of adaptation associated with different contexts regarding driving forces (see section 20.5).

_____ END BOX 20-3 HERE _____

Is it possible to have sustainable development that is not climate resilient? The relationship between climatic change and development has often been theorized as mainly twofold. On the one hand, climate change will affect development policy as needs to respond to negative, and perhaps positive, impacts arise (Schipper, 2007; Burton et al., 2002; Halsnaes and Verhagen, 2007). On the other hand, development policy critically shapes carbon emission paths, the ability to develop sustainable adaptation and mitigation options, and to build overall adaptive capacity (Bizikova, Robinson, and Cohen, 2007, Garg, et al., 2009, Metz and Kok, 2008, Lemos, et al. 2007). Because of the recognized relationship between development and climate change drivers and responses, some authors have called for a "political economy of climate change" that takes into considerations ideas, power and resources at different scales from the local to the global (Allouche and Tanner, 2011). Enhancing resilience to respond to effects of climate change includes adopting good development practices that are consonant with building sustainable livelihoods and, in some cases, challenging current models of development (Boyd et al., 2008). Moreover, promoting development pathways that are both equitable and sustainable is also key to addressing climate change (Wilbanks, 2003, Nelson et al. 2007). It is now widely recognized that activities necessary to enhance adaptive capacity are also important for promoting sustainable development and vice-versa, although adaptation on its own -- without sustained mitigation of greenhouse gas emissions– cannot offset all of the negative impacts of climate change. And yet, whereas climate change impacts are often strongly correlated with threats to sustainability, the debate on climate change has tended to run separately from the wider sustainability discourse (Cohen et al., 1998, IPCC, 2001). Integrating sustainable development and overall climate change policy can be all the more relevant if "cross-linkages between poverty, the use of natural capital and environmental degradation" are recognized (Veeman and Politylo, 2003: 317; also see Matthew and Hammill, 2009). Especially in less developed countries/regions, the relationship between vulnerability to climate impacts and development is often inclusive and mutually dependent as such realities as low per capita income and inequitable distribution of resources; lack of education, health care, and safety; and weak institutions, unequal power relations and weak democracy fundamentally shape sensitivity, exposure and adaptive capacity to climate impact (Garg et al., 2009; Lemos et al., 2007). In these regions, reducing risks that affect resource-dependent communities is increasingly viewed as a necessary, but insufficient way to tackle the myriad of problems associated with climate change impacts (Jerneck and Olsson, 2008). Hence, building adaptive capacity is both a function of dealing with underdevelopment and of improving risk-management (Mirza, 2003; Schipper and Pelling, 2006; Tompkins, Lemos, and Boyd, 2008). In this context, it becomes critical not only to understand the relative importance of different kinds of interventions (climate and non-climate) in building adaptive capacity but also the potential positive and negative synergies between them. They include both actions that address underdevelopment such as socio-developmental policies (e.g. poverty alleviation, reducing risks related to famine and food insecurity, enabling/implementing public health and mass literacy programs) and also conventional climate impact risk management (e.g. alert systems, disaster relief, crop insurance, climate forecasts).

While research increasingly highlights the intersection between vulnerability, adaptive capacity and developmental structural deficits, however, there is also growing recognition that the intractability of many of these problems may inhibit the development of climate resilient pathways. For example, research by Wolf et al. (2009) on climate change responses in western Canada shows that self-efficacy and ecological citizenship play an important role in the identification and implementation of sustainable responses to water scarcity. In contrast, a lack of voice can suppress innovative decisions about the future. Research focusing on disaster response in Mexico shows that alienation of individuals is instrumental to creating a compliant citizenry, and that resilience is undermined by a limited breadth of learning and experimentation, centralized power, and limited economic diversity (Pelling and Navarrete, 2010). In NE Brazil, the fact that local traditional politics relied on client-list relationships with drought-affected households to maintain power suggests that there was little incentive for policies that dramatically decreased their level of vulnerability (Tompkins, Lemos, and Boyd, 2008). Omolo (2010) argues that in the Northern western Kenya, in pastoralist societies of Turkana, in spite of increasing numbers of women headed households, participation of women in key decisions such as investment, resource allocation, and planning on where to move or settle in the aftermath of drought and floods is still quite low. One serious concern is that our inability to readily address these structural problems may limit options for future generations of marginalized social groups as active agents of a climate resilient future. In this sense, it is critical to understand how existing path dependent trajectories (e.g., socio-technical, behavioral, institutional) that form the contextual basis for climate change action at different scales (Burch 2011) may inhibit (or help) the realization of future climate resilient pathways.

The role of values in responding to climate change becomes important from a variety of perspectives, including intergenerational, particularly when those currently in positions of power and authority assume that their prioritized values will be shared by future generations (O'Brien, 2009). Acknowledging the importance of intergenerational equity, it has been argued that participatory processes and 'deliberative democracy' can include the concerns, values and perceptions of a wide range of stakeholders, raising some of the ethical impacts attached to climate related risks (Backstrand, 2003, see also Deere-Birebeck, 2009). Such an approach could have a bearing on the way those risks are assessed and addressed at the science-policy interface, with significant implications for sustainable development. A number of studies recognize that not every possible response to climate change is consistent with sustainable development, in that some strategies and actions may have negative impacts on the well-being of others and future generations (Eriksen, et al., 2011; Gardiner et al., 2010). For example, some mitigation measures, such as changing the composition of the atmosphere through geoengineering, could influence large-scale weather systems and create potentially dangerous conditions or new problems for many others (Gardiner et al., 2010, Carlin, 2007; Brovkin et al., 2009; de Sherbinin et al., 2011; also see section 20.2.3.4). Likewise, some adaptation measures, such as using more surface water or groundwater for irrigation, may have negative effects on other users and more rapidly deplete scarce natural resources that could come under increasing pressure with climate change (Eriksen et al., 2010). The consequences of responses to climate change, whether related to mitigation or adaptation, can negatively influence future vulnerability, unless they are linked to the wider context of sustainable development (Bizikova et al., 2010). In light of the complex interactions among climate change responses and sustainable development, there is a need for more holistic responses that place human well being and security at the forefront, while building on existing strengths and capacities (Tompkins and Adger, 2004; O'Brien et al., 2010). This entails integrating multiple objectives and policy goals to promote sustainable responses to climate change that contribute to resilience (Meadowcroft, 2000; Tompkins and Adger, 2004).

One reality in many countries may be that development – which seeks to increase economic wealth – can enhance the capacity to adapt while at the same time adding to greenhouse gas emissions. Yet, the World Development Report 2010 suggests that climate change responses have the potential to enhance sustainable development as, for example, in the case of financial assistance with transition to low-carbon growth paths (World Bank, 2010) or in the case of mitigation policies that increase incomes in vulnerable groups such as REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries). And while vulnerable sectors such as agriculture give us particular reasons for concern (see Box 20-4), they may offer opportunities to reduce climate related risks and threats by integrating both adaptation and mitigation strategies as a lever for reducing poverty and promoting climate compatible development. Particularly necessary is addressing institutional and social capacities for responding to both climate change impacts and mitigation responses. For example, Chhatre and Agrawal (2009) show that climate change mitigation can benefit livelihoods if ownership of forest commons is transferred to local communities. These kinds of possible implications of climate change connect with drivers of sustainable development, and in turn social and economic dimensions of development affect the likelihood of effective responses to climate change risks (see Box 20-4). Moreover, some interventions related to climate change responses aim to combine goals of sustainable development, climate change adaptation, and climate change mitigation into "triple win" approaches that highlight overlaps between these goals. Examples include mechanisms such as CDM and IJI (e.g., Millar, Stephenson, and Stephens, 2007), which seek to offset carbon emissions, build adaptive capacities of local communities, and provide sustainable development dividends (Corbera and Brown, 2008). Because relationships among the three goals can lead to both positive and negative consequences, however, it is important to unravel conditions that lead to desirable outcomes (Chhartre and Agrawal, 2009). (See section 20.2.3.3. for a detailed discussion).

_____ START BOX 20-4 HERE _____

Box 20-4. Climate-Related Vulnerabilities and Adaptation of African Smallholder Farming

Small holders in Africa are vulnerable not just to climate but also to myriad of stressors that increase both their exposure and sensitivity. In Ghana, bushfires and forest clearance in the 1980s forced communities to abandon the once lucrative business of cocoa farming. Instead, communities resorted to maize production. Attempts to re-establish cocoa farms after the bush fires were unsuccessful mostly because of to decline in soil fertility, declining rainfall and high rates of deforestation. Adaptation options to help improve soil fertility and boost production of maize included planting of early maturing crops, planting of different crop varieties; planting of drought tolerant crops; changing of planting times; construction of firebelt and intercropping. As a result of intercropping activities, farmers reported an increase in maize grain yield from 0.90 t ha^{-1} to 3.0 t ha^{-1} on unfertilized plots. What this case study reveals is that without viable adaptation strategies that include appropriate knowledge and access to improved technologies, poor communities may resort to unsustainable farming practices which deplete ecological goods and services, further jeopardizing the well-being of the ecosystems and reducing choices to live off the land (see, for example, Green and Raygorodetsky, 2010; Nyong et al., 2007; Speranza et al., 2010).

In the Ugandan areas of the Tororo, Kisoko and Osukuru, soil quality is poor and farmers' capacity to adopt recommended soil fertility management practices remains weak. Rainfall in the Tororo district tends to be bimodal – with two annual crop growing seasons. Because sorghum and finger millet have been replaced by maize and upland rice in marginal areas largely suited for small grain crops, there has been an overwhelmingly high rate of crop failure, leaving many households vulnerable to food shortages. Adaptation options include the implementation of Integrated Soil Fertility Management (ISFM) through which farmers were able to boost the productivity of sorghum, millet and prioritized grain legumes under changing climate where rainfall conditions were poor and erratic. Yet risks related to food deficits as a result of soil fertility problems worsened, and coupled with climatic change, has and could further expose smallholder farmers threatening the sustainability of their prevailing livelihoods structures.

In Northern Zambia, deforestation is a major problem and it is largely attributed to charcoal burning and slash/burn Chitemene shifting cultivation system. Climate variability including floods, droughts and other extreme events contributes to decreasing livestock population, crop failure, food insecurity and reduced crop yields. Knowledge generated from learning centres indicates that late-planted crops result in high yield penalties. For instance, a four-week delay in planting reduced maize yields from more than 6 t/ha to 1.5 t/ha in Mungwi (http://www.aec.msu.edu/fs2/zambia/wp47_final.pdf). Poor natural resource management practices tended to reinforce their vulnerability. Inorganic fertilizers, lime and hybrid seeds represented potential solutions, but remained out of the reach of poor farmers. Communities embarked on a number of adaptation strategies including using drought-tolerant crops such as cassava; engaging in intercropping activities; and taking advantage of available irrigation furrows for crop production. During periods of floods, they used indigenous fruits as a source of food; planted local maize varieties that are perceived as more robust, and used varieties that can tolerate floods.

Source: Mapfumo *et al*. (2010)

_____ END BOX 20-4 HERE _____

Given these natural connections, there is growing consensus in the literature about the need to integrate development and climate policies (Huq et al., 2005; Jerneck and Olsson, 2008; Klein, Schipper, and Dessai, 2005; Kok et al., 2008; Metz and Kok, 2008). However the means to achieve this integration differ. One option is the "development first" approach which suggests that the incorporation of climate concerns within prevalent development interventions is the best option since development is what most countries care about (Kok et al., 2008). In this approach, governments take into consideration tradeoffs between different dimensions of sustainability and look for climate-inclusive policy options that offer positive synergies with development, aiming at both low greenhouse gas emissions and low vulnerabilities to climate impacts. Lessons from this literature also emphasize the contextual and place-based character of these processes and the need to understand opportunities and constraints relative to local, national, and global priorities (Wilbanks and Sathaye, 2007). Moreover, factors constraining the 'mainstreaming' of climate adaptation into development include discrepancies between immediate development goals and future climate change scenarios, especially in less developed regions and emerging economies. They also include a growing disconnect between donors' goals and developing countries' own development agendas (Agrawala, 2004; Klein, Schipper, and Desai, 2005), potentially inhibiting the development of robust local institutions that can effectively integrate or mainstream climate change policy into to their development priorities. Many developing countries lack technical assistance and capacity development to support their climate change agendas and to identify and manage risks. Often, programs tend to be poorly coordinated, fragmented and bureaucratic, thus accentuating the isolation that vulnerable communities feel with regard to access to such programs (Chukwumerije and Schroeder, 2009). Other factors such as lack of financial and human resources, unclear distribution of costs and benefits, fragmented management, mismatches in scale of governance and implementation, lack and unequal distribution of climate information, and trade-offs with other priorities may also limit the smooth mainstreaming of climate adaptation action into development (Agrawala and van Aalst, 2008; Bizikova et al., 2007; Eakin and Lemos, 2006; Kok et al., 2008; Metz and Kok, 2008). Finally, empirical evidence suggests that the relationship between development variables and climate change responses can be a mixture of positives and negatives, if development variables are not managed well (Garg et al., 2009). For example, in a study of the relationship between malaria incidence, development and climate variables in India, Garg et al. (2009) found that while some development interventions such as increased availability of irrigation canals and dams can negatively affect the incidence of malaria and water-borne diseases, others such as higher per capita income can reduce negative health impacts of climate change significantly – although the distribution of benefits can differ between types of interventions (also see Campbell-Landrum and Woodruff, 2006).

Understanding how development variables intersect with climate responses is especially important because governments and other actors rarely make decisions in isolation; rather they respond to multiple stressors both in rural and urban environments (Agrawal, 2008; Eakin, 2005; Wilbanks and Kates, 2010). Moreover, some evidence suggests that in practice, decision-makers (from heads of households to policy-makers) often do not place climate change at the top of their priority list of critical issues to address (Garg, Shukla, and Kapshe, 2007; Kok et al., 2008), although in some regions (e.g., in Africa) special climate-oriented bureaus are being placed strategically in the offices of government leaders. For instance, in Kenya and Tanzania special a climate change coordination units have been created in high-level scales of government. These institutional arrangements constitute a growing realization of the strategic place that climate change matters occupy in some countries in Africa. The growing importance of climatic change in shaping social and governmental policy agendas has resulted in multiple examples of specific interventions to respond to climate change both in developed and developing regions (Ayers and Huq, 2009; Burch, 2010; Dang, Michaelowa, and Tuan, 2003), for reasons that appear to vary widely.

20.2.3. Contributions to Climate Resiliency

If greenhouse gas emissions continue along trajectories leading to relatively significant climate changes and impacts (NRC, 2010b), resilient pathways for sustainable development will require explicit attention to climate change responses in virtually all regions, sectors, and systems. Sustainable development will depend fundamentally on changes in social awareness and values that lead to innovative actions and practices, as well as to changes to institutions and systems that currently support unsustainable practices in order to support vulnerable groups that are showing capacities for self-organization and adaptation. In most cases, such a new climate-resilient development paradigm is likely to benefit from bottom-up engagement in risk management and evolving problem-solving and from human development to enhance capacities for risk management and adaptive behavior (Tompkins, Lemos, and Boyd, 2008).

One of the most challenging aspects of climate-resilient pathways is that they are rooted in distinctive local contexts, but at the same time that they are shaped by external linkages which require attention and care. For example, resilience cannot be achieved in a few privileged places if it is not achieved in others, because instabilities in adversely impacted situations will spill over to other situations through such effects as resource supply constraints, conflict, migration, or disease transmission (Wilbanks, 2009).

Addressing these profound challenges will require combinations of two kinds of responses. One key component will be actions to reduce vulnerabilities to climate change through climate change mitigation and adaptation in balanced and integrated strategies (20.3). But the other key component is sustainable development pathways themselves and how they enable (or complicate) effective resolution of complex nature-society tradeoffs (20.4).

20.3. Contributions To Resilience Through Climate Change Responses

Combined with appropriate development strategies (Section 20.4), pathways for sustainable development become more climate-resilient by risk management and vulnerability reduction strategies that include (a) reducing the net rate of growth of greenhouse gas (GHG) emissions and stabilizing – or reducing – their concentrations in the atmosphere (mitigation) and (b) improving capacities to cope with climate changes without disruptions of systems that we value (adaptation). Recently, discussions also been initiated about a third, last-resort option that is surrounded by uncertainties and concerns: geoengineering.

20.3.1. ***Mitigation***

In IPCC's assessment reports, mitigation is the subject of Working Group III, to which the reader is referred for comprehensive information about options and strategies for reducing GHG emissions and increasing GHG uptakes by the earth system. For this chapter, the issue is how climate change mitigation relates to sustainable development, which is addressed by Chapter 12 of Working Group III's Fourth Assessment Report (IPCC, 2007) and Chapter 4 of its Fifth Assessment Report, including attention to equity issues.

In general terms, mitigation is important for sustainable development in two ways. First, it reduces the rate and magnitude of climate change, which reduces climate-related stresses on sustainable development, including effects of climate extremes and extreme events (IPCC SREX, 2012). For example, many smaller developing nations argued at UNFCCC COP 15 in Copenhagen in December 2009 that stabilizing the global atmospheric concentration of carbon dioxide at 450 parts per million (ppm) projected to result in a 2^{o}C increase in global mean temperature), which appeared to be the goal of many larger countries, would mean unacceptable impacts on their prospects for sustainable development; in fact, some low-lying island nations would cease to exist in the face of the eventual sea-level rise that would be implied by that concentration level. For these countries, any concentration level above 350 ppm (projected to result in a 1.5ºC increase), was considered simply unacceptable (Liverman and Billett, 2010). In this sense, mitigation is a critically important part of climate change risk management (Washington et al., 2009).

Second, trajectories for technological and institutional change in order to reduce net GHG emissions interact with development pathways. In some cases, national strategies to promote low-carbon growth (e.g., Table 20-1) may be congruent with development transformations such as green growth strategies, for instance by reducing local and regional air pollution, enhancing prospects for development transformations, and encouraging broader participation in development processes. In other cases, such effects as higher energy prices associated with transitions from fossil fuels to renewable energy sources have the potential to have adverse effects on local and regional economic and social development (IPCC SRREN, Chapter 9). The challenge for climate-resilient pathways is to identify and implement mixes of technological options that reduce net carbon emissions and at the same time support sustained economic and social growth. For example, such strategies as increasing carbon uptakes in the soil through better agricultural management practices can improve soil water storage capacity and also reduce the workload of women, and practices such as conservation tillage can also increase water retention in drought conditions and help to sequester carbon in soils.

[INSERT TABLE 20-1 HERE
Table 20-1: Examples of national plans for low carbon growth (Araya, 2010).]

However, mitigation and development also interact in a third fundamental way in that different groups and countries' ability to implement mitigation critically depends on their 'mitigative capacity' (Yohe, 2001), that is, their "ability to reduce anthropogenic greenhouse gas emissions or enhance natural sinks" or the "skills, competencies, fitness, and proficiencies that a country has attained which can contribute to GHG emissions mitigation" (Winkler et al., 2007). Here, many of the determinants of mitigative capacity are fundamentally shaped by different countries' level of development, including their stock of human, financial and technological capital, such as the ability to pay for mitigation; the cost of available abatement opportunities; the regulatory effectiveness and market rules; the education and skills base; the suite of mitigation technologies available; the ability to absorb new technologies, and the level of infrastructure development.

20.3.2. Adaptation

Adaptation is the subject of four chapters of this Working Group II Fifth Assessment Report (14-17), to which the reader is referred for comprehensive descriptions of concepts, options, strategies, and examples of adaptation practices.

Two decades ago, climate change adaptation was a lower priority than climate change mitigation. First, some interested parties were concerned that attention to adaptation reduced an essential emphasis on mitigation, thereby increasing the likelihood of substantial climate change. In addition, it was assumed that the impacts of climate change would emerge slowly over time and could be dealt with piecemeal, as they appeared. It was also assumed that adaptation was largely local and could thus be managed at national level or lower, with some financial assistance for the most vulnerable countries. Both of these assumptions are now recognized as too limited (e.g., Pielke and Sarewitz, 2011). Climate change has been swifter than initially anticipated. Impacts are already being observed and greenhouse gas emissions and atmospheric concentrations continue to rise, while the projections imply a significantly more rapid emergence of enhanced climate risks. In short, the reality of substantial and no longer avoidable climate change has been recognized at an international level (IPCC, 2007; IPCC SREX, 2012).

Historically, global climate change impact and adaptation research has often been predicated on a global mean surface temperature increase of plus 2 degrees Celsius (e.g., Richardson et al., 2009; UK Royal Society, 2011), although othere scenarios have been considered as well (IPCC, 2007). Recent trends in GHG emissions and projections of climate futures, however, are suggesting that it may be more realistic to ask what adaptation would mean if the average temperature increase is 4 degrees or more (e.g., Auerswald, Konrad, and Thum, 2011; Smith et al., 2011). If so, adaptation cannot be limited to gradually emerging responses at national and sub-national scales;

impacts of climate change will be serious and widespread, demanding adaptive measures to match. Adaptation can include incremental changes that are relatively inexpensive because they offer co-benefits for other development objectives, but adaptation may also require considering transformational changes, in which potentially impacted systems move to fundamentally new patterns, dynamics, and/or locations (Schipper, 2007; Kates, Travis, and Wilbanks, 2012). In both cases, desirable adaptation strategies are likely to vary according to climate change threat, location, impacted system, the geographical scale of attention, and the time frame of strategic risk management planning (Heltberg, Siegel, and Jorgensen, 2009; Thomalla et al., 2006; NRC, 2010a).

Effective and efficient adaptation choices vary from place to place according to local circumstances. There is no single measure for adaptation on a global scale in the way that mitigation can be measured by emissions and concentrations. But it is crucial for sustainable development and for climate resilience that the world community of nations as a whole be effectively adaptive. Successful adaptation in any one place or region does not mean, of course, that such places or regions would be immune to the impacts of climate change, because lack of adaptive capacity in one place or region will inevitably spread to some degree to other regions, such as neighboring regions where transboundary effects will be felt and also in distant places by interconnections through world trade and other economic and social linkages (NRC, 2010a). For example, where food production is adversely affected, this may result in higher global prices and/or increases in poverty, disease, and migration affecting distant places.

A pathway that includes sustainable and resilient climate change adaptation is one that contains a number of components in order to avoid maladaptive or unsustainable pathways/practices. Climate resilient adaptation pathways can ensure or promote food and water security, human health, and air and water quality and natural resource management, while promoting gender equality. By selecting environmentally friendly materials; promoting energy, water and other resource conservation; promoting re-use and recycling; minimizing waste generation; protecting habitat and addressing needs of marginalized groups (Bizikova et al., 2008), adaptation can contribute to double win or even triple win options that promote resilience and a diverse array of development goals.

In any case, the challenges for climate-resilient pathways include enhancing adaptive capacity, so that systems at risk can assess vulnerabilities and respond to reduce risks, and providing adaptation options: technological, institutional, and financial (Wilbanks et al., 2007). Adaptation can be vitally important in reducing stresses on development processes, especially in vulnerable areas, it can help to promote and support sustainable development (see Box 20-5), and it can stimulate participative social processes. For example, in many cases climate change adaptation planning is encouraging communities to think more clearly about broader sustainable development goals and pathways (NRC, 2010a). On the other hand, it is clear that some potential adaptations might not lead to equitable and sustainable outcomes (Thomas and Twyman, 2005; Eriksen et al., 2011; Eriksen and Brown, 2011; K. Brown, 2011). Moreover, adaptation at one scale may negatively affect vulnerability in another. For example, in Vietnam, policies for forestry protection and the construction of electric dams while benefiting low land areas (by regulating flooding) have critically constrained the access to land and forest products to mountain populations, decreasing their adaptive capacity (Beckman, 2011).

_____ START BOX 20-5 HERE _____

Box 20-5. Case Studies from China

Water-saving irrigation has enhanced the climate change adaptation capacity, improved ecosystem services, and promoted regional sustainable development in China.

Water-Saving Irrigation Measures in Cropland Adaptation to Climate Change

For sustainable development in developing countries, facing impacts of climate change, low-carbon emission strategies and effective adaptation to climate change are especially important. Water-saving irrigation is one effective measure to deal with the water scarcity and food security issues caused by climate change (Hanjra et al, 2010; Tejero et al., 2011). Given an increase in non-agricultural water use, China's agriculture could be faced with a situation of severe shortages of water resources (Xiong et al, 2010). The saved water was expand the irrigated cropland by 3.80-7.80 Mhm^2 and increased grain production by 14.68-30.15 Mt, ensured one year grain needs of 73-

151 million people in 2009 (Zou et al., 2011). It is also estimated that the performance of water-saving irrigation from 2007-2009 saved about 61.81-129.66 Bm^3 of water and 9.59-20.85 Mt of standard coal and reduced 21.83-47.48Mt CO^2 emissions (Table 20-2). Therefore, water-saving irrigation has a positive significance in dealing with climate change and sustainable development (Zou et al., 2011).

[INSERT TABLE 20-2 HERE
Table 20-2: Effectiveness of water-saving irrigation dealing with climate change (Zou et al., 2011).]

Water-Saving Irrigation Measures in Alpine Grassland for Adapting to Climate Change

Northern Tibet is the headwater region for the Yangtze, Nu (Salween River), Lancang (Mekong River), and numerous other rivers and high mountain lakes (Gao et al., 2009). Sustaining the environmental conditions in the region is of vital importance not only for Tibet but also for the whole China. Being a fragile ecosystem, the alpine grassland ecosystem in Northern Tibet is extremely sensitive to climate change and human activity. In recent years, the rise in precipitation and temperature results in the melting of glaciers and expansion of inland high mountain lakes, and affect the alpine grassland degradation with diverse annual fluctuations in Northern Tibet (Ga et al., 2010). Among the many of grassland protection measures, alpine grassland water-saving irrigation measures could be reasonable to redistribute and make full use of the increased precipitation and lake water in the dry period, which would be reduce the negative effects of climate change and make full use of favourable conditions (EBNCCA, 2011). The results of three-year demonstration of alpine grassland water-saving irrigation measures showed that alpine grassland yield increased nearly 2 times (Figure 20-2) while the plant species increased from 19 to 29, helping to protect and restore the alpine grassland ecosystem and ecosystem services and to promote the regional socio-economic sustainable development in Northern Tibet (Gao et al., forthcoming).

[INSERT FIGURE 20-2 HERE
Figure 20-2: The demonstration of alpine grassland water-saving irrigation measures for adaptation to climate change in Northern Tibet.]

_____ END BOX 20-5 HERE _____

20.3.3. Integrating Climate Change Adaptation and Mitigation for Sustainable Risk Management

Recent research suggests that adaptation is likely to be more effective when it is designed and implemented in the context of other interventions within the broader context of sustainability and resilience (Wilbanks and Kates, 2010), and the same is often true for mitigation. Moreover, studies focusing on the intersection between sustainable development and climate policy point out that integration between the two is a desirable although complex path (Halsnaes, Shukla and Garg, 2008; Wilson and McDaniels, 2007; Ayers and Huq, 2009). Wilson and McDaniels (345) argue that the reasons to integrate across adaptation, mitigation and sustainable development are straightforward because (1) many dimensions of the *values* that are important for decision-making are common to all three decision contexts; (2) impacts from any one of the three decision contexts may have important *consequences* for the other contexts; and (3) the *choice among alternatives* in one context can be a means for achieving the underlying values important in the other contexts.

Integrating mitigation and adaption in a development context is complicated by the facts that the distribution of costs and benefits is different (e.g., mitigation benefits more global, adaptation benefits often more localized), the research and policy discourses are often unrelated, and the constituencies and decision-makers are often different (Wilbanks et al., 2007). In many cases, the challenge of bringing the entire range of issues and options into focus – seeking synergies and avoiding conflicts – is most likely to come into focus in discussions of climate change responses and development objectives in places: localities and small regions (Wilbanks, 2003). In such contexts, a challenge is to reconcile practices that make resources available for mitigation efforts only for reducing emissions beyond that which would have occurred without those resources, while it has been suggested that access to resources for adaptation efforts should recognize the critical role of *co-benefits*, or the positive effect in supporting development in other ways while at the same time reducing vulnerabilities to climate change impacts (NRC, 2010a; also see section 20.3.3).

The choice of a climate-resilient development pathway varies according to the circumstances of each locality. In the more highly vulnerable countries, adaptation may be seen as the highest priority because there are immediate benefits to be obtained by reducing vulnerabilities to current climate variability and extremes as well as future climate changes. In the case of more highly developed countries, adaptation initiatives have often been seen as a lower priority because there is abundant adaptive capacity and because, in some cases, losses from climate variability and extremes have been less salient. Mitigation may be seen as a higher priority for those countries which contribute the larger proportion of GHG emissions, where their actions can significantly reduce total global emissions.

As indicated above, one emerging strategy to integrate between climate and development policies is the design of "triple-win" interventions that seek to achieve an appropriate mix of mitigation and adaptation within the context of sustainable development, although potentials for such triple wins may be limited (Swart and Raes, 2007). When integrating across these three goals, decision-makers often need to address issues of scale, complex relationships between ends and means, uncertainty and path dependencies, institutional complexity and insufficient opportunities (Klein, Schipper, and Desai, 2005; Tol, 2004; Wilson and McDaniels, 2007). They must also consider the possibility of ancillary and co-benefits, complementarities and potential trade offs, opportunity costs, and unknown negative and positive feedbacks (for example interaction among options and paybacks: NRC, 2010a; Kok, et al., 2008; Wilbanks and Sathaye, 2007; Swart and Raes, 2007; Rosenzweig and Tubiello, 2007; IPCC, 2007: Chapter 18). For example, in Bangladesh, waste-to-compost projects contribute to mitigation through reducing methane emissions; to adaptation through soil improvement in drought-prone areas; and to sustainable development through the preservation of ecosystem services (Ayers and Huq, 2009). In synthetizing evidence from a series of empirical articles focusing on the intersection between mitigation and adaptation (M&A), Wilbanks and Sathaye (2007: 958) argue that M&A pathways might be alternatives in reducing costs, complementary and reinforcing to each other (e.g., improvements in building energy efficiency), or competitive and mutually contradictory (e.g., coastal protection vs. reductions in sea level rise).

There is also growing research focusing on the relationship and feedbacks (trade-offs and complementarity) between mitigation and adaptation in different sectors, including energy, e.g. to what extent the siting of nuclear power plants might constrain future adaptation to sea-level rise (Kopytko and Perkins, 2011) or how the production of biofuels might affect local adaptation (La Rovere, Avzaradel and Monteiro, 2009); agriculture and water (Rounsevell et al., 2010; Turner et al., 2010; Rosenzweig and Tubiello, 2007; Falloon and Betts, 2010; Shah, 2009); conservation (Rounsevell et al., 2010; Turner et al., 2010); use of mitigation programs to finance adaptation (Hof et al., 2009); and the urban environment (Biesbroek, Swart, and van der Knaap, 2009; Hamin and Gurran, 2009; Roy, 2009; Romero-Lankao et al., 2011).

Swart and Raes (2007) suggest a number of factors that should be taken into consideration when evaluating combined adaptation and mitigation policy designs, including: (1) *avoiding trade-offs* - when designing policies for mitigation or adaptation, (2) *identifying synergies*, (3) *enhancing response capacity*, (4) *developing institutional links* between adaptation and mitigation - e.g. in national institutions and in international negotiations, and (5) *mainstreaming* adaptation and mitigation considerations into broader sustainable development policies.

20.3.4. Third Climate Change Response Option: Geoengineering

If climate change mitigation is not successful in moderating the rate of increase in GHG emissions, and if climate change adaptation is not successful in coping with the resulting impacts without socially unacceptable pain and distress, policymakers may be faced with the question: what do we do now?

A third option is geoengineering: intentional large-scale interventions in the earth system either to reduce the sun's radiation that reaches the surface of the earth or to increase the uptake of carbon dioxide from the atmosphere. An example of the former is to inject sulfates into the stratosphere. Examples of the latter include facilities to scrub carbon dioxide from the air and chemical interventions to increase uptakes by oceans, soil, or biomass (UK Royal Society, 2009).

Discussions of geoengineering have only recently become an active area of discourse in science, despite a longer history of efforts to modify climate (Schneider, 1996, 2009; Keith, 2000). Many of the possible options are known to be technically feasible, but their side-effects are exceedingly poorly understood (NRC, 2010b). For example, interventions in the atmosphere might not be unacceptably expensive, but they might affect the behavior of such earth systems as the Asian monsoons (Robock et al., 2008; Brovkin et al., 2009). Interventions to increase uptakes, such as scrubbing carbon dioxide from the earth's atmosphere, might be socially acceptable but economically very expensive. Moreover, it is possible that optimism about geoengineering options might invite complacency regarding mitigation efforts (Barrett, 2008).

In any case, implications for sustainable development are largely unknown. Even though some advocates argue that geoengineering is needed now, in order to avoid irreversible impact such as the loss of ocean corals, the general view is that this is a research priority rather than current decision-making option (NRC, 2010b). The challenge is to understand what geoengineering options would do to moderate global climate change – and also to understand what their ancillary effects might be – so that, if policymakers find some decades from now that social responses to climate change have not been sufficient to avoid severe disruptions and, as a result, there is a need to consider rather dramatic technology alternatives, our understanding of potential costs and benefits for sustainable development is far better than it is now.

20.4. Contributions to Resilience through Sustainable Development Strategies and Choices

Although climate change responses can contribute significantly to climate-resilient development pathways, some of the key elements of resilience lie in sustainable development pathways themselves, which can make resilience either more or less achievable. Examples of ways that development strategies and choices can contribute to climate resilience include clarifying objectives of sustainable development, considering determinants and potentials for resilience, being capable of resolving tradeoffs among economic and environmental goals (e.g., Bamuri and Opeschoor, 2007), assuring effective institutions in developing, implementing, and sustaining resilient strategies, and enhancing the range of choices through innovation (e.g., Hallegatte, 2009; Chuku, 2009).

20.4.1. Clarifying Objectives of Sustainable Development

One way that sustainable development pathways can contribute to climate resilience is by pursuing consumption patterns that assure social and economic development without being wasteful of natural resources and the environment. It is possible that if, rather than letting consumption be driven by familiar patterns of resource demands, the desired objectives of consumption might be met in ways that require lesser quantities of resources and produce lesser quantities of environmental emissions (Kates, 2000; also see Leiserowitz, Kates, and Parris, 2005).

Overall, development is a means to social and economic ends, not (usually) an end in itself; the objective is to develop in order to increase the abundance and reliability of services that are important to well-being, such as food, shelter, productivity, and enjoyment (Sen, 1999; Morgan and Farsides, 2009). For example, we do not develop improved energy systems because we want to consume kilowatts of electricity for their own sake; we consume them because they deliver comfort, convenience, and other qualities that we desire (Von Bernard and Gorbaran, 2010). Within the context of a changing climate, continued use and unlimited expansion of the limited resources of this planet does not seem consistent either sustainable development or climate resilient development (Ehrenfeld, 2008; Gilbert, 2006; also see Victor, 2008 and Victor and Rosenbluth, 2007).

There is a growing debate about economic growth and material consumption. Sustainable development is all about lifestyles and ways of life, which in turn is associated with – but not necessarily defined by -- the consumption of natural and material resources (e.g., Easterlin, 1974 and 2001). One point of view in social research suggests that ever-increasing material consumption does not necessarily bring greater happiness or satisfaction or material comfort (DeLeire and Kalil, 2010; Cafaro, 2010; Huesemann, 2006). On the other hand, in many cases growth in consumption, especially among populations with incomes rising from low levels, is often greatly beneficial (Clark, Frijters, and Shields, 2008; and Deaton, 2008). Measuring social welfare as a dimension of sustainable development that is not entirely captured by monetary income and level of consumption remains both a challenge and a need (Dolan and White, 2007; Fleurbaey, 2009).

20.4.2. Considering Determinants and Potentials for Resilience in the Face of Serious Threats

A second contribution might be made by pursuing sustainable development pathways that are resilient in the face of a wide range of serious threats: e.g., threats of economic downturns, threats of pandemics, and threats of technological and/or non-climate environmental disasters as well as threats of climate-related extreme weather events.

Resilience is rooted in capacities to identify threats to human and natural systems, to take actions to reduce those threats, to respond in the event of a threat, and to recover after a threat in ways that make the systems stronger (e.g.,Wilbanks and Kates, 2010; Young, 2010). It includes access to information and planning tools, but it is more fundamentally linked to social dynamics that enable problem identification and problem-solving in effective ways, including in the event of surprises or multi-hazard contingencies (e.g., Schipper and Pelling, 2006).

Resilience is an issue for systems at all scales, from national to local, often focused on community activities supported by appropriate policies and resources at larger scales but also depending on values and actions of individuals. “Resilience thinking” (Walker and Salt, 2006) may provide a useful framework to understand the interactions between climate change and other challenges, and in reconciling and evaluating trade-offs between short-term and longer-term goals in devising response strategies (IPCC SREX, Chapter 8). Resilience thinking suggests a move “away from policies that aspire to control change in systems assumed to be stable, towards managing capacity of social-ecological systems to cope with, adapt to and shape change” (Folke, 2006, p. 254). At the current state of science, however, at least for applications to development rather than ecological change and risk management, it is more of a conceptual construct than an operational goal: e.g., although research is under way to develop indicators of resilience, it remains very difficult to measure the resilience of a community or system in order to monitor changes through time; it is difficult to assess how resilience at one geographical or temporal scale relates to other scales; and it is not yet clear what resilience means for situations faced with threats that seem to require transformational change if development is to be sustained (e.g., Miller et al., 2010).

What does seem clear is that relatively severe climate change is likely to pose needs for transformational changes in systems and societies in order to sustain development. Transformational change can be defined as fundamental changes in the composition or structure of a system and/or of its location (IPCC SREX, Chapter 8; Pelling, 2010; Schipper, 2007; O’Brien, 2011). Because it involves changes in values and structures, and therefore both winners and losers, transformational change is often difficult to initiate and sustain. Factors that – where they exist – improve prospects for both initiating and sustaining such major paradigm-shifting actions include (a) external drivers such as dramatic focal events that catalyse attention to vulnerabilities, the presence of other sources of stress that also encourage considerations of major changes, and supportive social contexts such as the availability of understandable and socially acceptable options, access to resources for action, and the presence of incentives and (b) internal drivers related to effective institutions and organizations, such as adaptive management, learning, innovation, and leadership (IPCC SREX, Chapter 8).

In many cases, transformational changes include looking for strategies that allow people to remain where they currently live and work. If transformational change does not take place within the relevant time frame, countries will be called on to identify resettlement strategies that protect people’s lives and livelihoods. In the case of areas where habitable land becomes acutely scarce—such as small island developing countries—it may be necessary to identify appropriate admissions policies in potential destination countries (Martin, 2010; UNHCR, 2011; Leighton et al., 2011; Leighton, 2011).

In many ways, such societal responses to environmental stresses as human migration are examples of intersections of sustainable development pathways and the stresses themselves that lead to transformational change. Climatic variability and shifts are already affecting some human mobility patterns (Jäger et al., 2009; de Sherbinin et al., 2011). National adaptation plans from least developed countries repeatedly indicate that loss of habitat and livelihoods could precipitate large-scale migration, particularly from coastal areas that may be affected by rising sea levels and from areas susceptible to increased drought, flooding or other environmental hazards that affect agriculture (Martin, 2010). Several existing plans give examples of migration already occurring in relation to climatic processes combined with other drivers for development. Some movements relate to human migration as a traditional mechanism to manage weather variability. But, increasingly, evidence-based research notes that migration is occurring as a widespread phenomenon related to food and livelihood insecurity (Massey, 2007; Warner et al., 2010; Warner et al., 2009: see Table 20-3).

[INSERT TABLE 20-3 HERE
Table 20-3: The link between scarcity of resources, environmental degradation, and migration for resource dependent communities.]

20.4.3. Resolving Tradeoffs among Economic and Environmental Goals

Clearly, sustainable development pathways are very likely to be more climate-resilient if they develop and utilize socioeconomic and institutional structures that are effective in resolving tradeoffs among economic and environmental goals.

There is a longstanding assumption that economic growth is in conflict with environmental management (Victor and Rosenbluth, 2007; Hueting, 2010). Much of this thinking can be traced back to Malthus and his assertions that population growth (and associated consumption) would expend at a geometrical rate until the limits of the earth's capacity were reached (Malthus, 1798). The very idea of sustainable development itself springs from a need to respond to such Malthusian ideas. The views expounded in the Brundtland Report, for example, are that development should not be unconstrained but it should be modified into a ”sustainable” form (WCED, 1987). More recently arguments have emerged to support the more radical idea that (far from being antithetical) economic growth and environmental quality (protection) are mutually reinforcing (Lovins, 2011). Unlimited damage to the environment and development that is therefore unsustainable can be the result of unconstrained economic growth (WCED, 1987), but it can also be the result of poverty. Poorer countries that are seeking to develop as a way of reducing poverty often do so to the neglect of environmental quality (e.g., air and water pollution and land degradation). But as such societies develop and have more disposable wealth, continued growth can be seen to be more compatible with environment, including opportunities to invest in cleaner energy technologies (Bradshaw et al., 2010; Duraiappah, 1998; Finco, 2009; Broad, 1994; Daly and Cobb, 1989). Some theories of ecological modernization have, however, been criticized as responses to acute and urgent risks because of a lack of marketable technological solutions and because there tends to be a rebound effect whereby growth processes offset incremental environmental improvements (Jänicke, 2008; Bailey et al., 2011).

Sustainable development therefore depends on effective and equitable mechanisms for dealing with inevitable tradeoffs among various social goals, and the development and implementation of climate-resilient pathways are deeply imbedded in such tradeoffs (Boyd et al., 2008). The nature of such tradeoffs varies with different levels of development. Examples of concepts related to tradeoffs are multi-metric valuation and co-benefits:

- *Multi-metric valuation*. In evaluating development pathways, there are often needs to combine a number of dimensions associated with different valuation metrics and information requirements, such as monetary measures of returns and non-monetary metrics of risk. Fields ranging from aquatic ecology to risk assessment and financial management have developed tools for such complex valuations, including graphical mapping (e.g., Rose, 2010) and the construction of multi-metric indexes (e.g., an index of “biotic integrity”: Johnston et al., 2010). More commonly in collective decision-making, however, analytical-deliberative group processes (NRC, 1996) are used to evaluate, weight, and combine different dimensions and metrics qualitatively.

- *Co-benefits*. An issue in both climate and development policy, related in some cases to access to financial support (e.g., Miller, 2008), is the fact that a specific resilience-enhancing action is often likely to have benefits for both development and for addressing concerns about climate change. Mitigation policy has commonly adopted the concept of "additionality," which takes the position that financial support should be limited to those climate change response benefits that are *in addition to* what would be happening in development processes otherwise (e.g., Muller, 2009). A co-benefits approach, on the other hand, takes the position that actions which benefit *both* development and climate change responses simultaneously should be encouraged and that a combination of both kinds of benefits should increase the attractiveness of a proposed action (http://www.kyomecha.org/cobene/e/cobene.html -- accessed 10/6/11). For example, mechanisms such as REDD are designed to achieve both carbon emissions reduction and to benefit livelihoods of those living in forested areas. However, empirical research shows that the evidence of the correlation between carbon storage and livelihoods benefits is mixed (Chhartre and Agrawal, 2009). Tools for analyzing such issues are associated with research on "externalities" (e.g., Baumol and Oates, 1989), but participative planning and decision-making usually incorporate a co-benefits perspective as a matter of course.

In practice, tradeoff issues may or not be resolved in coherent ways. In many cases, resolutions emerge through untidy social processes of evolution and attrition, reflecting dynamics of values, power, control, and surprises, rather than through formal analysis. In some cases, tradeoffs are addressed with the assistance of scenario development, the creation of descriptive narratives, and other projections of future contingencies (IPCC SREX: Chapter 8), along with participative vulnerability assessments (NRC, 2010a).

20.4.4. Assuring Effective Institutions in Developing, Implementing, and Sustaining Resilient Strategies

Climate resilience will benefit from institutions that are effective and sustainable in the face of a wider range of challenges for problem-solving and issue resolution as well. Transformative action and change in integrating sustainable development within a framework of climate resilient pathways is in fact rooted in strong and viable institutions and within an institutional context that adaptively manages the allocation of resources and processes of change. Institutions at different levels have for long periods gone through different societal pressures and challenges relating to environmental change. Local institutions are particularly adroit in coping with multiple changes. These changes have forced them to rethink their institutional arrangements and make adjustments that will allow them to cope with the multiple vulnerabilities they face. According to Agrawal et al, organizational mechanisms are central to building linkages between local level adaptation action and national level planning. However, in six cases studies in west and Latin America, they argue that these connections are missing in almost all the countries under study, and external policy support can catalyze adaptation action through three types of intervention mechanisms– information, incentives, and institutions. (Agrawal A., R. Mearns, and N. Perrin, 2011). The assumption is that fundamental social transformation is often needed in order to achieve sustainable development and processes of maladaptation (Eriksen and Brown, 2011), The term "institutions" is not necessarily limited to formal structures and processes, but can also refer to the rules of the game as well as the norms and cultures that underpin environmental values and belief systems. Ostrom (1986) defines institutions as the rules defining social behavior in a particular context, the action arena. Institutions define roles and provide social context for action and structure social interactions (Hodgson, 2003). Definitions of sustainability are largely shaped by institutional values, cultures and norms. Institutions also critically define our ability to govern and manage the resources and systems that shape adaptation, mitigation and sustainable development. Adopting an adaptation and mitigation pathway requires strong institutions that are able to foster an enabling environment through which adaptive and mitigative capacities can be built.

Institutions for integrated climate-resilient pathways are therefore not limited to governmental institutions; in fact, in many cases a majority of the key decisions are made and implemented by non-governmental actors, from the private sector to communities and families. For instance, in projects supported by the Climate Change Adaptation in Africa Programme (CCAA), in both Tanzania and Morocco, local governments are providing improved seeds that are drought resistant to vulnerable groups and financially supporting initiatives at community level. Consequently, embarking on a climate resilient pathway may necessitate including local institutions as part of the governance regime. Local institutions tend to know what is needed for effective adaptation. Similarly, as local communities become more and more exposed to climate extremes and variability, they are already adapting to the negative impacts of climate variability and change. However, a sustainable route depends largely on the organisational capacity of vulnerable groups and their ability to translate challenges into opportunities. For instance, in Morocco, where local communities have strong institutions, such as in the Tabant mountain community, they were found to be adapting collectively; but where institutions were less effective and weak, as in the arid plain of Lamzoudia, adaptation action was characterised by individual initiatives (Denton et al., forthcoming 2013)

Integrating across adaptation, mitigation, and sustainable development requires multilevel governance systems that involve decision-making processes and actors at multiple levels (local, regional, national and global) and 'hybrid' forms of governance suchas public-private partnerships, public-social partnerships (across market and communities) and co-management (across state and communities) (Figure 20-3; Lemos and Agrawal, 2006; Betsill and Bulkeley, 2006; Paterson, 2009). Weak governance can affect the viability of political instruments such as National Adaptation Programme of Actions (NAPAs). NAPAs are the most tangible political instruments vis a vis adaptation action, policy and measures in least developing countries. They give national governments the license to be part of the institutional "game" and to contribute to its overall design. However, in spite of this plurality of institutional actors for effective governance in adaptation and mitigation, it would seem that the capacity to co-ordinate and harmonise activities at several levels needs in many cases a strong state sponsored formal institution/s to support and enable adaptation and mitigation initiatives.

[INSERT FIGURE 20-3 HERE
Figure 20-3: A Notional Depiction of Alternative Climate-resilient Sustainable Development Pathways (lower left). Regarding SSP's see Box 20-3; SSPs are representations of alternative socioeconomic pathways within which climate change responses might evolve.]

Scholars have suggested that response to climate change may require a new concept of policy transitions that includes "policy integration, long-term thinking for short-term action, keeping multiple options open and learning-by-doing and doing-by-learning." (Kemp and Rotmans, 2009: 303). Finally, recent literature also suggests that polycentric forms of governance may be more robust and adaptable than policies implemented by a single unit of government (Ostrom, 2005) and thus better suited to adaptive risk management. Understanding what relevant institutional capacities exist is an important requirement for framing and supporting both adaptation and mitigation. Similarly, inherent institutional weaknesses can also affect the potential for good adaptation and mitigation action to take root, particularly where knowledge gaps and climate expertise are missing (Michonski and Levi, 2010).

In particular, local institutions crucially influence the ability of communities to adapt and benefit from adaptation and mitigation programs in rural and urban settings (Agrawal, 2008; Chhartre and Agrawal, 2009; Corbera and Brown, 2008). For instance, institutions tend to play an influential role in shaping farmers' decisions and helping them make strategic choices with several implications for livelihoods and sustainable development (Agrawal, 2008). However, institutional dynamics tend to ignore informal institutions and the role they play in enabling societies to adapt. Informal institutions are custodian of knowledge and knowledge generation. However, often in developing countries, particularly in Africa, traditional knowledge is not valorized as a reference point for managing climate risks and emerging threats. In Kenya, the importance of indigenous knowledge, given increased uncertainty and climate related risks have compelled national agencies such as the Kenyan Meteorological Agencies and vulnerable groups such as the indigenous communities commonly known as rainmakers to form strategic reciprocal links. Both groups were able to work closely together to calibrate their forecasts and test the efficacy of the results against climate change impacts on agricultural productivity. Hence, the two groups have been able to demonstrate the benefits of western science and traditional knowledge systems to ensure maximum (Ziervogel and Opere, 2010). Integrating meteorological and indigenous knowledge-based seasonal climate forecasts in the agricultural sector. In addition, participatory processes which call for a deliberative form of decision making amongst stakeholders are well suited to the governance culture necessary for effective adaptation and mitigation. Scholars such as Benn have found that deliberative processes of democracy provide greater efficacy in decision-making and lead to more sustainable outcomes. They argue that some deliberative democracy methods can bring diverse stakeholders together- lay, expert and indigenous knowledge - thus putting in place a more communicative model of science (Benn, Dunphy, and Martin, 2009).

In addition, the complexity of different resource flows and distributional effects related to adaptation and mitigation is at the heart of the sustainable development debate with numerous implications for equity and justice (O'Brien and Leichenko, 2003; Roberts and Parks, 2006). Institutions are also needed to handle the large flows of funds and other resources that are associated with managing and improving the delivery systems that will allow people and organizations to take advantage of opportunities that will trigger a set of actions to combat the negative impacts of climate change. The nature and dynamics of climate change call for institutions that are able to facilitate the enhancement of adaptive capacity and 'allow society to modify its institutions at a rate commensurate with the rapid rate of environmental change' (Gupta et al., 2008). Institutional 'renewal' is essential in some case to achieve a degree of social cohesion and transformation. A case study in Morocco, under the Climate Change Adaptation in Africa (CCAA), showed that the `Cellule de Littoral`, created to serve as a consultative committee on coastal development in Morocco, has gained some recognition at both local and national levels as it is integrated formally into the institutional framework for the implementation of ICZM Plans of Action (Denton et al., forthcoming 2013). Similarly, assessing vulnerability calls for an understanding of institutions, their evolutionary context, and their roles in the creation and distribution of wealth. In a great many respects, poverty and uses of resources are mediated by institutional factors (Kelly and Adger, 2000). For example, property rights are defined, controlled, and enforced by formal institutions and structures; and institutional structures are especially important where common pool resources are concerned. However, in less developed regions, vulnerability is seldom the result of single stressors, rather most poor communities are double exposed to climate impacts and globalizations processes that shape their overall vulnerability and adaptive capacity (O'Brien et al., 2004).

Common problems with institutional roles include:

- (An) incompatibility of current governance structures with many of those that are likely to be necessary for promoting social and ecological resilience' and the fact that 'adaptive ecosystem management overturns some major tenets of traditional management styles which have in many cases operated through exclusion of users and the top-down application of scientific knowledge in rigid programmes.' (Tompkins and Adger, 2003: 10).
- A need for stronger political will within nations and at the international level' 'to initiate and further sustainable development' and overcome 'the classic "free-rider" problem'(Veeman and Politylo, 2003: 331).
- A lack of experience with and/or confidence in approaches to adaptive planning that incorporate rich bodies of knowledge and experience regarding risk management and decision-making under uncertainty (IPCC, SREX; NRC, 2010a).

20.4.5. Enhancing the Range of Choices through Innovation

Finally, climate resilience will in most cases depend on innovation, developing new ideas and options or adapting robust familiar ideas and options to meet emerging new needs and to respond to surprises. Integrated strategies for climate-resilient strategies need not be limited to currently available policies, practices, and technologies. In many cases, as indicated in the previous section, they can benefit from considering possibilities to develop new options through social, institutional, and technological innovation. For example, if a climate-resilient pathway for a particular region calls for coping with greater water scarcity, innovations might consider changes in water rights practices, improving the understanding of groundwater dynamics and recharge, improving technologies and policies for water-use efficiency improvements, and in coastal areas the development of more affordable technologies for desalination (NRC, 2010a). One key issue for risk management, therefore, is assessing needs for and possible benefits from targeting innovation efforts on critical vulnerabilities.

Innovations can include both technological and social changes, which in many cases are closely related (Rohracher, 2008; Raven et al., 2010), as technology and society evolve together (Kemp, 1994). An important characteristic of such socio-technical transitions are the interactions and conflicts between new, emerging systems and established regimes, with strong actors defending business as usual (IPCC, SREX; Kemp, 1994; Perez, 2002).

Effective use of innovations depends on more than idea and/or technology development alone. Unless the options, the skills required to use them, and the institutional approaches appropriate to deploy them are effectively transferred from providers to users (e.g., "technology transfer"), effects of innovations – however promising – are minimized (IPCC, SREX). Challenges in putting science and technology to use for sustainable development, in particular, have received considerable attention (e.g., Nelson and Winter, 1982; Patel and Pavit, 1995; NRC, 1999; International Council for Science, 2002; and Kristjanson et al., 2009), emphasizing the wide range of contexts that shape both barriers and potentials. If obstacles related to intellectual property rights can be overcome, however, the growing power of the information technology revolution could accelerate the transfer of technologies and other innovations (linked with local knowledge) in ways that would be very promising (Wilbanks and Wilbanks, 2010).

20.5. Toward Climate-Resilient Pathways

In looking toward what to do in response to concerns about climate change impacts, it is useful to think both about how to frame climate-resilient pathways, and about attributes that such pathways are likely to share, and about the degree to which alternative pathways are available.

20.5.1. Framing Climate-Resilient Pathways

Climate-resilient pathways recognize that impacts are certain, because climate change can no longer be avoided. Ignoring this source of stress will endanger sustainable development. As a result, vulnerability assessments and risk management strategies are important, considering both possible/likely climate effects – extremes as well as average – and also development conditions such as demographic, economic, and land use patterns and trends; institutional structures; and technology development and use (IPCC, SREX).

In most cases, vulnerabilities and appropriate risk management approaches will differ from situation to situation, calling for a multi-scale perspective built solidly on fine-grained contextual realities (IPCC SREX: Chapter 8). But most situations share at least one fundamental characteristic: threats to sustainable development are greater if climate change is substantial than if it is moderate (Wilbanks et al., 2007). With more substantial change, resilience is more likely to require *transformational* adaptations: responses that change the nature, composition, and/or location of threatened systems in order to sustain development (Smit and Wandel, 2006; Stringer et al., 2009; NRC, 2010a; Pelling, 2010; IPCC, SREX). For near term time horizons, responses are likely to emphasize climate change mitigation and relatively low-cost adaptations with development co-benefits (e.g., Van Aalst, Cannon, and Burton, 2008; NRC, 2010a). For longer-term time horizons, responses are likely to combine the monitoring of emerging impacts and threats with evaluation, learning, and contingency planning for possible needs for transformational adaptations (NRC, 2010a; IPCC, SREX). But the more rapidly climate change emerges, the more likely it is that actions will be needed sooner rather than later in order to assure resilience and sustainability (Stafford et al., 2010).

20.5.2. Attributes of Climate-Resilient Pathways

Climate-resilient pathways of development deliberately minimize the negative impacts of climate change. Such pathways acknowledge the relationship between greenhouse gas emissions and climate change impacts, and hence the importance of integrating both climate change mitigation and adaptation into sustainable development strategies. One of the most challenging aspects of climate-resilient pathways is that they are rooted in distinctive local contexts, but at the same time that they are shaped by external linkages that require attention and care. For example, resilience cannot be achieved in a few privileged places if it is not achieved in others, because instabilities in adversely impacted situations will spill over to other situations through such effects as resource supply constraints, conflict, migration, or disease transmission (Wilbanks, 2009).

Consequently, if climate change continues on its current path toward relatively significant changes and impacts (NRC, 2010b), resilient pathways for sustainable development will become increasingly challenging, requiring explicit attention to climate change responses in virtually all regions, sectors, and systems. Sustainable development will depend fundamentally on changes in social awareness and values that lead to innovative actions and practices, including increased attention to both disaster risk management and climate change adaptation in anticipation of (and in response to) changes in climate extremes (IPCC SREX). In most cases, such a new climate-resilient development paradigm is likely to benefit from bottom-up engagement in risk management and evolving problem-solving and from human development to enhance capacities for risk management and adaptive behavior (Tompkins, Lemos, and Boyd, 2008).

One of the most challenging aspects of climate-resilient pathways is that they are rooted in distinctive local contexts, but at the same time that they are shaped by external linkages that require attention and care. For example, resilience cannot be achieved in a few privileged places if it is not achieved in others, because instabilities in adversely impacted situations will spill over to other situations through such effects as resource supply constraints, conflict, migration, or disease transmission (Wilbanks, 2009).

With these perspectives in mind, Box 20-6 lists a number of attributes of climate-resilient pathways for sustainable development. Taken as a whole, this characterization of climate-resilient pathways may appear daunting, but in fact each of the items is amenable to strategy development in appropriate national, regional, and local contexts; and notable, measurable progress should be possible in a great many cases.

_____ START BOX 20-6 HERE _____

Box 20-6. Attributes of Climate-Resilient Pathways for Sustainable Development

Awareness and capacity

- A high level of social awareness of climate change risks
- A demonstrated commitment to contribute appropriately to reducing global net GHG emissions, integrated with national development strategies
- Institutional change for more effective resource management through collective action (Tompkins, Adger, 2003)
- Human capital development to improve risk management and adaptive capacities
- Leadership for sustainability that effectively responds to complex challenges (Brown, 2012)

Resources

- Access to scientific and technological expertise and options for problem-solving
- Access to financing for appropriate climate change response strategies and actions
- Information linkages in order to learn from experiences of others with mitigation and adaptation

Practices

- Continuing, institutionalized vulnerability assessments and risk management strategy development and refinement based on emerging information and experience
- Monitoring of emerging climate change effects and contingency planning for possible significant impacts and needs for transformational responses
- Policy, regulatory, and legal frameworks that encourage and support distributed voluntary actions for climate change risk management
- Effective programs to assist the most vulnerable populations and systems in coping with impacts of climate change

_____ END BOX 20-6 HERE _____

20.5.3. Alternative Climate-Resilient Pathways

Does climate resilience imply one and only one pathway for sustainable development or are there alternative pathways, any one of which will be resilient? Given that there are a great many alternative sustainable development pathways, how does one evaluate which one or ones meet a criterion of climate resilience?

The concept of Shared Socioeconomic Pathways (Box 20-3) offers one framework of thought for considering this question. SSPs consider alternative socioeconomic pathways according to dimensions related to both the resource intensity of economic growth and the effectiveness of institutions in resolving tradeoffs (Kriegler, et al., 2012). These dimensions, fundamental to sustainable development, can then be related to socioeconomic challenges surrounding climate change mitigation and adaptation, with lesser or greater challenges depending on socioeconomic conditions. For example, in Figure 20-3, an SSP 1 pathway has relatively limited challenges to both mitigation and adaptation, while an SSP 3 pathway has very substantial challenges to both. SSP 2 has moderate challenges to both adaptation and mitigation, while SSP4 is described as having high challenges to adaptation and low challenges to mitigation. SSP 5 combines high challenges to mitigation with low challenges to adaptation. Any pathway characterized by limited challenges to both is likely to be climate-resilient, while any pathway facing high challenges is likely not to be climate-resilient. It is reasonable to suggest, then that a variety of possible pathways in the lower-left portion of the figure might very well be climate-resilient, where a heavy emphasis on either mitigation or adaptation capacity might somewhat reduce requirements for the other, although both would have to be represented substantially in the pathway.

This view is, of course, more likely to frame climate-resilient pathways at a global or large-regional scale than at a local or small-regional scale, because many localities and small regions have limited capacities to contribute to climate change mitigation because their greenhouse emissions and carbon sinks are limited in magnitude. In other words, at a large scale, climate-resilient pathways will include actions that promote both adaptation and mitigation in a sustainable manner. At a relatively small scale, however, climate-resilient pathways will involve a range of actions appropriate to differences in potentials for vulnerability and risk reduction, contributing to the cumulative effect of local efforts on larger-scale aggregates.

20.5.4. Implications for Current Sustainable Development Strategies and Choices

Although payoffs from specific long-term pathways may be uncertain at this time, such uncertainties need not preclude actions now. Climate-resilient development pathways are not about actions taken in the future, but rather about the strategies and choices that are taken today. The range of potential climate outcomes, discussed in Box 20-3, will have dramatically different implications for human security, as well as for the health and status of species and ecosystems (IPCC WGII, AR5). Increasingly, the literature linking climate change to greenhouse gas concentrations shows that the emissions in the coming decades will be decisive for future climate outcomes (Anderson and Bows, 2008; Meinshausen et al., 2009; Solomon et al., 2009). In fact, waiting to take action may reduce the range of choices for climate resilient pathways in the future (NRC, 2011). The IPCC Special Report on Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX), 2012, makes the case that a “solution space” exists now for considering possible strategies that would increase climate resilience while at the same time helping to improve human livelihoods and social and economic well-being (Figure 20-4). It suggests that a process of iterative monitoring, evaluation, learning, innovation, and contingency planning will reduce climate change disaster risks, promote adaptive management, and contribute significantly to prospects for climate-resilient pathways. The solution space emphasizes the linkages between different strategies, recognizing that no single approach alone is likely to be sufficient. In discussing approaches to sustainability in the context of climate extremes, the SREX report draws attention not only to the role of incremental change, but also to transformation, which is defined as “the altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems) (IPCC SREX, p. 564). Climate-resilient development pathways that deliberately address mitigation and adaptation through both incremental and transformative strategies are likely to present more options for sustainable development than those pathways that reactively respond to the challenges of climate change.

[INSERT FIGURE 20-4 HERE
Figure 20-4: The Solution Space for Current Strategies (SREX, 2012)**.]**

20.6. Priority Research/Knowledge Gaps

Simply stated, the fact is that what is known about integrating climate change mitigation, climate change adaptation, and sustainable development is dwarfed by what is not known. If national and global decision-makers care about realizing potentials from a fusion of these three imperatives, then research should be a very high priority indeed. The most salient research need is to improve the understanding of how climate change mitigation and adaptation can be combined with resilient sustainable development pathways in a wide variety of regional and sectoral contexts (Wilbanks, 2010). One starting point is simply improving the capacity to characterize benefits, costs, potentials, and limitations of major mitigation and adaptation options, along with their external implications for equitable development, so that integrated climate change response strategies can be evaluated more carefully (Wilbanks et al., 2007). What are the major tradeoffs? What are the potential synergies? How do implications of integrated mitigation/adaptation strategies vary with location, climate change risks and vulnerabilities, scale, and development objectives and capacities?

Related to this general priority are at least three specific research needs:

1. Research on how to reconcile the importance of co-benefits from climate change adaptation and mitigation actions with widespread use of the concept of additionality, e.g., how to establish criteria for access to financial support for adaptation that incorporates the development importance of co-benefits.
2. Advances in conceptual and methodological understandings of, and tools to support research on, multiple drivers of development pathways and climate change impacts; possible feedback effects among mitigation, adaptation, and development; and possible thresholds/tipping points that could cause particular challenges for development (NRC. 2009, 2010a).
3. Advances in knowledge about how to respond sustainably to climate change extremes and extreme events, when and where they pose development challenges that would appear to require transformative changes in impacted human and/or environmental systems. What might the options be, and how can they be facilitated where they should be considered? (e.g., Pelling, 2010).

Further research needs include:

1. Research attention to potentials for technological and institutional innovations to ease threats to sustainable development from climate change impacts and responses. In other words, how might climate change responses represent opportunities for innovative development paths? How might technological development be part of a strategy for development/climate change response integration? (Wilbanks, 2010)
2. Research on strategies for institutional development, including improving understandings of how social institutions affect resource use (NRC, 2009), improving understandings of risk-related judgment and decision-making under uncertainty (NRC, 2009), and best practices in creating institutions that will effectively integrate climate change responses with sustainable development outcomes such as participation, equity, and accountability
3. Research on strategies for the implementation of adaptive management strategies for development. Examples of important research needs include improving the understanding of respective roles and interactions between autonomous response behavior and policy initiatives, improving the body of empirical evidence about how to implement changes that are judged to be desirable: e.g., adaptive management and governance capacity, and improving the understanding of differences between retrofitting older infrastructures (the challenge in many industrialized countries) and designing new infrastructures (the challenge in many rapidly developing countries) (IPCC SREX, Chapter 8).
4. Research on how to resolve differences between adaptation and development in ways that enable the flow of financial resources to support adaptations: e.g., how to acknowledge co-benefits in allocating investment resources without inviting every party seeking development investment to use climate change as an opportunity (NRC, 2010a).
5. Research to improve the understanding of how to build social inclusiveness into development/climate change response integration. As suggested above, research is needed on issues of social values/climate justice/equity/participation and how they intersect with the deployment of mitigation, adaptation interventions and sustainable development policy in different regional/sociopolitical contests (IPCC SREX, Chapter 8).

6. Research on factors that influence deliberate transformations that are ethical, equitable, and sustainable (O'Brien, 2012; Kates, Travis, and Wilbanks, 2012).
7. The development of structures for learning from emerging integrated climate change response/development experience: e.g., approaches and structures for monitoring, recording, evaluating, and learning from experience, identifying "best practices" and their characteristics (NRC, 2010a; IPCC, SREX, Chapter 8).

Finally, it is very possible that progress with global climate change mitigation will not be sufficient to avoid relatively high levels of regional and sectoral impacts, and that such conditions would pose growing challenges to the capacity of adaptation to avoid serious disruptions to development processes. If this were to become a reality later in this century, one response could be a rush toward geo-engineering solutions. In preparation for such a contingency, and perhaps as an additional way to show how important progress with mitigation is likely to be in framing prospects for sustainable development in many contexts, there is a very serious need for research on geo-engineering costs, benefits, a wide range of possible impacts, and fair and equitable structures for global policymaking and decision-making (UK Royal Society, 2009; Kates, Travis, and Wilbanks, 2012).

But a fundamental aim of research to improve capacities for climate-resilient pathways for sustainable development is to avoid such an unfortunate outcome. It seeks to do so by strengthening the base of knowledge that underlies and supports effective actions by viewing climate change mitigation, climate change adaptation, and sustainable development in an integrative and mutually-supportive way.

Frequently Asked Questions

FAQ 20.1: What difference is climate change likely to make for sustainable development?
Climate change can no longer be avoided; and, added to other stresses on sustainable development, its effects – temperature increases, precipitation changes, changes in storm behavior, and sea-level rise – will make sustainability more difficult to achieve for many locations, systems, and affected populations. The challenges presented by climate change vary widely according to threat, the sensitivities of vulnerable systems, and coping capacities; but projected impacts – especially from climate extremes and extreme events – are serious for enough locations, systems, and populations to present dangers for all in this interlinked, interdependent world.

FAQ 20.2: Is it possible to find climate-resilient sustainable development pathways?
If climate change is moderate rather than substantial, climate-resilient sustainable development pathways will be possible for most locations and systems, although perhaps not for all (for instance, some especially vulnerable areas and climate-sensitive endangered species). If climate change is substantial, the threats to resilience are far more problematic, and resilience is much more likely to require transformational adaptations: responses that change the nature, composition, and/or location of threatened systems in order to sustain development.

FAQ 20.3: What are the main characteristics of a climate-resilient sustainable development pathway?
A climate-resilient sustainable development pathway combines flexibility, innovativeness, and capacities for participative problem-solving with effectiveness in mitigating and adapting to climate change. Although this is a significant challenge for any location or system, it is profoundly exacerbated by the fact that different locations and systems are often so linked with each other that a sustainable development pathway cannot be climate-resilient in its own context unless other pathways with which it is connected are also climate-resilient.

FAQ 20.4: What are the main roles of climate change mitigation and adaptation in climate-resilient sustainable development pathways?
The main role of climate change mitigation is to keep climate change and its impacts as moderate as possible. The main role of climate change adaptation is to enable a potentially impacted system to reduce its sensitivities to impacts and/or to improve its capacity to cope with stresses and disruptions. Mitigation is necessary because adaptation is more feasible with moderate climate change than with severe climate change. Adaptation is necessary because impacts are already emerging and will increase in coming decades, even if mitigation is relatively successful. But climate change responses cannot assure climate-resilient pathways unless they are accompanied by sustainable development pathways that enable effective resolution of complex nature-society tradeoffs.

FAQ 20.5: Are there things that we can be doing now that will put us on the right track toward climate-resilient sustainable development pathways?

Although payoffs from specific long-term pathways may be uncertain, such uncertainties should not preclude actions now. Doing nothing now reduces the range of choices of climate-resilient pathways in the future. Actions at the present time will emphasize co- benefits (i.e., actions that reduce vulnerabilities to climate change impacts in the future and that, at the same time, reduce stresses on sustainable development now) and iterative learning (i.e., monitoring emerging information about climate change effects and efforts to reduce them), with risk management strategies refined continually on the basis of growing bases of knowledge and experience.

References

Adger, W.N., N.W. Arnell, and E.L. Tompkins, 2005: Successful adaptation to climate change across scales. Global Environmental Change, 15, 77-86.

Agrawal, A., 2008: Social Dimensions of Climate Change. The Role of Local Institutions in Livelihoods Adaptation to Climate Change, Social Development Department, The World Bank, Washington, DC, .

Agrawal, A., R. Mearns, and N. Perrin, 2011: Area-Based Development, Local Institutions & Climate Adaptation: A Comparative Analysis from West Africa and Latin America, Global Environmental Facility, Washington, DC, .

Agrawala, S., 2004: Adaptation, development assistance and planning: Challenges and opportunities. IDS Bulletin-Institute of Development Studies, 35, 50.

Agrawala, S. and A. van Aalst, 2008: Adapting development cooperation to adapt to climate change. Climate Policy, 8, 183-193.

Andersosn, K. and A. Bows, 2008: Reframing the climate change challenge in light of post-2000 emission trends. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 366(1882), 3863-3882.

Auerswald, H., K. Konrad, and M. Thum, 2011: CESifo Working Paper Series 3320. Adaptation, Mitigation and Risk-Taking in Climate Policy, CESifo Group, Munich, Germany, .

Ayers, J.M. and S. Huq, 2009: The value of linking mitigation and adaptation: A case study of bangladesh. Environmental Management, 43(753), 764.

Bäckstrand., K., 2003: Civic science for sustainability: Reframing the role of experts, policy-makers and citizens in envirionmental governance, . Global Environmental Politics, 3(4), 24-41.

Bailey, I., A. Gouldson, and P. Newell, 2011: Ecological modernisation and the governance of carbon: A critical analysis. Ecological Modernisation and the Governance of Carbon: A Critical Analysis, 43(3), 682-703.

Bamuri, T. and M.H. Opeschoor, 2007: Climate change and sustainable development: Realizing the opportunity. Ambio, 35(1), 2-8.

Barrett, S., 2008: The incredible economics of geoengineering. Environmental Resource Economics, 39, 45-54.

Baumol, W. and W. Oates, 1989: The theory of environmental policy. Cambridge University, Cambridge, MA, .

Beckman, M., 2011: Converging and conflicting interests in adaptation to environmental change in central vietnam. Climate and Development, 3, 32-41.

Benn, S., D. Dunphy, and A. Martin, 2009: Governance of environmental risk: New approaches to managing stakeholder involvement, Journal of Environmental Management, 90, 1567-1575.

Betsill, M.M. and H. Bulkeley, 2006: Cities and the multilevel governance of global climate change. Global Governance, 12(2), 141-159.

Biesbroek, G.R., J. Swart, and W.G.M. van der Knaap, 2009: The mitigation-adaptation dichotomy and the role of spatial planning. Habitat International, 33, 230-237.

Bizikova, L., S. Burch, S. Cohen, and J. Robinson, 2010: Climate change, ethics, and human security. In: Linking sustainable development with climate change adaptation and mitigation. [O'Brien, K. A. St. Clair, B. Kristoffersen (ed.)]. Cambridge University Press, Cambridge, MA, pp. 157-179.

Bizikova, L., J. Robinson, and S. Cohen, 2007: Linking climate change and sustainable development at the local level. Climate Policy, 7, 271-277.

Boyd, E., H. Osbahr, P.J. Ericksen, E.L. Tompkins, M.C. Lemos, and F. Miller, 2008: Resilience and “climatizing” development: Examples and policy implications. Development, 51(3), 390-396.

Bradshaw, C.J.A., X. Giam, and N.S. Sodhi, 2010: Evaluating the relative environmental impact of countries. PloS One, 5(5).
Broad, R., 1994: The poor and the environment: Friends or foes? World Development, 22(6), 811-822.
Brovkin, V., V. Petoukhov, M. Claussen, E. Bauer, A. Archer, and C. Jaeger, 2009: Geoengineering climate by stratospheric sulfur injections: Earth system vulnerability to technological failure. Climatic Change, 92, 243-259.
Brown, K., 2011: Sustainable adaptation: An oxymoron? Climate and Development, 3, 21-31.
Brown, L., 1981: Building a sustainable society. Norton, New York,
Burch, S., 2010: Transforming barriers into enablers of action on climate change: Insights from three municipal case studies in british columbia, canada. Global Environmental Change-Human and Policy Dimensions, 20, 287-297.
Burton, I., S. Huq, B. Lim, O. Pilifosova, and E.L. Schipper, 2002: From impact assessment to adaptation priorities: The shaping of adaptation policy. Climate Policy, 2, 145-159.
Cafaro, P., 2010: Getting to less. Ethics, Place, and Environment, 13(1), 11-14.
Calvin, K. and et al, 2012: Implications of simultaneously mitigating and adapting to climate change: Initial experiments using GCAM. Climatic Change, .
Campbell-Lendrum, D. and R. Woodruff, 2006: Comparative risk assessment of the burden of disease from climate change. Environmental Health Perspetives, 114, 1935-1941.
Carlin, A., 2007: Global climate change control: Is there a better strategy than reducing greenhouse gas emissions? Pennsylvania Law Review, 155, 1401-1497.
Chhatre, A. and A. Agrawal, 2009: Proceedings of the National Academy of Sciences of the United States Trade-Offs and Synergies between Carbon Storage and Livelihood Benefits from Forest Commons, National Academy of Sciences, 17667-17670 pp.
Chuku, C.A., 2009: Pursuing an integrated development and climate policy framework in africa: Options for mainstreaming. Mitigation and Adaptation Strategies for Global Change, 15(1), 41-52.
Chukwumerije, O. and H. Schroeder, 2009: How can justice, development and climate mitigation be reconciled for developing countries in a post-kyoto settlement. Climate and Development, 1, 10-15.
Clark, A.E., P. Frijters, and M.A. Shields, 2008: Relative income, happiness, and utiity: An explanation for the easterlin paradox and other puzzles. Journal of Economic Literature, 46, 95-144.
Cohen, S., D. Demeritt, J. Robinson, and D. Rothman, 1998: Climate change and sustainable development: Towards dialogue. Global Environmental Change, 8(4), 341-371.
Corbera, E. and K. Brown, 2008: Building institutions to trade ecosystem services: Marketing forest carbon in mexico. World Development, 36, 1956-1979.
Daly, H.E. and J.B. Cobb Jr., 1989: For the common good: Redirecting the economy towards community, the environment, and sustainable future. Beacon Press, Boston, MA, .
Dang, H.H., A. Michaelowa, and D.D. Tuan, 2003: Synergy of adaptation and mitigation strategies in the context of sustainable development: The case of vietnam. Climate Policy, 3, S81-S96.
Deaton, A., 2008: Income, health and well-being around the world: Evidence from the gallup world poll. Journal of Economic Perspectives, 22, 53-72.
Deere-Birbeck, C., 2009: Global governance in the context of climate change: The challenges of increasingly complex risk parameters. International Affairs, , 1173-1194.
DeLeire, T. and A. Kalil, 2010: Does consumption buy happiness? evidence from the united states. International Review of Economics, 57(2), 163-176.
Denton, F. and et al (eds.), 2013: Adapting african institutions to meet climate change.
deSherbinin, A., K. Warner, C. Erhart, and S. Adamo, 2011: Climate change and migration. Scientific American, , 50-58.
Dolan, P. and M.P. White, 2007: Howo can measures of subjective well-being be used to inform public policy? Perspectives in Psychological Science, 2, 71-85.
Duraiappah, A., 1998: Poverty and environmental degradation: A literature review and analysis of the nexus. World Development, , 2169-2179.
Eakin, H., 2005: Institutional change, climate risk, and rural vulnerability: Cases from central mexico. World Development, 33, 1923-1938.
Eakin, H. and M.C. Lemos, 2006: Adaptation and the state: Latin america and the challenge of capacity-building under globalization. Environmental Change-Human and Policy Dimensions, 16, 7-18.
Easterlin, R.A., 1974: Does Economic Growth Improve the Human Lot?", Academic Press, Inc., New York, .

Easterlin, R.A., 2001: Income and happiness: Toward a unified theory. Economic Journal, 111, 465-484.
Editorial Board of National Climate Change Assessment (EBNCCA), 2011: Second National Climate Change Assessment Report, Science Press, Beijing, China, .
Ehrenfeld, J., 2008: Sustainability by design: A subversive strategy for transforming our consumer culture. Yale University Press, New Havenm CT, .
Eriksen, S., et al, 2011: When not every response to climate change is a good one: Identifying principles for sustainable adaptation. Climate and Development, 3, 7-20.
Eriksen, S. and K. Brown, 2011: Sustainable adaptation to climate change. Climate and Development, 3(3), 6.
Falloon, P. and R. Betts, 2010: Climate impacts on european agriculture and water management in the context of adaptation and mitigation—The importance of an integrated approach. Science of the Total Environment, 408(23), 5667-5687.
Finco, M., 2009: Poverty-environment trap: A non linear probit model applied to rural areas in the north of brazil. American-Eurasian Journal of Agricultural and Environmental Science, 5(4), 533-539.
Fleurbaey, M., 2009: Beyond GDP: The quest for a meaure of well-being and social welfare. Journal of Economic Literature, 47, 1029-1075.
Folke, C., 2006: Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change, 16(3), 253-267.
Frey, G.W. and D.J. Linke, 2002: Hydropower as a renewable and sustainable energy resource meeting global energy challenges in a reasonable way. Energy Policy, 30, 1261-1265.
Gallopin, G., 2006: Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change, 16(3), 293-303.
Gao, Q. and et al, 2009: Dynamics of alpine grassland NPP and its response to climatec change in northern tibet. Climatic Change, 97(515), 528.
Gao, Q. and et al., 2009: Dynamics of alpine grassland NPP and its response to climate change in northern tibet. Climatic Change, 97(3-4), 515-528.
Gardiner, S.M., S. Caney, and D. Jamieson, 2010: Climate ethics: Essential readings. Oxford University Press, New York, NY, pp. 368.
Garg, A., R. Dahiman, S. Bhattacharya, and P.R. Shukla, 2009: Development, malaria and adaptation to climate change: A case study from india. Environmental Management, 43, 779-789.
Garg, A., P.R. Shukla, and M. Kapshe, 2007: From climate change impacts to adaptation: A development perspective for india. Natural Resources Forum, 31, 132-141.
Gilbert, D., 2006: Stumbling on happiness. Vintage Books, New York, NY, .
Green, D. and G. Raygorodetsky, 2010: Indigenous knowledge of a changing climate. Climatic Change, 100(2), 239-242.
Gupta, J., et al., 2008: Institutions for Climate Change: A Method to Assess the Inherent Characteristics of Institutions to Enable the Adaptive Capacity of Society, Institute for Environmental Studies, Amsterdam, .
Hallegatte, S., 2009: Strategies to adapt to an uncertain climate change. Global Environmental Change, 19(2), 240-247.
Halsnaes, K. and J. Verhagen, 2007: Development based climate change adaptation and mitigation—conceptual issues and lessons learned in studies in developing countries. Mitigation and Adaptation Strategies for Global Change, 12(5), 665-684.
Halsnaes, K., P.R. Shukla, and A. Garg, 2008: Sustainable development and climate change: Lessons from country studies. Climate Policy, 8, 202-219.
Hamin, E.M. and N. Gurran, 2009: Urban form and climate change: Balancing adaptation and mitigation in the US and australia. Habitat International, 33, 238-245.
Hanjra, M.A. and M.E. Qureshi, 2010: Global water crisis and future food security in an era of climate change. Food Policy, 35, 365-377.
Heltberg, R., P.B. Siegel, and S.L. Jorgensen, 2009: Addressing human vulnerability to climate change: Toward a "no-regrets" approach. Global Environmental Change, 19(1), 89-99.
Hodgson, G.M., 2003: The hidden persuaders: Institutions and individuals in economic theory. Cambridge Journal of Economics, 27(2), 159-175.
Hof, A.F., K.C. deBruin, R.B. Dellink, M.G.J. denElzen, and D.P. vanVuuren, 2009: The effect of different mitigation strategies on international financing of adaptation. Environmental Science & Policy, 12, 832-843.

Hopwood, B., M. Mellor, and G. O'Brien, 2005: Sustainable development: Mapping different approaches. Sustainable Development, 13(1), 38-52.
Huesemann, M.H., 2006: Can advances in science and technology prevent global warming? A critical review of limitations and challenges. Mitigation and Adaptation Strategies for Global Change, 11(3), 539-577.
Hueting, R., 2010: Why environmental sustainability can most probably not be attained with growing production. Journal of Cleaner Production, 18(6), 525-530.
Huq, S., F. Yamin, A. Rahman, A. Chatterjee, X. Yang, S. Wade, V. Orindi, and J. Chigwada, 2005: Linking climate adaptation and development: A synthesis of six case studies from asia and africa. IDS Bulletin-Institute of Development Studies, .
International Council for Science, 2002: Consensus Report and Background Document, Mexico City Synthesis Conference, may 2002. Science and Technology for Sustainable Development, ICU Series on Science for Sustainable Development No. 9, .
IPCC, 2001: Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, .
IPCC, 2007: Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University, New York, .
IPCC SREX 2012: Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, Geneva,
IPCC SSREN, 2011: Special Report on Renewable Energy Sources and Climate Change Mitigation, Geneva, .
Jabareen, Y., 2008: A new conceptual framework for sustainable development Environ Dev Sustain, 10(179), 192.
Jäger, J., J. Frühmann, S. Günberger, and A. Vag, 2009: Project Synthesis Report, may 14, 2009, Deliverable 044468. Environmental Change and Forced Migration Scenarios, German Marshall Fund, Washington, DC, .
Jänicke, M., 2008: Ecological modernisation: New perspectives. Journal of Cleaner Production, 15, 557-565.
Jerneck, A. and L. Olsson, 2008: Adaptation and the poor: Development, resilience and transition. Climate Policy, 8, 170-182.
Johnston, R., et al., 2010: George Perkins Marsh Institute (GPMI) Working Papers no. 2010-12. Indices of Biotic Integrity in Stated Preference Valuation of Ecosystem Services, Clark University, Worcester, MA, .
Kates, R.W., 2000: Population and consumption: What we know, what we need to know. Environment, 42(3), 10-19.
Kates, R.W.; Travis, W.R.; Wilbanks, T.J.; 2012; Transformational adaptation when incremental adaptations to climate change are insufficient. PNAS 109(19). 7157-7161.
Keith, D.W., 2000: Geoengineering the climate: History and prospect. Annual Review, Energy and Environment, 25, 245-284.
Kelly, P.M. and W.N. Adger, 2000: Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change, 47, 325-252.
Kemp, R., 1994: Technology and the transition to environmental sustainability: The problems of technological regime shifts. Futures, 26(10), 1023-1046.
Kemp, R. and J. Rotmans, 2009: Transitioning policy: Co-production of a new strategic framework for energy innovation policy in the netherlands. Policy Sci, 42, 303-322.
Klein, R., E. Schipper, and S. Dessai, 2005: Integrating mitigation and adaptation into climate and development policy: Three research questions. Environmental Science and Policy, 8(6), 579-588.
Kok, M., B. Metz, J. Verhagen, and S. Van Rooijen, 2008: Integrating development and climate policies: National and international benefits. Climate Policy, 8, 103-118.
Kopytko, N. and J. Perkins, 2011: Climate change, nuclear power, and the adaptation-mitigation dilemma. Energy Policy, 39, 318-333.
Kriegler, E., et al., 2011: Socioeconomic scenario development for climate change analysis. Global Environmental Change, .
Kristjanson, P., et al., 2009: Linking international agricultural research knowledge with action for sustainable development. PNAS, 106(5047), 5052.
La Rovere, E.L., A.C. Avzaradel, and J.M.G. Monteiro, 2009: Potential synergy between adaptation and mitigation strategies: Production of vegetable oils and biodiesel in northeastern brazil. Climate Research, 40, 233-239.
Lafferty, W. and J. Meadowcroft, 2010: Implementing sustainable development. Oxford University Press, .

Leighton, M., 2011: Climate Change and Migration: Key Issues for Legal Protection of Migrants and Displaced Persons, UNU-EHS, Bonn, Germany, .
Leighton, M., S. Xiaomeng, and K. Warner (eds.), 2011: Climate change and migration: Rethinking policies for adaptation and disaster risk reduction. SOURCE 15. UNU-EHS, Bonn, Germany, .
Leiserowitz, A.A., R.W. Kates, and T.M. Parris, 2005: What is sustainable development? goals, indicators, values, and practice. Environment: Science and Policy for Sustainable Development, 47(1), 8-21.
Lemos, M.C. and A. Agrawal, 2006: Environmental governance. Annual Review of Environment and Resources, 31, 3.1-3.29.
Lemos, M.C., E.L. Emily-Boyd, H. Tompkins, H. Osbahr, and D. Liverman, 2007: Developing adaptation and adapting development. Ecology and Society, 12(2), 26.
Liverman, D. and S. Billett, 2010: Copenhagen and the governance of adaptation. Environment, 52(3), 28-36.
Lovins, L.H. and B. Cohen, 2011: Climate capitalism: Capitalism in the age of climate change. Hill and Wang, New York, .
Lux Research, 2009: Global Energy: Unshackling Carbon from Water, .
Malthus, T.R., 1798: An essay on the principle of population, as it affects the future improvement of society, first edition J. Johnson, London, .
Mapfumo, P. and et al., 2010: Project Number 104140. Lack of Resilience in African Smallholder Farming : Exploring Measures to Enhance the Adaptive Capacity of Local Communities to Pressure Climate Change : Final Technical Report - Zimbabwe, Department of Soil Science and Agricultural Engineering, University of Zimbabwe, Harare ZW, .
Martin, S.F., 2010: World Migration Report (WMR) 2010 Background Paper: Climate Change and International Migration, German Marshall Fund Study Team on Migration and Climate Change, .
Massey, D. and A.W. Ghimire, 2007: Environmental Change and Out-Migration Evidence from Nepal. University of Michigan, Institute for Social Research, Ann Arbor, Michigan, .
Matthew, R.A. and A. Hammill, 2009: Sustainable development and climate change International Affairs, 85(6), 1117-1128.
Meadowcroft, J., 2000: Sustainable development: A new(ish) idea for a new century? Political Studies, 48(2), 370-387.
Meinshausen, M. and et al., 2009: Greenhouse-gas emission targets for limiting global warming to 2oC. Nature, 458(8017), 1158-1162.
Metz, B. and M. Kok, 2008: Integrating development and climate policies. Climate Policy, 8, 99-102.
Michonski, K. and M.A. Levi, 2010: Harnessing International Institutions to Address Climate Change, Council on Foreign Relations, New York, .
Millar, C.I., N.L. Stephenson, and S.L. Stephens, 2007: Climate change and forests of the future: Managing in the face of uncertainty. ecological applications. Ecological Applications, 17(8), 2145-2151.
Miller, A.S., 2008: Financing the integration of climate change mitigation into development. Climate Policy, 2, 152-169.
Miller, E.R., 2007: Futures literacy: A hybrid strategic scenario method. Futures, 39(241), 362.
Miller, K.A. and et al., 2010: Climate change, uncertainty, and resilient fisheries: Institutional responses through integrative science. In: Progress in oceanography. Elsevier, Ltd., pp. 338-346.
Mirza, M.M.Q., 2003: Climate change and extreme weather events: Can developing countries adapt? Climate Policy, 3, 233-248.
Morgan, J. and T. Farsides, 2009: Measuring meaning in life. Journal of Happiness Studies, 10, 197-214.
Muller, B., 2009: Additionality in the Clean Development Mechanism: Why and what? Oxford Institute for Energy Studies, Oxford, UK, .
Munasinghe, M., 2010: Addressing the sustainable development and climate change challenges together: Applying the sustainonomics framework. Procedia - Social and Behavioral Sciences, 25(5), 6634-6640.
Najam, A., M. Papa, and N. Taiyab, 2006: Global environmental governance: A reform agenda. International Institute for Sustainable Development, Canada, .
National Research Council, 2011: America's Climate Choices, National Academies Press, Washington, DC, 118 pp.
Nelson, D.R., N. Adger, and K. Brown, 2007: Adaptation to environmental change: Contributions of a resilience framework. Annual Review of Environment and Resources, 32(1), 395-419.
Nelson, R. and S. Winter, 1982: An evolutional theory of economic change. Cambridge, Harvard, .
NRC, 1996: Understanding risk. National Academy Press, Washington, DC, .

NRC (ed.), 1999: Our common journey: A transition toward sustainability. National Academy Press, Washington, DC, .
NRC, 2009: Restructuring Federal Climate Research to Meet the Challenges of Climate Change. Appendix D: Fundamental Research Priorities to Improve the Understanding of Human Dimensions of Global Change, National Academies Press, Washington, DC, .
NRC, 2010a: Adapting to Impacts of Climate Change, Report of the Panel on Adapting to Impacts of Climate Change, NAS/NRC Committee on America's Climate Choices, NAS/NRC Committee on America's Climate Choices, Washington, DC, .
NRC, 2010b: Climate Choices: Panel on Advancing the Science of Climate Change, National Research Council of the National Academy of Sciences, Washington, DC, .
Nyong, A., F. Adesina, and B.O. Elasha, 2007: The value of indigenous knowledge in climate change mitigation and adaptation strategies in the african sahel. Mitigation and Adaptation Strategies for Global Change, 12(5), 787-797.
O'Brien, K., 2009: Do values subjectively define the limits to climate change adaptation? In: Adapting to climate change: Thresholds, values, governance [Adger, N., J. Lorenzoni, and K. O'Brien(eds.)]. Cambridge University Press, pp. 164-180.
O'Brien, K., 2011: Global environmental change II: From adaptation to deliberate transformation. Prog Hum Geogr,
O'Brien, K. and et al., 2004: Mapping vulnerability to multiple stressors: Climate change and globalization in india. Global Environmental Change, 14, 303-313.
O'Brien, K. and R.M. Leichenko, 2003: Winners and losers in the context of global change. Annals, Association of American Geographers, 93(1), 89-103.
O'Brien, K.L., 2012: Global environmental change: From adaptation to deliberate transformation. Progress in Human Geography, .
O'Brien, K.L., A.L. St. Clair, and B. Kristoffersen (eds.), 2010: Toward a new science on climate change. Cambridge University Press, Cambridge, pp. 215-227.
Omolo, N., 2010: Gender and climate change-induced conflict in pastoral communities: Case study of turkana in northwestern kenya. African Journal on Conflict Resolution, 10(2).
Ostrom, E., 1986: An agenda for the study of institutions. Public Choice, 48, 3-25.
Ostrom, E., 2005: Understanding institutional diversity. Princeton University Press, Princeton, NJ, .
Patel, P. and K. Pavit, 1995: Patterns of technological activity: Their measurement and interpretation. In: Handbook of economics of innovation and technological change. Oxford, pp. 14-51.
Paterson, M., 2009: Post-hegemonic climate politics? British Journal of Politics & International Relations, 11(1), 140-158.
Pelling, M., 2010: Adaptation to climate change: From resilience to transformation. Routledge, London, .
Pelling, M. and D. Manuel-Naverrette, 2011: From resilience to transformation: Exploring the adaptive cycle in two mexican urban centres. Ecology and Society, 16(2), 11.
Perez, C., 2002: Technological revolutions and financial capital: The dynamics of bubbles and golden ages. Edward Elgar, Northampton, MA, .
Pielke, R., Jr., G. Prins, S. Rayner, and D. Sarewitz, 2007: Climate change 2007: Lifting the taboo on adaptation. Nature, 445, 597-598.
Raskin, P. and et al., 2002: Great Transition: The Promise and Lure of the Times Ahead, Stockholm Environmental Institute, Tellus Institute, .
Raven, R., S. Van den Bosch, and R. Weterings, 2010: Transitions and strategic niche management: Towards a competence kit for practitioners. International Journal of Technology Management, 51(1), 57-74.
Richardson, K., W. Steffen, and D. Liverman (eds.), 2009: Climate change: Global risks, challenges and decisions. Cambridge University Press, Cambridge, .
Roberts, J.T. and B.C. Parks, 2006: A climate of injustice: Global inequality, north-south politics, and climate policy. MIT Press, Cambridge, MA, .
Robinson, J., 2004: Squaring the circle? some thoughts on the idea of sustainable development. Ecological Economics, 48, 369-384.
Robinson, J., et al., 2006: Climate change and sustainable development. Ambio, 35(1), 2-8.
Robock, A., L. Oman, and G. Stenchikov, 2008: Regional climate responses to geoengineering with tropical and arctic SO2 injections. Journal of Geophysical Research, 113(D16101), 15.

Rohracher, H., 2008: Energy systems in transition: Contributions from social sciences. International Journal of Environmental Technology and Management, 9(203), 144-161.
Romero-Lankao, P. and et al, 2011: Conclusions and policy directions. In: Cities and climate change. UN Human Settlements Programme, pp. 163-183.
Rose, S., 2010: The importance of multi-metric, scale, an sector climate change impacts valuation. In: Proceedings of Energy modeling forum, July 2010, Snowmass, CO, .
Rosenzweig, C. and F.N. Tubiello, 2007: Adaptation and mitigation strategies in agriculture: An analysis of potential synergies. Mitig Adapt Strat Glob Change, 12, 855-873.
Rounsevell, M.D.A., T.P. Dawson, and P.A. Harrison, 2010: A conceptual framework to assess the effects of environmental change on ecosystem services. Biodiversity and Conservation, 19, 2823-2842.
Roy, M., 2009: Planning for sustainable urbanization in fast growing cities: Mitigation and adaptation issues addressed in dhaka, bangladesh. Habitat International, 33(3), 276-286.
Schipper, L., 2007: Working Paper 107. Climate Change Adaptation and Development : Exploring the Linkages Tyndall Centre for Climate Change Research, 1-17 pp.
Schipper, L. and M. Pelling, 2006: Disaster risk, climate change and international development: Scope for, and challenges to integration; special issue: Climate change and disasters. Disasters, 30(1), 19-38.
Schneider, S., 1996: Geoengineering: Could - or should we do it? Climatic Change, 33, 291-302.
Schneider, S., 2009: Geoengineering: Could we or should we make it work? Philosophical Transactions of the Royal Society A, 366, 3843-3862.
Sen, A., 1999: Development as freedom. Alfred A. Knopf, New York, NY, .
Shah, T., 2009: Climate change and groundwater: India's opportunities for mitigation and adaptation. Environ. Res. Lett., (3).
Sitarz, D. (ed.), 1994: Agenda 21: The earth summit strategy to save our planet. Earthpress, Boulder, CO, .
Smit, B. and J. Wandel, 2006: Adaptation, adaptive capacity and vulnerability. Global Environmental Change, 16(3), 282-292.
Smith, J., et al, 2009: Assessing dangerous climate change through an update of the intergovernmental panel on climate change (IPCC): Reasons for concern In: Proceedings of Proceedings of the national academies of science (PNAS), Washington, DC, pp. 4133-4137.
Smith, M., L. Horrocks, A. Harvey, and C. Hamilton, 2011: Rethinking adaptation for a 4°C world. Phil. Trans. R. Soc. A, 369(1934), 196-216.
Sneddon, C., R.B. Howarth, and R.B. Norgaard, 2006: Sustainable development in a post-brundtland world Ecological Economics, 57, 253-268.
Solomon, S. and et al., 2009: Irreversible climate change due to carbon dioxide emissions. PNAS, 106, 1704-1709.
Speranza, C.I., B. Kiteme, P. Ambenje, U. Wiesmann, and S. Makali, 2010: Indigenous knowledge related to climate variability and change: Insights from droughts in semi-arid areas of former makueni district, kenya. Climatic Change, 100(2), 295-315.
Stafford, S. G. et al., 2010: Now is the time for action: Transitions and tipping points in complex environmental systems. Environment, 52(1), 38-45.
Stringer, L.C. and et al., 2009: Adaptations to climate change, drought and desertification: Local insights to enhance policy in southern africa. Environmental Science & Policy, 12(7), 748-765.
Swart, R., J. Robinson, and S. Cohen, 2003: Climate change and sustainable development: Expanding the options. Climate Policy, Climate Policy(3S1), S19-S40.
Swart, R. and F. Raes, 2007: Making integration of adaptation and mitigation work: Mainstreaming into sustainable development policies
Climate Policy, 7, 288-303.
Tanner, T. and J. Allouche, 2011: Political economy of climate change. Institute of Development Studies, United Kingdom, 42.3rd ed., pp. 120.
Tanner, T. and J. Allouche, 2011: Towards a new political economy of climate change and development. Ids Bulletin-Institute of Development Studies, 42(3), 1-14.
Tejero I.G and et al., 2011: Improved water-use efficiency by deficit-irrigation programmes: Implications for saving water in citrus orchards. Scientia Horticulturae, 128(274), 282.
Thomalla, F., T. Downing, E. Spanger-Siegfried, and G. Han, 2006: Reducing hazard vulnerability: Towards a common approach between disaster risk reduction and climate adaptation. Environment, 30(1), 39-48.

Thomas, D.S.G. and C. Twyman, 2005: Equity and justice in climate change adaptation amongst natural-resource-dependant societies. Global Environmental Change, 15(2), 115-124.
Tol, R.S.J., 2004: Adaptation and mitigation: Trade-offs in substance and methods. Environmental Science and Policy, 8, 572-578.
Tompkins, E.L. and W.N. Adger, 2004: Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society, 9, 2-10.
Tompkins, E.L., M.C. Lemos, and E. Boyd, 2008: A less disastrous disaster: Managing response to climate-driven hazards in the cayman islands and NE brazil. Global Environmental Change-Human and Policy Dimensions, 18, 736-745.
Turner, W.R. and et al., 2010: Climate change: Helping nature survive the human response. Conservation Letters, 3, 304-312.
UK Royal Society, 2009: Geoengineering the climate: Science, governance, and uncertainty. The Royal Society, London, .
UK Royal Society, 2011: Four degrees and beyond. Philosophical Transactions of the Royal Society, Special Issue, 369(1934).
UNHCR, 2011: Summary of Deliberations on Climate Change and Displacement, Bellagio Principles, United Nations High Commissioner for Refugees, Bellagio, Italy, .
van Aalst, M., T. Cannon, and I. Burton, 2008: Community level adaptation to climate change: The potential role of participatory community risk assessment. Global Environmental Change, 18(1), 165-179.
Veeman T. S. Politylo, J., 2003: The role of institutions and policy in enhancing sustainable development and conserving natural capital. Environment, Development and Sustainability, 5, 317-332.
Victor, P., 2008: Managing without growth: Slower by design, not disaster. Edward Elgar, Cheltenham, UK and Northampton, MA, USA, .
Victor, P. and G. Rosenbluth, 2007: Managing without growth. Ecological Economics, 61, 492-504.
Von Bernard, H. and M. Gorbarán, 2010: Causes for unsustainability. Ecologia Austral, 20(3), 303-306.
Walker, B. and D. Salt, 2006: Resilience thinking: Sustaining ecosystems and people in a changing world. Island Press, Washington, .
Warner, K., 2010: Global environmental change and migration: Governance challenges. Global Environmental Change, 20(3), 402-413.
Warner, K.e.a., 2010: Climate change, environmental degradation and migration. Natural Hazards, Special Volume. Extreme Events, Vulnerability, Environment and Society, 55(3), 689-715.
Washington, W., et al., 2009: How much climate change can be avoided by mitigation? Geophysical Research Letters, 36(L08703), 1-5.
WCED, 1987: Our Common Future, a Report of the World Commission on Environment and Development, Annex to General Assembly Document A/42/427, Development and International Co-Operation: Environment, Oxford University Press, .
Westley, F.P., 2011: Tipping toward sustainability: Emerging pathways of transformation. Ambio, 40, 762-780.
Wilbanks, J.T. and T.J. Wilbanks, 2010: Science, open communication, and sustainable development. Sustainability, 2, 993-1015.
Wilbanks, T.J., 2003: Integrating climate change and sustainable development in a place-based context. Climate Policy, 3S1, 147-154.
Wilbanks, T.J., 2009: How Geographic Scale Matters in Seeking Community Resilience, Community and Regional Resilience Initiative, CARRI Research Paper Number 7, Oak Ridge, TN, .
Wilbanks, T.J., 2010: Inducing transformational energy technological change. Energy Economics, 33(4), 699-708.
Wilbanks, T. J., et al., 2007: Toward an integrated analysis of mitigation and adaptation: Some preliminary findings Mitigation and Adaptation Strategies for Global Change, 12(5), 713-725.
Wilbanks, T.J. and R.W. Kates, 2010: Beyond adapting to climate change: Embedding adaptation in responses to multiple threats and stresses. Annals of the Association of American Geographers, 100(4), 719-728.
Wilbanks, T.J. and J. Sathaye, 2007: Integrating mitigation and adaptation as responses to climate change: A synthesis. Mitig Adapt Strat Glob Change, 12, 957-962.
Wilson, C. and T. McDaniels, 2007: Structured decision-making to link climate change and sustainable development. Climate Policy, , 353-370.
Winkler, H., et al., 2007: What factors influence mitigative capacity. Energy Policy, 35, 15-28.

Wolf, J., K. Brown, and D. Conway, 2009: Ecological citizenship and climate change: Perceptions and practice. International Politics, 18(4), 467-485.
World Bank, 2010: World Development Report: Development and Climate Change, World Bank, Washington, DC,
Xiong, W., L. Holman, and E.D. Lin, 2010: Climate change, water availability, and future cereal production in chi. Agriculture, Ecosystems, and Environment, 135, 58-69.
Yohe, G., 2001: Mitigative capacity: The mirror image of adaptive capacity on the emissions side. Climatic Change, 49, 247-262.
Young, O.R., 2010: The future of the arctic: Cauldron of conflict or zone of peace? International Affairs, 87(1), 185-193.
Ziervogel, G. and A. Opere (eds.), 2010: Climate change adaptation in africa learning paper, 2010 series. In: Integrating meteorological and indigenous knowledge-based seasonal climate forecasts in the agricultural sector. International Development Research Centre, Ottawa, Canada, .
Zou, X. and et al., 2011: Quantitative analysis on the role of water-saving irrigation measures in china to contribute to mitigation and adaptation. Mitigation and Adaptation Strategies for Global Change

Table 20-1: Examples of national plans for low carbon growth (Araya, 2010).

Country	Vision	Innovation
China	Low carbon zones to provide a laboratory for large-scale low carbon private and public investment. Europe-China collaboration to pioneer approaches compatible with Chinese institutions and development.	Low Carbon Zones build on 1980s Special Economic Zones (SEZs)
Maldives	Carbon neutrality by 2020 Climate change central development priority for government	Island with focus beyond adaptation
Mexico	Emissions peaking in 2012 and 50 percent reduction below 2000 levels by 2050 Establishment of low carbon development scenarios and priorities	2050 time horizon; peaking objectives; investment platform
South Korea	Plan to guide transition to low carbon economy 80 percent of economic stimulus package going into low carbon measures	Green recovery; public resources commitment
Japan	25% reduction in 2020 compared with 1990 level 80% reduction in 2050 compared with 1990 level Development of mid- and long-term roadmap	Mid- and long-term roadmap Subcommittee, Global Environmental Committee, Central Environmental Council

Table 20-2: Effectiveness of water-saving irrigation dealing with climate change (Zou et al., 2011).

	2007	2008	2009
Water saved (Bm^3)	19.37-40.86	19.86-41.55	22.58-47.25
Energy saved (Mt)	2.92-6.39	3.08-6.72	3.58-7.73
CO_2 emission reduction (Mt)	6.66-14.58	7.02-15.31	8.15-17.59

Table 20-3: The link between scarcity of resources, environmental degradation, and migration for resource dependent communities.

Country	Impacts of climate change	Coping mechanism to climate variability
Ethiopia	Frequent droughts	Temporary and *permanent migration in search of employment*.
Mali	Drought	Migration from north to south within the country and towards coastal countries and the west as a spontaneous adaptation strategy.
Cape Verde	Devastating famines, frequent torrential rains	Emigration
Bangladesh	High depth of standing water which prevents crop cultivation during the Kharif season.	Migrate to cities for jobs.
Cambodia	Increased crop losses have led to increased food shortages and poor health,	Rural-urban migration and cross-border migration
Gambia	Unpredictable rainy seasons and dry spells result in lower crop yields, reduced availability of forest products, and poor animal pasture	Rural-urban migration
Guinea-Bissau	Increased pressure on the uplands as the longer dry season, particularly in countryside regions (eastern part of the country).	Displacement of whole villages
Haiti	Poverty, population growth and environmental problems.	Migration of large numbers of people from rural areas to Port au Prince.
Mauritania	Loss of livestock as result of decreased rainfall.	Massive rural exodus among livestock herders and their cessation of a nomadic lifestyle
Tanzania	Erosion and rising sea levels leading to a loss of settlements in coastal areas.	Potential adaptation activity being the relocation of these vulnerable communities to other areas

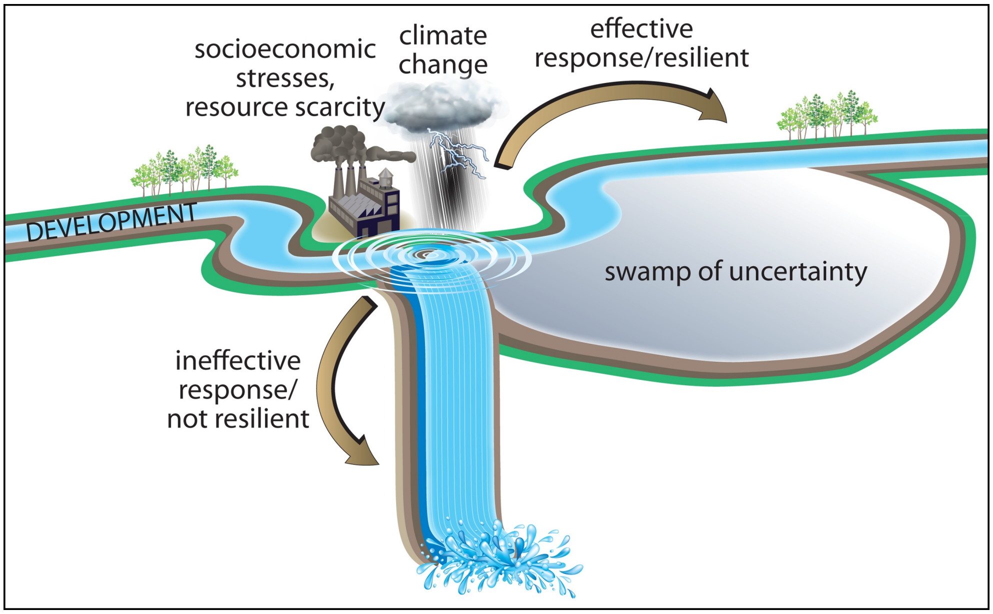
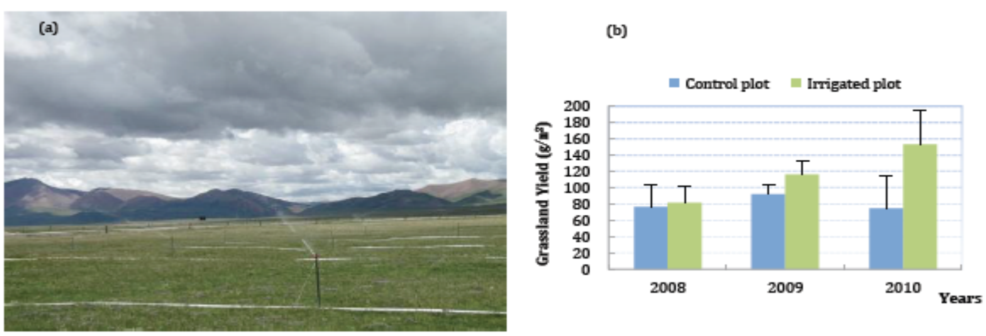


Figure 20-1: Sustainable development depends on effective responses to climate change and other stresses.



In this figure, (a) is the demonstration photo of alpine grassland water-saving irrigation; (b) is the grassland yield changes after irrigation

Figure 20-2: The demonstration of alpine grassland water-saving irrigation measures for adaptation to climate change in Northern Tibet.]

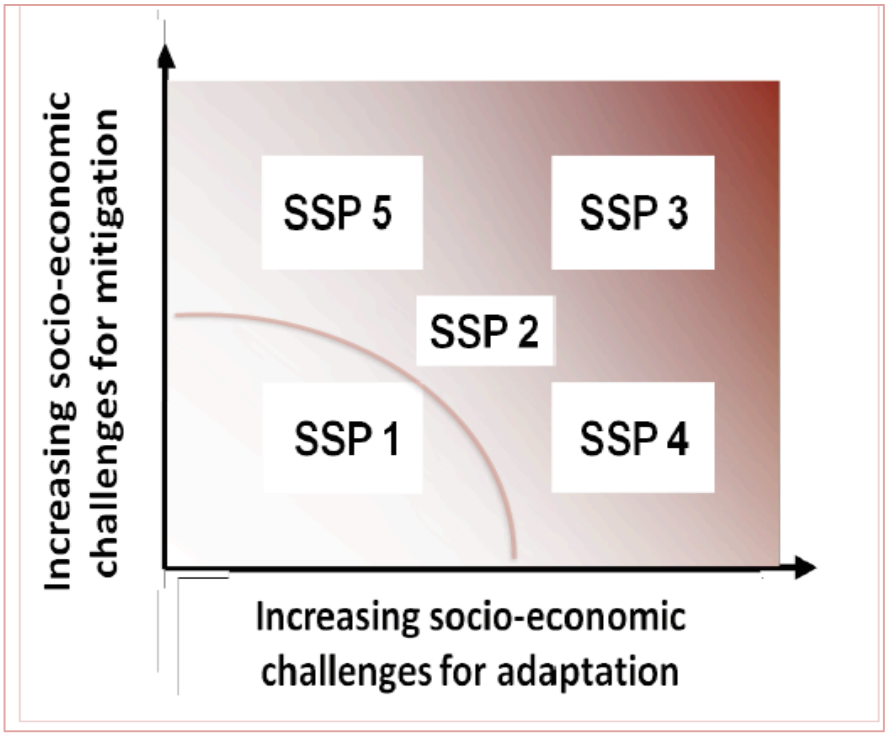


Figure 20-3: A Notional Depiction of Alternative Climate-resilient Sustainable Development Pathways (lower left). Regarding SSP's see Box 20-3; SSPs are representations of alternative socioeconomic pathways within which climate change responses might evolve.

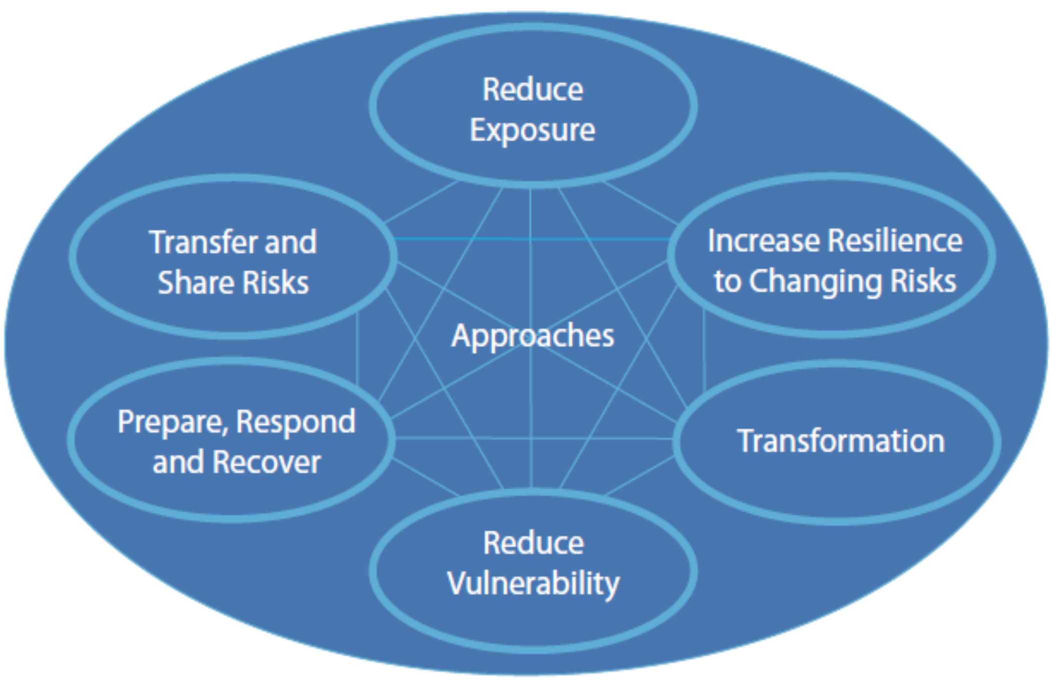


Figure 20-4: The Solution Space for Current Strategies (SREX, 2012).