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

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Executive Summary

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. 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, and adaptation as a response strategy to cope with impacts that cannot be (or are not) avoided. The chapter's distinctive contribution is not to provide arguments to substantiate the logic for viewing both mitigation and adaptation strategies as a precursor to sustainable development – but more importantly to consider how the alignment of adaptation and mitigation is possible within a climate-resilient sustainable development pathway. In particular, it aims to explore how adaptation and mitigation can both contribute to and impede sustainable development, for example in their relationships with extreme climate changes and events.

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. 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. For near term time horizons, responses are likely to emphasize climate change mitigation and relatively low-cost adaptations with development co-benefits. 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. 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.

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 impacts of climate change begin to emerge, the "so what" of climate change is becoming more salient as an issue for policymaking and decision-making. Responses are shifting from risk management with respect to *projected* impacts toward responses to *observed* impacts, which in many cases converts "what to do" from prudent long-term contingency planning to planning for relatively near-term actions.

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 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, as expanded by the Delhi Ministerial Declaration on Climate Change and Sustainable Development: Decision 1/CP.8.

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 – 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, and adaptation as a response strategy to cope with impacts that cannot be (or are not) avoided. It is organized in four parts: fundamental dimensions of climate-resilient pathways for sustainable development (20.2), major issues for integrated strategies (20.3), perspectives on appropriate and effective pathways (20.4), and important gaps in existing knowledge for clarifying what to do (20.5). The chapter's distinctive contribution is not to provide arguments to substantiate the logic for viewing both mitigation and adaptation strategies as a precursor to sustainable development – but more importantly to consider how the alignment of adaptation and mitigation is facilitated through climate-resilient development pathways. In particular, the chapter shows that adaptation and mitigation can both contribute to and impede sustainable development, with the outcomes dependent upon the capacity to reconcile responses across both spatial and temporal scales (for example in their relationships with extreme climate changes and events).

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). For literatures on "sustainable development," see section 20.2.1 below. A summary definition is development that achieves continuing economic and social 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 potentials and possible limitations of pathways for sustainable development that are resilient to impacts of climate change: i.e., 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 (Fig 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: An illustration of the possibility that, in some systems and regions, an ability to reduce climate change vulnerabilities and risks by a combination of mitigation and adaptation might be a factor in determining whether or not development paths are sustainable.]

Woven through the chapter are two themes: (1) an effort to understand interdependencies and interactions among the wide range of issues and concepts, transcending familiar approaches that are focused on a narrow range of issues and concerns (e.g., see V. Brown, 2010; Wickson et al., 2006), and (2) attention to knowledge about not only *what* pathways are the most promising, but also about *how* such pathways might be realized.

20.2. Elements of Climate-Resistant Pathways for Sustainable Development

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 development.

20.2.1. Sustainable Development as the Context – Both Longer Term and Nearer Term, including such Moral Dimensions as Equity

"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 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.

Among many definitions of sustainable development, the best-known dates back to 1987, in an influential report published by the United Nations entitled "Our Common Future" (or "The Brundtland Report"). In this publication (WECD, 1987), sustainable development is defined as a principle to be pursued in order to meet the needs of the present without compromising the ability of future generations to meet their own needs. The report recognized that poverty is one of the main causes of environmental degradation and that equitable economic development is a key to addressing environmental problems. The report also emphasized the issue of the legacy that the present generation is leaving for future generations. While the Brundtland Report drew attention to the need for sustainable economic and social development at the global level, the concept of sustainable development applies to all levels and contexts, including industrialized countries (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). The United Nations Commission for Sustainable Development was established to ensure followup, and it includes participation by diverse governmental and non-governmental actors.

The international discourse that has developed over the past two decades has helped to establish some commonly held principles of sustainable development, even though the concept remains rather distant from operational definition (e.g., Hopwood, Mellow, and O'Brien, 2005; Jabareen, 2008). These principles include, for instance, the achievement of a standard of human well-being that meets human needs and provides opportunities for social and economic development; that sustains the life support systems of the planet; that broadens participation in development processes and decisions; and that accelerates the movement of knowledge into action in order to provide a wider range of options for achieving development goals (WCED, 1987; NRC, 1999; Swart, Robinson, and Cohen, 2003; MA, 2005; Sneddon, Howarth, and Norgaard, 2006). Meanwhile, the term and concept have been criticized as being vague and immeasurable; and its connections with continued economic growth have drawn suspicion from two contrasting directions: from those who suspect that sustainable development is a strategy to slow or limit development in the developing world and those who believe that continued growth is itself non-sustainable, thus that the term is an oxymoron (e.g., Robinson, 2004).

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 continues to emerge (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, Shukla, and Garg, 2008; Munasinghe, 2010). A number of key reasons why climate change can pose both physical and social threats to sustainable development are summarized in Box 20-1, showing that some areas, systems, and population groups are particularly vulnerable. Note, in addition, that climate *policies* can have critical development impacts as well as climate change effects per se. For instance, policies that have the effect of raising the price of energy services would be a development issue, and policies that have the effect of favoring one energy resource vs. another could mean development benefits for some areas but difficulties for others (Risse, 2008). On the other hand, 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). 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 (Box 20-2).

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Box 20-1. 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

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).

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Box 20-2. Connecting Representative Concentration Pathways (RCPs) with Shared Socioeconomic Pathways (SSPs)

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?

[INSERT TABLE 20-1 HERE
Table 20-1: Representative concentration pathways.]

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.

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Climate constitutes an important resource for sustainable development, because it influences opportunities in sectors ranging from agriculture to tourism, affecting all economic (market) sectors, all social (non-market) sectors, and all environmental/ecosystem services; but it poses manifold threats to natural resource dependent communities. Many communities are vulnerable to changes in climate and climate variability. These vulnerabilities are influenced by the coping and adaptive capacities of individuals and communities, including their abilities to respond to external perturbations, shocks, stresses and surprises. Reducing risks that affect resource-dependent communities is increasingly viewed as a necessary, but insufficient way to tackle the myriad problems associated with climate change impacts (Jerneck and Olsson, 2008). Addressing institutional and social issues is considered necessary 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. Promoting development pathways that are both equitable and sustainable is seen as a key to addressing climate change (Wilbanks, 2003). Box 20-3 illustrates how vulnerabilities of the development process in three African countries are related to climate variables.

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Box 20-3. Climate-Related Vulnerabilities of African Smallholder Farming (Mapfumo *et al*., 2010)

Ghana – Bushfires and forest clearance in the 1980s forced communities to abandon the once lucrative business of cocoa farming, and they resorted to maize production. Attempts to re-establish cocoa farms after the bush fires were unsuccessful. The reasons attributed to this were mainly related to decline in soil fertility and high rates of deforestation. Other factors such as decline in mean and annual rainfall as well as economic factors such as market conditions and producer price have been cited as reasons why cocoa production did not take off. Households with insecure access to land were perceived as the most vulnerable to negative impacts of climate change. Farmers identified different types of adaptation strategies to help improve soil fertility and boost production of maize. These strategies 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. This increase in maize yields occurred following cowpea-cowpea and soyabean –soyabean systems, notably due to the N contributions from these N_2-fixing legumes. What this case study reveals is that problems relating to soil fertility can directly lead to poverty. 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 jeopardising the well-being of the ecosystems and reducing choices to live off the land (need references to literatures on how indigenous knowledge helps in coping (Green and Raygorodetsky, 2010; Nyong et al., 2007; Speranza et al., 2010).

Uganda – Project activities were carried out in two main 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. In addition, sorghum and finger millet have been replaced by maize and upland rice in marginal areas largely suited for small grain crops. Hence, there has been an overwhelmingly high rate of crop failure leaving many households vulnerable to food shortages. Climate variability and change is an additional stressor that will heighten the vulnerability of communities in the Tororo district. Project activities sought to build on the technical knowledge of farmers to use Integrated Soil Fertility Management (ISFM) as an adaptation tool. Through ISFM, farmers were able to boost the productivity of sorghum, millet and prioritized grain legumes under changing climate where rainfall conditions were poor and erratic. Risks related to food deficits as a result of soil fertility problems worsened. Climate change and variability have the potential to threaten the very security of smallholder farmers, their assets base, their production systems and sustainability of their prevailing livelihoods structures.

Zambia – In Northern Zambia, perceptions of climate change among farmers vary. Deforestation is a major problem and it is largely attributed to charcoal burning and as a result of a slash/burn Chitemene shifting cultivation system. Today, 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, experience showed that 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 – dependent on the type of extreme event they were faced with, they used drought-tolerant crops such as cassava; engaged in intercropping activities; took 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

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There are many implications of pursuing climate resilient pathways within a context of sustainable development. First, enhancing resilience to respond to effects of climate change includes adopting good development practices that are consonant with building sustainable development livelihoods – and understanding when they are (Boyd, et al., 2008). It is now widely recognized that activities necessary to enhance adaptive capacity are also important for promoting sustainable development, although adaptation on its own -- without sustained mitigation of greenhouse gas emissions – cannot offset all of the negative impacts of climate change. The ability to mediate the impacts of climate variability and change, along with actions to reduce those impacts, is an important challenge for sustainable development (Schipper, 2007; Burton et al., 2002; Halsnaes and Verhagen, 2007). Second, because climate change integrates across physical, human, and environmental systems, it requires an interdisciplinary approach to understand its full implications (Cohen et al., 1998; NRC, 2010b). Third, climate change impacts are often strongly correlated with threats to sustainability, yet the debate on climate change has tended to run separately from the wider sustainability discourse (Cohen et al., 1998, IPCC, 2001). Fourth, vulnerable sectors such as agriculture give us particular reasons for concern, but 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. This chapter summarizes a rapidly evolving body of knowledge that seeks to frame climate change within the context of resilience pathways that perceive sustainable development as an incremental, but important transition. However, while 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. Note that vulnerabilities include both economic vulnerability (poverty) and also social vulnerability, where social stratification is a factor in access to resources and exposures to risks. If sustainable development is interpreted by national development authorities in ways designed to promote the interests of those who dominate existing social structures, sustainable development and associated climate change responses could leave the most vulnerable parts of society behind. Is it possible to have sustainable development that is not climate resilient? The relationship between climatic change and development has often been theorized as twofold. On the one hand, climate change will likely affect development policy as needs to respond to negative, and perhaps positive, impacts arise. 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). 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 and unequal power relations and weak democracy fundamentally shape sensitivity, exposure and adaptive capacity to climate impact (Garg et al., 2009; Lemos et al., 2007). Hence, in those regions, building adaptive capacity is both a function of dealing with underdevelopment and in improving risk-management (Mirza, 2003; Schipper and Pelling, 2006; Tompkins, Lemos, and Boyd, 2008). In this context, it becomes critical to understand the relative importance of different kinds of interventions (climate and non-climate) in building adaptive capacity. They include both action that addresses 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 conventional climate impact risk management (e.g. alert systems, disaster relief, crop insurance, climate forecasts). One reality in many countries may be that development – which increases wealth – enhances the capacity to adapt while at the same time adding to greenhouse gas emissions.

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). Many developing countries are on a risk governance trajectory and need technical assistance and capacity development to support their climate change agendas as well as identify and manage commensurate 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) . Hence, while external assistance is needed, it can be closely aligned to donor priorities and thus have implications for the development of robust local institutions that can effectively focus on discrete agendas such as climate mainstreaming. Finally, 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). Indeed, the priorities for addressing adaptation and mitigation risks, the costs associated with these risks, and their potential impacts tend to vary across scale, regions and sectors to the extent they can make 'mainstreaming' more difficult to operationalize.

In addition, empirical evidence suggests that the relationship between development variables and climate change responses can be mixed, 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).

Sustainable development and climate change responses share strong complementary tendencies: they are multi-sectoral, they both require international cooperation to address the problem, and the problem is interwoven through economic and technological development in increasingly complex networks. Responses to climate change, if appropriately implemented, can help to foster sustainable development. While not all actions to address climate change are synonymous with sustainable development, it seems likely that a broad long-term approach – in forestry, energy, technology, and consumption patterns—could be incorporated in a sustainable development framework. In this sense, climate change negotiations could benefit from a broadened discussion that is informed by integrative thinking about sustainable development. For example, mitigation could be addressed within a discussion of energy and economic growth, and adaptation could benefit from an understanding of “resilient development,” although structural issues within negotiation processes often present obstacles to such broader perspectives. Meanwhile, climate change policy discourses often become arenas for discussions of other development agendas, as climate change responses trigger discussions of development stresses in other contexts as well.

This is especially important because responses to climate change by governments and other decision-makers rarely happen in isolation; rather they are often a response 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 countries (e.g., in Africa) special climate-oriented bureaus are being placed strategically in the offices of government leaders. For instance, in Kenya, a climate change coordination unit is lodged within the office of the Prime Minister. Similarly in Tanzania, there is a climate change department within the Ministry of Environment, housed within the office of the Vice President, to give the department leverage and enforcement powers. These institutional arrangements constitute a growing realization of the strategic place that climate change matters occupy in some countries in Africa. In fact, 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. 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).

Moreover, in linking issues of climate change with sustainable development, the question of voice and agency becomes important. Having a sense of agency to shape individual and collective futures has been shown to be significant. For example, research in Mexico by Pelling and Manuel-Navarrete (Redclift et al., 2011) 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. The role of values in responding to climate change also emerges as important in this respect, in that current generations in positions of power and authority often assume that the values that are prioritized in the present will continue to be prioritized by future generations (O’Brien, 2009). One example may be related to gender, where women in some parts of society lack voice and are not consulted about adaptation choices, technologies, or even invited to participate in strategic farming decisions. 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.. In many ways, exclusion decisions are based on values that can establish paradigms that limit options for future generations of marginalized social groups. Given this concept of intergenerational equity, it is argued that ‘deliberative democracy,’ in other words avoiding vertical structures to embrace participatory processes with a wide range of stakeholders, that takes into account their concerns, values, perceptions and ethical impacts attached to climate related risks, could have a bearing on the way those risks are assessed and the approach to the science policy interface (Backstrand, 2003, see also Deere-Birebeck, 2009).

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). As Matthew and Hammill suggest, the first challenge and principle issue for sustainable development is to resolve ‘how to reduce poverty and improve the welfare and security of the poor…’ alongside the protection of natural resources and ecosystem base which often fall prey to overexploitation and damage as a result of development practices. (Matthew and Hammill, 2009). As Klein et al. explains, ‘climate change is not the primary reason for poverty and inequality, yet addressing these concerns is seen as a prerequisite for successful climate policy in many developing countries’ (Klein et al, 2005: 584). Indeed, while negative forms of environmental change are closely associated with production and consumption patterns of the world's rich and the implications of this behavior become an issue for future generations to address, these impacts are often transposed to the immediate environment of poorer societies – whose very survival and livelihood structures are predicated on access to natural resources.(Matthew and Hammill, 2009). To a large extent, in the area of climate change, 'issues of climate justice, compensation, and government responsibility for reducing vulnerabilities through adaptation are central to policy debates' (Nelson et al., 2007: 396).

In light of this situation, integrating climate change responses and sustainable development can help to find more 'holistic responses' (Tompkins and Adger, 2004) 'that build on strengths rather than needs, and that put human well-being at the centre of the issue'. This would entail integrating 'different dimensional objectives and policy goals' (Meadowcroft, 2000: 9), notably through building resilience, which 'offers the prospect of a sustainable response' (Tompkins and Adger, 2004).

A number of studies recognize that not every possible response to climate change is a good one, 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). Hence, 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).

20.2.3. Contributions to Resilience through Climate Change Responses

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.

20.2.3.1 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). 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), 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 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

20-2) may be congruent with development transformations, 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 less-expensive fossil fuels to more-expensive 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 20-2 HERE
Table 20-2: 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.

20.2.3.2. 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, adaptation was a lower priority than mitigation because it was assumed that the impacts of climate change would arise slowly over time and could be dealt with piecemeal, as they emerged. 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 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).

Historically, global impact and adaptation research has generally be predicated on a global mean surface temperature increase of plus 2 degrees Celsius (e.g., Richardson et al., 2009; UK Royal Society, 2011). 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 contained within national boundaries: the 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, and adaptation can also include transformational changes, in which potentially impacted systems move to fundamentally new patterns, dynamics, and/or locations (Schipper, 2007). 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 regional 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. For instance, resilient adaptation pathways do not increase or exacerbate poverty. Climate resilient adaptation pathways ensure or promote, for instance, 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 are to enhance adaptive capacity, so that systems at risk can assess vulnerabilities and respond to reduce risks, and to provide adaptation options: technological, institutional, and financial (Wilbanks et al., 2007). Again, adaptation can be vitally important in reducing stresses on development processes, especially in vulnerable areas, and it can help to promote and support sustainable development (see Box 20-4). 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).

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Box 20-4. Case Studies from China

Water-Saving Irrigation Measures in Agricultural 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 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). In 2008, China's total water-saving measures from irrigation reached 31.40-47.31Bm^3, calculated according to the percentage of present agricultural water use; increased 4.32-5.57M hm^2 in irrigated areas; increased grain yield about 16.59-21.39Mt, and ensured one year grain needs of 83 million-107 million people. It is estimated that further implementation of water-saving irrigation approaches could save about 3.26-4.96Mt of standard coal, reduce about 8.72-13.23Mt of CO_2 emissions, and therefore have a positive significance in dealing with climate change and sustainable development (Zou et al., forthcoming).

Adaptation to Climate Change Impacts on Alpine Grassland Ecosystems in Northern Tibet, China
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 for Tibet and the whole of China. Being a fragile ecosystem, the alpine grassland ecosystem in Northern Tibet is extremely sensitive to climate change and human activity. Observed rising trends of temperature and precipitation are likely to continue in the future, with projections that the climate in Northern Tibet becomes warmer and dryer (Gao et al., forthcoming). The rise in precipitation and temperature results in the melting

of glaciers and expansion of inland high mountain lakes. In recent years, severe alpine grassland degradation with diverse annual fluctuations has been detected in Northern Tibet (Gao 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 2.4 times 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).

Conservation Tillage Practice in Cropland for Adapting to Climate Change

Conservation tillage (CT) is aimed at reducing the disturbance of soil, employing practices such as no-tillage or minimum tillage, land covering with straw, and controlling weeds with herbicides (see FAO CA web site: http://www.fao.org/ag/ca/1a.html). CT reduces the disturbance of and exposure of soil to wind/water erosion, improves the soil structure, and increases the content of soil organic carbon (Hobbs et al., 2008). CT can also cut down the consumption of energy; reduce environmental pollution caused by straw burning. FAO stated that CT is a new revolution for tillage practice, and is a win-win practice for agricultural production and environmental protection (FAO website). In the coming 10-20 years, conservation tillage will play an increasingly important role in the sustainable development of agriculture (Hobbs et al., 2008). CT has been steadily accepted and applied in more than 70 countries since the 1980's and CT area has reached to 169 million ha in the world, which occupied 11% of the world's total cropland area (FAO). In recent years, Chinese government has paid considerable attention to the expansion of CT practice, and CT has resulted in higher yields and net incomes, reduced soil erosion, and improved soil conditions. It will be further adopted over wider areas with the development and highbred of indigenous no-tillage seeders in China (He et al., 2010).

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

Recent research suggests that adaptation is likely to be more effective when 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 but 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). Moreover, development contexts 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 country. 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, Metz, Verhagen, and Van Rooijen, 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 siting of nuclear plans constraint future adaptation to sea-level rise (Kopytko and Perkins, 2011) or how production of biofuels 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.

20.2.3.4. 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.

20.3. Issues for Integrated Strategies

Obviously, integrated strategies for climate-resilient sustainable development are enmeshed in a host of complex issues. Key issues include objectives of sustainable development, determinants and potentials for resilience, tradeoffs among economic and environmental goals (e.g., Bamuri and Opeschoor, 2007), roles of institutions in developing and implementing integrated strategies, and potentials to enhance the range of choices through innovation (e.g., Hallegatte, 2009; Chuku, 2009).

20.3.1. Objectives of Sustainable Development

Overall, development is a means to social and economic ends, not (usually) an end in itself; we seek to develop in order to increase what is increasingly referred to as "happiness:" 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).

Does the pursuit of happiness necessarily coincide with economic growth, and the production of ever more goods and services, and full employments such than all able bodies people can work for a minimum of 40 hours per week in order to be able to purchase more goods? Increasingly social research is showing that increased consumption (beyond a certain level) does not result in increased happiness. Continued use and unlimited expansion of the limited resources of this planet in the context of a changing climate does not sound to many observers like either sustainable development or climate resilient development (Ehrenfeld, 2008, Gilbert, 2006; also see Victor, 2008; Victor and Rosenbluth, 2007). 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. A fundamental challenge is that determinants of consumption behavior are not well-understood (NRC, 2009). Is it possible that what people really want could be supplied in ways that are far less resource-consumptive than current patterns of behavior?

There is, in fact, a growing debate about economic growth and material consumption. The conventional wisdom is that economic growth and the material consumption that it enables are the primary need and desire; but it is becoming evident that ever increasing material consumption does not bring greater happiness or satisfaction or material comfort – beyond a certain level where basic needs are met more wealth may add little to human happiness and may even detract from it (DeLeire and Kalil, 2010; Cafaro, 2010; Huesemann, 2006).

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

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 (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 (SREX, Chapter 8; Pelling, 2011; Schipper 2007). 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 (SREX, Chapter 8).

In many cases, transformational change 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).

Some of the most vulnerable regions may see their basis for livelihoods and food security erode without such 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 reference 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. 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).

For example, where migration is a traditional adaptive mechanism, Ethiopia notes that traditional and contemporary coping mechanisms to climate variability and extremes include changes in cropping and planting practices, reduction of consumption levels, collection of wild foods, use of inter-household transfers and loans, increased petty commodity production, temporary and *permanent migration in search of employment* (emphasis added), grain storage, sale of assets such as livestock and agricultural tools, mortgaging of land, credit from merchants and money lenders, and uses of early warning systems. Mali cites migration from north to south within the country and towards coastal countries and the west as a spontaneous adaptation strategy to deal with drought, but acknowledges that the internal migration was stressing the already fragile eco-system. In response to climate-related vulnerabilities and hazards, Cape Verde notes the thousands of its residents who have emigrated because of devastating famines resulting from the interplay of environmental and population pressures. Its national adaptation plan also references frequent torrential rains that have provoked large losses of infrastructure, agricultural production, enormous amounts of water into the sea, and at times, displacement of families or loss of human lives. Regarding climate-related threats to livelihoods and food security, Bangladesh notes that the high depth of standing water is preventing crop cultivation during the Kharif season, affecting jobs and livelihoods and leaving limited food sources, leading to migration to cities for jobs and livelihoods. Cambodia notes that farmers depend on subsistence rain-fed rice farming, which is vulnerable to foods and droughts. Increased crop losses have led to increased food shortages and poor health, serving as a catalyst for rural-urban migration and cross-border migration. Gambia notes that unpredictable rainy seasons and dry spells result in lower crop yields, reduced availability of forest products, and poor animal pasture, which leads in turn to decreased rural household incomes and serve as a catalyst for rural-urban migration. Guinea-Bissau notes increased pressure on the uplands as the longer dry season, particularly in countryside regions (eastern part of the country), are causing displacement of whole villages. Populations have to abandon rice fields due to salt-water invasion. Many farmers are seeking new lands and transforming them into rice fields. Others from the southern littoral are migrating to the north of Guinea. Haiti cites the migration of large numbers of people from rural areas to Port au Prince from a combination of poverty, population growth and environmental problems. As the 2010 earthquake tragically illustrated, many poor migrants move from one situation of vulnerability in rural areas to other exposed situations in urban environments. Mauritania has experienced a massive rural exodus among livestock herders and their cessation of a nomadic lifestyle because of loss of livestock as result of decreased rainfall. Tanzania cites erosion and rising sea levels leading to a loss of settlements in coastal areas, with potential adaptation activity being the relocation of these vulnerable communities to other areas. Hence, the links between scarcity of resources, environmental degradation, and migration for resource dependent communities are well documented. It is argued, although not verified, that the Rwanda genocide was accelerated by a growing depletion of resources and a population explosion which fueled the conflict in 1994 (Uvin, 1996).

20.3.3. Tradeoffs amongst 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 (WECD. 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 (WECD, 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).

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: Fig. 20.2). 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).

[INSERT FIGURE 20-2 HERE
Figure 20-2: Trade-offs and synergies in multiple outcomes from forest commons. Forest commons in this sample are spread across 10 tropical countries in Asia, Africa, and Latin America. The sample represents considerable variation in carbon stored as above-ground tree biomass and contributions to local livelihoods from forest commons, and very low association between the two outcomes.]

20.3.4. Roles of Institutions in Developing and Implementing Integrated Strategies

Transformative action and change in integrating sustainable development within a framework of climate resilient pathways is rooted in strong and viable institutions and within an institutional context that oversees the allocation of resources and the management of change. 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 behaviour 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 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. Most of the key roles relate to interactions among the different categories of institutions in determining economic, social, and environmental outcomes. Hence 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 such as 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). Scholars have suggested that response to climate change may require a new concept of policy transitions that include "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 (Michonswi and Levi, 2010).

[INSERT FIGURE 20-3 HERE
Figure 20-3: Title?]

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). 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).

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).

20.3.5. Potentials to Enhance the Range of Choices through Innovation

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).

20.4. 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 also about attributes that such pathways are likely to have to share.

20.4.1. 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, 2011; 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).

20.4.2. Attributes of Climate-Resilient Pathways

If climate change continues on its current path toward relatively significant 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. 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).

With these perspectives in mind, Box 20-5 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 20-5 HERE _____

Box 20-5. 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

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 20-5 HERE _____

20.5. 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 in ways that support sustainable development 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?

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, 2011).

Further research needs include:

- 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)
- 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
- 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) (SREX, Chapter 8).
- 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).
- 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 (SREX, Chapter 8).
- 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; 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).

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Table 20-1: Representative concentration pathways.

Pathway	Radiative Forcing	Concentration	Pathway Shape
RCP 8.5	>8.5 W/m2 in 2100	>-137-CO2-eq in 2100	Rising
RCP 6	~6 W/M2 at stabilization after 2100	~850 CO2-eq at stabilization after 2100	Stabilization without overshoot
RC - 4.5	~4.5 W/M2 at stabilization after 2100	650 CO2 eq at stabilization after 2100	Stabilization without overshoot
RCP 3-PD	Peak at ~3 W/m2 before 2100 and then decline	Peak at ~490 CO2 before 2 100 and then decline	Peak and decline

Table 20-2: 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)
Costa Rica	Carbon neutrality by 2021 including 100 percent renewable energy target Climate to be mainstreamed in foreign affairs and competitiveness agendas	Economy-wide focus; beyond REDD focus
Guyana	Shift toward low carbon development over a decade Strategy and multi-stakeholder process designed through partnership with Norway	Climate and development as reinforcing goals
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 Africa	Detailed long-term mitigation scenarios Assessment of growth potential of low carbon industries	Stakeholder consultation; long term planning
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
United Kingdom	Decarbonise economy by 2050 subject the economy to carbon budgets and independent monitoring – three key periods are defined 34 percent target by 2020 based on 1990 levels	First legally-binding commitment to 2050
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

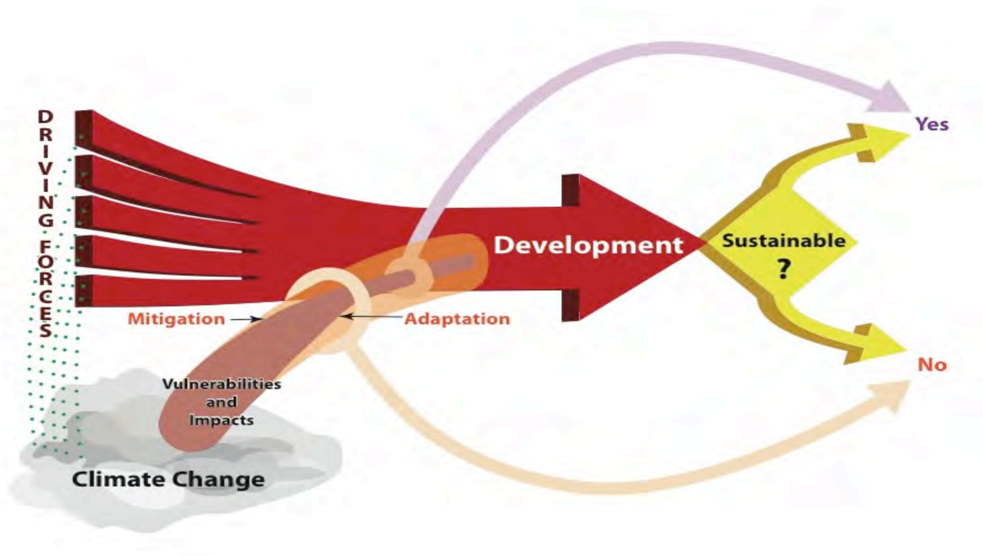

Figure 20-1: An illustration of the possibility that, in some systems and regions, an ability to reduce climate change vulnerabilities and risks by a combination of mitigation and adaptation might be a factor in determining whether or not development paths are sustainable.]

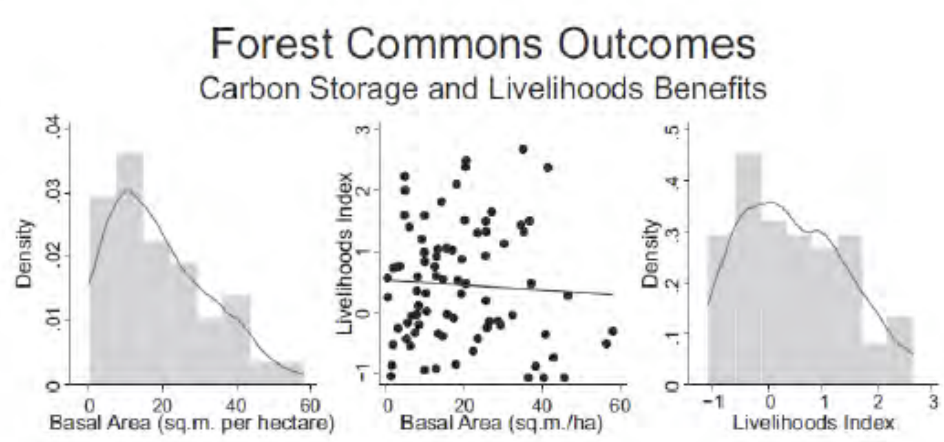

Figure 20-2: Trade-offs and synergies in multiple outcomes from forest commons. Forest commons in this sample are spread across 10 tropical countries in Asia, Africa, and Latin America. The sample represents considerable variation in carbon stored as above-ground tree biomass and contributions to local livelihoods from forest commons, and very low association between the two outcomes.

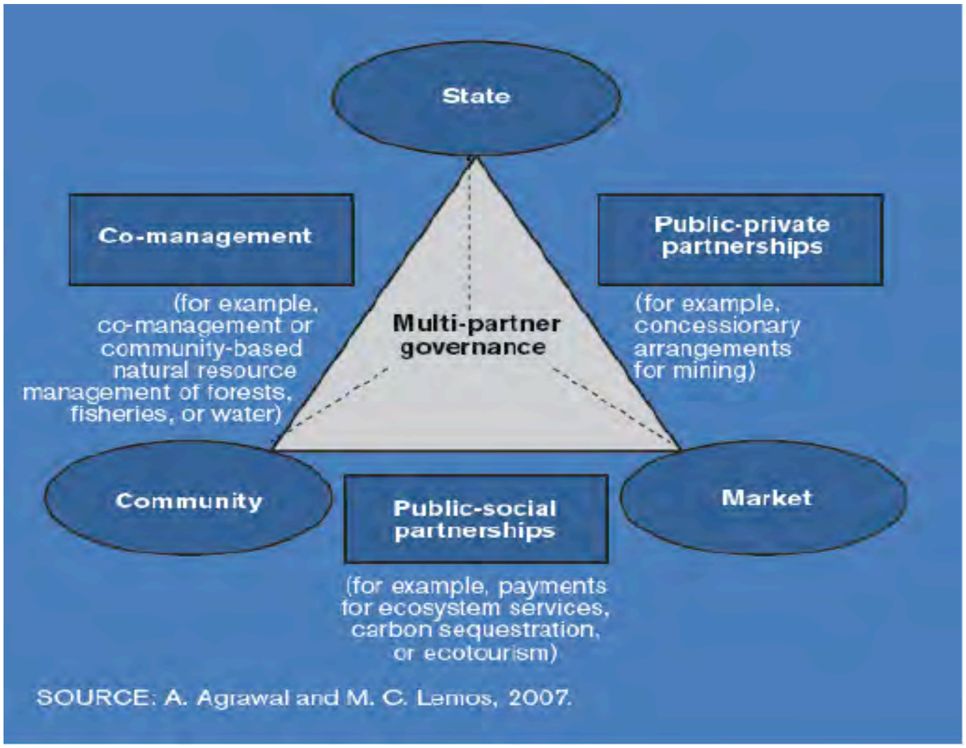

Figure 20-3
[title forthcoming]