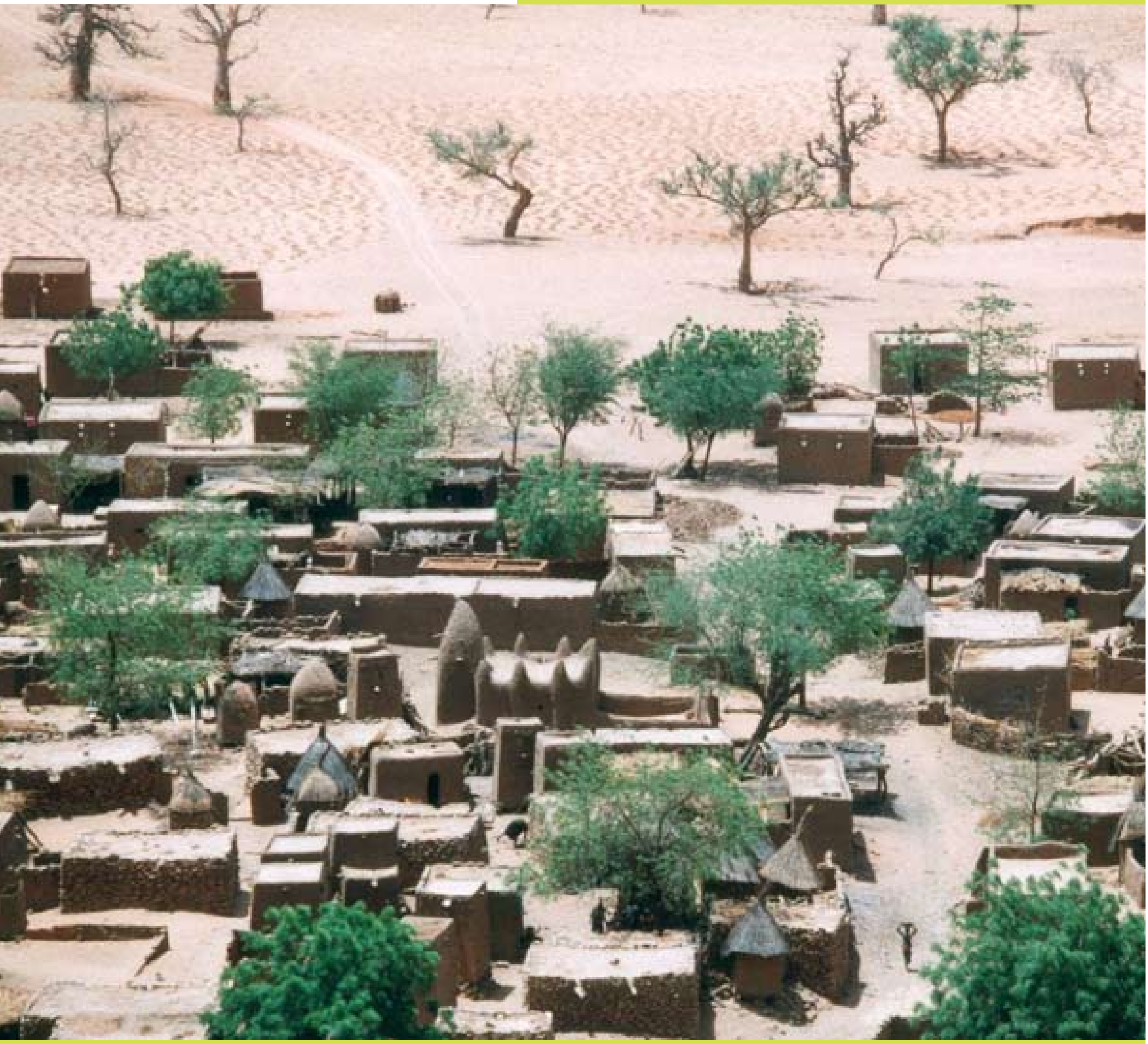
FOREST PERSPECTIVES



# Facing an uncertain future

## How forests and people can adapt to climate change

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CIFOR

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# Preface

The science of climate change has come a long way since the Earth Summit in Rio de Janeiro (1992) and the adoption of the Kyoto Protocol (1997). We now recognise that some degree of climate change is inevitable, and even the best case scenario is going to have major impacts on global weather patterns and, consequently, people's lives—especially the poor. Mitigation of climate change is no longer enough. We have to adapt to the impending changes as they arise; or, better still, anticipate those changes by having adaptation strategies in place. Climate change adaptation is one of the four building blocks of the Bali Action Plan.

Forests are a vital part of any global effort to address climate change. To date, however, forests have been mostly considered in the context of mitigation through reforestation, afforestation, and more recently, avoided deforestation and forest degradation. Yet with over a billion people dependent (in one way or another) on forests for their livelihood, forests can also play a crucial role in adaptation.

Forests provide many millions of people with raw materials in the form of food, fuel and materials for shelter. And they provide ecosystem services—such as water regulation, erosion control and carbon storage—to billions more. We need forests to continue providing these raw materials and ecosystem services into the future, and in the face of climate change.

In this report, the authors present the case for a dual agenda to enhance the role of forests in adaptation: assisting forests to weather the coming storm of climate change, and managing forests in ways that enable forest-dependent peoples and society in general to cope with the coming changes. They term these approaches 'adaptation for forests' and 'forests for adaptation'.

These approaches pose difficult challenges, requiring new policies and institutions inside and outside the forestry sector narrowly defined. But mainstreaming adaptation into forest management strategies, and mainstreaming forests into adaptation strategies, are objectives that cannot wait. Both are needed if forests are to meet their potential for increasing their own and society's resilience to the changes in climate that are already underway.

Frances Seymour
Director General, CIFOR

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# Summary

The most prominent international responses to climate change focus on mitigation (reducing the accumulation of greenhouse gases) rather than adaptation (reducing the vulnerability of societies and ecosystems). However, with some degree of climate change now recognised as inevitable, adaptation is gaining importance in the policy arena. Moreover, it is one of the four building blocks of the 2-year Bali Action Plan—ongoing negotiations towards an international framework to replace the Kyoto Protocol in 2012.

This report presents the case for adaptation for forests (reducing the impacts of climate change on forests and their ecosystem services) and forests for adaptation (using forests to help local people and society in general to adapt to inevitable changes). Linking adaptation and tropical forests are a new frontier: adaptation is a new arena for tropical foresters, and tropical forests are a new arena for adaptation specialists. Tropical forest management now needs to be adapted in a way that will smooth the transition through climate change. The goal may be to maintain important ecosystems or species—where adaptation measures will aim at resisting the effects of climate change. Alternatively, the goal may be to maintain the ecosystem services provided by the forest—where adaptation measures will aim at helping the forest to 'evolve' so that it does the same job in the new climate. The huge diversity of tropical forests and local situations means that a vast array of adaptation measures is required,

from which the most appropriate ones can be selected for each situation. Moreover, because the extent of future climate change is unknown, more than one measure is advisable in each case and implementation must be flexible to the changing situation.

Policies in the forest, climate change and other sectors need to address these issues and be integrated with each other—such a cross-sectoral approach is essential if the benefits derived in one area are not to be lost or counteracted in another. To date, tropical forests have been given a minor role in adaptation strategies, even in most of the National Adaptation Programmes of Action. Moreover, the institutions involved in policy development and implementation themselves need to change, to be in a position to enforce the new policies, and to become flexible and able to learn in the context of dynamic human and environmental systems. And all this needs to be done at all levels from the local community to the national government and the international community—again the emphasis is on integration, without which actions at different scales risk cancelling each other out.

The report looks at the two aspects in turn—adaptation for tropical forests, and tropical forests for adaptation—and includes an appendix on climate scenarios, concepts, and international policies and funds.

# 1 Introduction

In 2007, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) presented incontrovertible evidence that the global climate is changing because of human activities. Since the first IPCC report published in 1990, scientific knowledge has been growing and policy responses have been implemented at international, national and local levels. In the most prominent international responses to climate change, the United Nations Framework Convention on Climate Change (UNFCCC; established in 1992) and the Kyoto Protocol (1997), the focus is put on mitigation—reducing the accumulation of greenhouse gases in the atmosphere—rather than on adaptation—reducing the vulnerability of society and ecosystems to climate change.

However, adaptation is gaining importance in the climate change policy arena, as actors realise that climate change cannot be totally avoided and mitigation policies will take time before being effective (because of the inertia of economic, atmosphere and climate systems). In December 2007, the United Nations Conference on Climate Change (Bali) ended with the adoption of the Bali Action Plan, a 2-year plan for negotiating a new climate treaty. Adaptation is one of the four building blocks of the negotiation. The outcomes of the negotiation will shape a future international framework supporting adaptation activities in developing countries.

The role of tropical forests in mitigating climate change, through carbon storage, has been recognised and incorporated in international agreements and policy instruments. The contribution of tropical afforestation and reforestation activities is already acknowledged in the Clean Development Mechanism (CDM) of the Kyoto Protocol, many carbon markets reward tropical forestry activities, and the inclusion of avoided tropical deforestation in a future international agreement is being discussed. While tropical forests are an important component of mitigation science and policy, their role in adaptation is rapidly gaining significance. Linking adaptation and tropical forests is a new frontier for science and policy: adaptation is a new frontier for tropical foresters, and tropical forests are a new frontier for adaptation specialists.

The links between adaptation and tropical forests are two fold. First, as tropical forests are vulnerable to climate change, those managing or conserving them will have to adapt their management to future conditions. People living in forests are highly dependent on forest goods and services, and are vulnerable to forest changes both socially and economically. Even if local stakeholders know more in some ways about their forests than anyone else does, the unprecedented rates of climate change may jeopardise their capacity to adapt to new conditions. Capacity building and scientific knowledge are needed to understand the vulnerability of forests and local people, and to design and implement adaptation measures.

Second, tropical forests deliver ecosystem services that are vital for people beyond the forest worldwide. As these ecosystem services contribute to reducing the vulnerability of society to climate change, the conservation or management of tropical forests should be included in adaptation policies. The institutional links between tropical forests and other sectors should be created or reinforced by using an intersectoral approach to adaptation.

This report aims to demonstrate that: (1) tropical forests need to adapt or be adapted, because they are vulnerable to climate change; and (2) tropical forests are needed *for* adaptation, because they can help to decrease human vulnerability to climate change. First, we argue that adaptation measures should be defined and implemented for reducing the vulnerability of forests to climate change (Chapter 2). Then, we argue that forests should be included in adaptation policy for their contribution to reducing societal vulnerability (Chapter 3). At the end of the report, an appendix presents general information about climate change, the concepts of vulnerability and adaptation, and the international policies and funds related to adaptation.

# 2 Adaptation for tropical forests

Tropical forests are vulnerable to climate change and adaptation is needed to reduce their vulnerability. In this chapter, the vulnerability of tropical forests is introduced in section 2.1, possible adaptation options are presented in section 2.2, and the implementation of forest adaptation is discussed in section 2.3.

## 2.1 Vulnerability of tropical forests to climate change

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Parry *et al.* 2007) indicates that if global average temperature increases by more than 1.5–2.5°, there are projected to be major changes in local climates, in terms of mean and range of temperature, precipitation (rainfall) and extreme events (see Appendix). The changes in climate and carbon dioxide concentration will affect the structure and function of ecosystems, species' ecological interactions, and species' geographical ranges, with consequences for biodiversity (Malcolm *et al.* 2006) and ecosystem services. Many ecosystems, including tropical forests, are likely to be affected this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects), and other global change drivers (e.g., land use change, pollution, overexploitation of resources).

The effects of a changing climate on ecological systems have already been observed at various levels of ecological organisation from organisms to ecosystems. Observations include changes in structure and functioning, carbon and nitrogen cycling, species distributions, population size, timing of reproduction or migration, and length of growing season (Corlett and Lafrankie 1998; Gitay *et al.* 2002; Root *et al.* 2003; Clark 2007). These studies suggest that global change may be a current and future conservation threat, and emphasise the need for considering climate change in conservation, management or restoration of tropical forests. Additional threats will emerge as the climate continues to change, especially as it interacts with other stresses such as habitat fragmentation (McCarty 2001; Brook *et al.* 2008).

### *Potential impacts*

The potential impacts of climate change on tropical forests are a function of exposure and sensitivity (see definitions of these concepts in Appendix, Figure 7). Tropical forests are exposed to different factors of climate change and variability, as well as other drivers such as land use change or pollution that exacerbate the impacts of climate change (see Figure 1). Sensitivity refers to the degree to which a system will respond to a change in climate, either positively or negatively. Among the parameters of sensitivity are changes in disturbance regimes that are affected by climate and land use practices (Murdiyarso and Lebel 2007). For example, El Niño-induced droughts have increased the incidence of fire in humid tropical forests (Barlow and Peres 2004).

| Exposure | Sensitivity |
|---|---|
| Climate change and variability<br>  Increase in temperature<br>  Changes in precipitation<br>  Changes in seasonal patterns<br>  Hurricanes and storms<br>  Increase in $CO_2$ levels<br>Sea level rise<br>Other drivers<br>Land use change<br>Landscape fragmentation<br>Resource exploitation<br>Pollution | Changes in disturbance regimes<br>  e.g., fires, pests and disease<br>Changes in tree level processes<br>  e.g., productivity<br>Changes in species distribution<br>Changes in site conditions<br>  e.g., soil condition<br>Changes in stand structure<br>  e.g., density, height |

**Figure 1. Components of the exposure and sensitivity of forest ecosystems** (after Johnston and Williamson 2007).

**Tropical rainforests.** Studies of changes in tropical forest regions since the last glacial maximum show the sensitivity of species composition and ecology to climate changes (Hughen *et al.* 2004). Several studies have predicted impacts of climate change on tropical rainforests. In the humid tropics of north Queensland (Australia), significant shifts in the extent and distribution of tropical forests are likely, because several forest types are highly sensitive to a 1° warming and most types are sensitive to changes in precipitation (Hilbert *et al.* 2001). The decline in rainfall in the Amazon Basin predicted by some climate models, and the intensification of the Indian monsoon will have large-scale effects on availability of water for tropical forests (Bazzaz 1998). For the Amazon, several studies predict a die back of the forest and large-scale substitution by savannah (Cox *et al.* 2004; Nepstad *et al.* 2008). The sensitivity of tropical rainforests to climate is increased by interactions with ongoing extensive fragmentation. In the Amazon, the interactions between agricultural expansion, forest fires and climate change could accelerate the degradation process (Nepstad *et al.* 2008). However, some impacts of climate change on tropical rainforests remain uncertain (Granger Morgan *et al.* 2001; Wright 2005).

**Tropical cloud forests.** Tropical cloud forests are an important subset of tropical rainforests from a climate change perspective. Even small-scale shifts in temperature and precipitation are expected to have serious consequences for tropical forests on high mountains; indeed, changes in climate have already caused species extinctions (Pounds *et al.* 1999). Tropical cloud forests are especially sensitive because they are in areas with steep gradients and highly specific climatic conditions (Foster 2002). Atmospheric warming is raising the altitude of cloud cover that provides tropical cloud forest species with moisture via prolonged immersion in clouds (Pounds *et al.* 1999). The habitat for these species will shift up the mountains as they follow the retreating cloud base, forcing them into smaller and smaller areas (Hansen *et al.* 2003). The extreme sensitivity of the microclimates of tropical cloud forests to climate change makes a good case for using these habitats as a 'listening post' for detecting climate change (Loope and Giambelluca 1998). In the highland rainforests of Monteverde, Costa Rica, the lifting of the cloud base associated with increased ocean temperatures has been linked to the disappearance of 20 species of frog (Pounds *et al.* 1999). In East Maui, Hawaii, the steep microclimatic gradients in montane tropical forests combined with increases in interannual variability in precipitation and hurricanes are expected to produce a situation where endemic biota will likely be displaced by non-native plants and animals (Loope and Giambelluca 1998; Hansen *et al.* 2003).

**Tropical dry forests.** Ecosystems in semi-arid areas are very sensitive to changes in rainfall, which can affect vegetation productivity and plant survival (Hulme 2005). Studies conducted in Tanzania and Costa Rica show that tropical dry forests may be particularly sensitive to life zone[1] shifts under climate change (Mwakifwamba and Mwakasonda 2001; Enquist 2002). Tropical dry forests are likely to be affected most by drought and fire. A slight decrease in annual precipitation is expected to make tropical dry forests subject to greater risk from forest fires in the immediate future. Prolonging the dry seasons would enhance desiccation, making the forest system more exposed and sensitive to fires. However, increased fire occurrence can eventually lead to a decrease of fires due to the reduction of fuelbeds over time (Goldammer and Price 1998; Hansen *et al.* 2003). According to Miles *et al.* (2006), Latin American tropical dry forests will be more affected than those in Africa or Asia.

**Mangroves.** Mangroves have also been identified as among the forest types most threatened by climate change. The principal threat to mangroves comes from sea level rise and the associated changes in sediment dynamics, erosion and salinity. Sea level rise is expected to take place at about twice the rate at which sediment build-up (necessary for the mangrove's survival) will occur and so cause the sinking of many deltas. Furthermore, erosion will reduce the size of mangroves: cliff erosion on the seaward edge that undercuts mangrove roots, sheet erosion across the swamp surface, and loss of tidal creek banks (Hansen *et al.* 2003). Mangroves may be affected by other atmospheric changes as well, including temperature, carbon dioxide rise, and storms. Drying out of mangroves would be highly damaging, for example, droughts in Senegal and Gambia have affected mangroves (Dudley 1998).

### Forest adaptive capacity

The adaptive capacity of forests remains uncertain (Julius and West 2008). Tropical forests are more complex ecosystems than agricultural ones, which probably gives them greater resilience to small changes in their environment. Tropical forests are generally able to withstand some levels of climatic stress, especially intact forests (Malhi *et al.* 2008). However, many scientists are concerned that the adaptive capacity of forests will not be sufficient to adapt to unprecedented rates of climate change (Gitay *et al.* 2002).

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[1] In this context, life zones may be considered as the biological and geographical specifics of the habitat in which an organism lives. Under climate change, these are prone to move; for example, a habitat of specific vegetation may be hundreds of kilometres away after a 2° raise in global mean temperature.

We need a better understanding of the factors that enhance or limit the adaptive capacity of forests (Julius and West 2008), including the role of the landscape around a forest plot, as landscape connectivity may facilitate ecosystem adaptation and the adaptive capacity can be reduced by stresses outside the forest.

Species can adapt to climate change through phenotypic plasticity (acclimatisation), adaptive evolution, or migration to suitable sites (Markham 1996; Bawa and Dayanandan 1998). Without these options, species will decline and ultimately become extinct (Noss 2001). Evidence from coupled climate and vegetation models suggests that global warming may require migration rates much faster than those observed during postglacial times and hence has the potential to reduce biodiversity by selecting for highly mobile and opportunistic species (Malcolm *et al.* 2002; Pearson 2006).

It has been reported that species richness and diversity in a forest ecosystem can contribute to resistance and resilience, the most compelling explanation being the redundancy provided by multispecies membership in critical functional groups (Walker 1992, 1995; Peterson *et al.* 1998). Diversity of functional groups, in addition to diversity of species within groups, also appears to promote ecological resistance (Noss 2001).

## 2.2. Defining forest adaptation

### *The need for flexible and diversified approaches*

As tropical forests are vulnerable to climate change, current management or conservation practices should integrate climate change threats and aim at reducing vulnerabilities. Defining technical adaptation measures for forest is not straightforward, because adaptation measures depend on a variety of contextual factors (e.g., forest types, management goals, climatic threats, and non-climatic pressures). In addition, even though modelling has been used to study the vulnerability of tropical forests to climate change, the uncertainties inherent to ecosystem models and climate scenarios may hinder their use by forest managers or policy makers (Millar *et al.* 2007). For instance, future trends in precipitation are still unclear at local and regional scales, especially for the tropics. In many situations, models that cannot help determine future impacts will help envision possible directions of change. In terms of forest vulnerabilities, the main gap in our knowledge relates to the processes explaining the adaptive capacity of species: phenotypic plasticity, adaptive evolution, and migration (Noss 2001; Midgley *et al.* 2007).

The uncertainties about future climate and forest vulnerability mean that we need flexible and diverse approaches. Depending on the local context, these approaches should combine various measures selected from an 'adaptation toolbox' (Millar *et al.* 2007). The selection of measures depends on the uncertainties associated with the future of climate and forests. Where some dimensions of the future are reliably known, the choice can be specifically targeted to the projected future scenario. However, in most cases, the high degree of uncertainty will justify the selection a portfolio of measures to reduce the risk associated with choosing one inadequate measure.

The selection of adaptation measures also depends on the variables that the society considers of interest. For instance, depending on whether adaptation aims at conserving some high-value species or conserving hydrological ecosystem services, adaptation measures should be selected for either conserving the key species or facilitating the transition of the ecosystem towards another state in which vegetation structure allows the supply of hydrological ecosystem services. There may be many synergies between different goals, but sometimes there need to be tradeoffs. After defining the predicted likely effects of climate change and desired end state, decision makers should select measures and evaluate them, taking into consideration the uncertainties. The implementation of the measures should then be associated with monitoring and learning to enable ongoing and *ex post* evaluations and flexibility in management to the lessons learnt (Spittlehouse and Stewart 2003; Millar *et al.* 2007).

### *Categories of adaptation measures for forests*

Various authors have proposed adaptation measures for forests (e.g., Noss 2001; Spittlehouse and Stewart 2003; Hansen *et al.* 2003; Millar *et al.* 2007; Fischlin *et al.* 2007; Guariguata *et al.* 2008; Ogden and Innes 2008). Most measures have been defined for temperate or boreal forests, but can be extrapolated to tropical forests even though some may be difficult to apply there (because they are generally less intensively managed and host a higher diversity of trees than boreal and temperate areas).

Following Smithers and Smit (1997), we distinguish between two broad categories of adaptation measures for forests, depending on their intended outcomes or effects. The first category is adaptation measures aimed at buffering a system from perturbations, by increasing its resistance and resilience to change. Resistance is 'the ability of a system to resist external perturbations' (Bodin and Wiman 2007), while resilience is the ability of a system 'to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks' (Walker *et al.* 2004). According to Millar *et al.* (2007), buffering measures that try to conserve forests in their current or past state are not a panacea and may be effective only over a short term. With increasing changes in environmental conditions, such efforts may eventually fail. Because of these risks and their associated costs, such measures should be applied preferentially to high-value forests (e.g., those hosting high priority endangered species or providing important goods for local communities) or to forests with low sensitivity to climate change (Millar *et al.* 2007). These measures are also relevant for short-term management objectives, for example, a forest plantation close to harvest.

In the second category, the objective is to facilitate a shift or an evolution of the system towards a new state that meets altered conditions (Smithers and Smit 1997). In contrast to the first category, the objective is not to resist changes, but to ease and manage natural adaptation processes (Millar *et al.* 2007). However, as in the first category, the resilience of the ecosystem is key in this process, not necessarily to keep the ecosystem in the same state after a disturbance, but to help it evolve in a way that maintains its function, structure and identity (desired by the manager or the society), such as storing a similar amount of carbon, regulating water quality or producing goods for local communities.

### *Examples of adaptation measures for forests*

Some measures for increasing forest resistance and resilience (see Figure 2, left) focus on preventing perturbations, such as fire (managing fuel, suppressing or controlling fires), preventing the entry of or removing invasive species, and controlling insects and diseases (applying phytosanitary treatments). Another option for buffering systems from perturbations is to actively manage the ecosystem after a perturbation; for instance, favouring the establishment of prioritised species in a restoration plan.

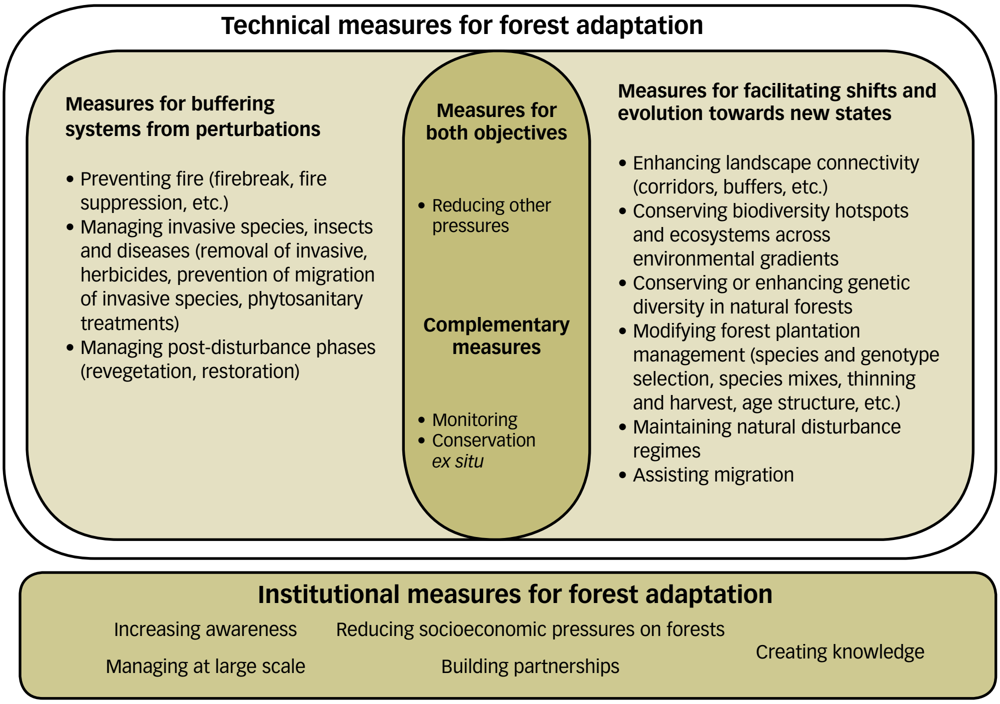


**Figure 2. Examples of measures for forest adaptation.**

Rather than suppressing fire and carrying out prescribed burning, Barlow and Peres (2004) propose two strategies for fire control in humid tropical forests: reducing forest flammability (e.g., forest management should *avoid* increasing understorey fuel load and reducing understorey humidity) and preventing fire from reaching flammable forests (e.g., with firebreaks, education, legislation and financial incentives).

Measures to buffer forests from perturbations may be very costly and beyond the economic means of most tropical countries (Barlow and Peres 2004). Moreover, some measures may have negative environmental impacts (e.g., herbicides) or not be sustainable. Fire control may be counterproductive in the long term when climate is changing (Hulme 2005).

To facilitate a shift or evolution of the ecosystem (see Figure 2, right), one measure is to enhance landscape connectivity and reduce fragmentation. Connectivity between habitats increases the ability of species to migrate. Corridors established in the direction of the climate gradient could help species to adapt to climate change (Noss 2001). Another measure consists of defining high priority areas for conservation under scenarios of climate change. Because of the uncertainties about the vulnerabilities of different forests, a good strategy is to conserve a large spectrum of forests—for instance, ecosystems across environmental gradients or biodiversity hotspots—for their value and their possible higher resilience (Noss 2001). Landscape connectivity also plays a role in genetic diversity.

As genetic diversity is a key element for understanding ecosystem adaptive capacity, some authors propose measures for maintaining or enhancing it in managed forests (see Table 1 from Guariguata *et al.* 2008). For forest plantations, the array of technical measures is wide, as these ecosystems are generally intensively managed and the management can be modified to adapt to climate change. For instance, the selection of species and genotypes can be adapted to future climates, while a mix of species and uneven age structure can increase resistance or resilience, or harvesting can be anticipated for reducing risks (Guariguata *et al.* 2008).

**Table 1. Examples of adaptation measures for managed forests** (after Guariguata *et al*. 2008)

| **Forest management type** | **Adaptation measures** | |
|---|---|---|
| | Measures for facilitating adaptive capacity | Other sylvicultural measures |
| Natural forest management based on selective logging | Maximise juvenile and reproductive population sizes<br>Maintain interpopulation movement of pollen and/or seeds (by minimising harvesting impacts on forest structure and by maximising landscape connectivity)<br>Maximise genetic variation of planted seedlings when enriching logging gaps<br>Use of translocated material in enrichment planting | Intensify liana removal<br>Minimise levels of slash through reduced impact logging<br>Widen buffer strips/firebreaks |
| Tree plantation | Plant a range of genotypes and 'let nature take its course'<br>Implement appropriate species selection (particularly in transitional zones)<br>Use seed sources adapted to expected future conditions<br>Use 'stable' genotypes that tend to perform acceptably in a range of environments | Plant mixtures of species and implement appropriate species selection<br>Widen buffer strips/firebreaks |

Some authors argue that natural disturbance regimes (e.g., fires) should be maintained because several fire suppression programmes have caused the decline of endangered plant species (Noss 2001; Hansen *et al.* 2003). However, it is also recognised that fires set by human agency are a threat for many ecosystems, especially in the tropics. A right balance must be found between suppressing fire, letting natural fires burn, and using prescribed burning for reducing the risk of high-intensity fires. The assisted migration of plant species to areas where climate is projected to become suitable is also a controversial measure,[2] because of the potential risk that human-aided translocation of species introduces invasive species (Mueller and Hellmann 2008).[3]

Some adaptation measures can contribute to both buffering the system from perturbations and facilitating shifts (see Figure 2, centre); for instance, reducing other pressures such as habitat destruction, fragmentation and degradation (Noss 2001; Hansen *et al.* 2003; Malhi *et al.* 2008). As a threat, climate change is adding to other stresses, some of which are currently more pressing than the climate. If these other threats are not addressed, adaptation may be irrelevant or may look like a purely academic question (Markham 1996). Reducing other threats will also increase ecosystem resilience and facilitate shifts (see Box 1).

**Box 1. Planning for climate change in the Amazon**

The possibility that climate change could enhance drought in the Amazon is a major concern. Malhi *et al*. (2008) propose several key elements of a development, conservation and adaptation plan to increase the resilience of the Amazon socioecological system: (1) keeping deforestation below a threshold; (2) controlling fire use through education and regulation; (3) maintaining broad corridors for species migration; (4) conserving river corridors as humid refugia and for migration; (5) keeping the core northwest Amazon largely intact.

Malhi *et al*. (2008) discuss the governance and financial issues associated with this plan, as well as the roles of protected areas, indigenous people, smallholders and agroindustries, and governments.

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2 Populations of plants (including trees) may migrate hundreds or thousands of metres a year through seed dispersal.

3 Translocated species may behave as invasives in their new habitat.

Other measures are complementary to those listed above. For instance, monitoring is vital to allow ongoing adjustments in adaptation strategies (Fischlin *et al.* 2007). At a different level, conservation *ex situ* has been cited as an adaptation measure by some authors. Even though it does not refer to the adaptation of the ecosystem itself, it may help conserve genetic diversity threatened with extinction. Collections could allow reintroduction of species in the future (Hansen *et al.* 2003).

In parallel to technical measures, institutional measures must be developed, such as increasing awareness within the forest communities and the forest sector about adaptation to climate change (Spittlehouse 2005; see also section 2.3).

## 2.3. Implementing forest adaptation

### *Building on the local*

The complexities and uncertainties related to forests and climate change adaptation are magnified by enormous geographical and human variation. There are powerful forces and traditions that discourage attention to local variation—such attention is typically seen as too complex, too difficult, too costly and impractical. Yet the importance, indeed the necessity, to attend to local variation has become increasingly obvious (e.g., Agrawal 2008). It is now time to 'bite the bullet' and make the institutional changes needed to allow us to build on the local, rather than trying to make broad-scale plans that will inevitably fail in most localities.

To successfully address climate change adaptation in any of the world's populated forests, a number of institutional changes will be needed. Macqueen and Vermeulen (2006), for instance, point to the need for 'increasing local ownership and access to forest resources; developing local monitoring and analysis of climate change impacts, and building institutional responsibility for adaptation strategies', among others. Agrawal (2008) emphasises the importance of assessing and strengthening local institutions, developing locally appropriate solutions and linking actors at various scales. Most fundamentally, managers at all levels will need to use any existing mechanisms that allow people in particular settings to adapt their own systems more effectively as their conditions change.

### *Learning from previous experiences*

Implementing forest adaptation should not start from scratch, but be built on experiences of building adaptive and collaborative management, recognising the need for links and mutual support among levels.

Researchers in various contexts have been experimenting, since the 1990s, with approaches that emphasise adaptation and collaboration. A large body of literature is relevant for implementing forest adaptation at local scales—for example, CIFOR's ACM (Adaptive Collaborative Management) series (see below), Buck *et al.* (2001), Tompkins and Adger (2004), Armitage *et al.* (2008). These approaches were developed partly because, in the late 1990s, the researchers had a growing sense that the processes involved in improving sustainability and human wellbeing needed to be studied and improved, rather than simply documenting the obvious failures in those realms. This concern is even more pressing now than it was at that time.

### *The Adaptive Collaborative Management approach*

The ACM approach, as a good example, is built on three prongs, all of which will be crucial in adapting to climate change. These three prongs build on the following observations (each followed by the kinds of actions needed to address them):

1. The need to understand the views of the many stakeholders typically interested in forests and their management. Tools have been developed to identify the relevant people and to fashion forums in which they can communicate more effectively with each other, as they deal with change.
2. The need to have better mechanisms for learning from experience. Researchers have worked with groups of people to successfully analyse, plan, monitor and alter course—crucial abilities as the climate changes.
3. The need to address the inequitable distribution of power in today's forests (and into the future). Action researchers have worked with marginalised and dominant groups, women and men at various scales, to level the playing field, in an attempt to address the needs of those who currently have crucial (and probably growing) needs, but little voice in the management of local forests and other decisions affecting their wellbeing.

Typically, trained local facilitators have played central roles. Such facilitators use participatory action research to work with local community groups (and more recently, with local governments) to strengthen local analytical capabilities and adaptive capacity, as well as a variety of other skills, such as collective action, negotiation, networking and conflict management. In other cases, researchers and facilitators have worked with broader scale actors, such as the timber industry, conservation projects, regional and national governments, to strengthen support for the local actions and expand the impacts of local efforts. Different approaches are described in Colfer (2005), CIFOR (2008) and Pfund *et al.* (2008).

Monitoring is likely to be critical in global efforts to address climate change adaptation. Early work by Prabhu and his associates (e.g., Prabhu and Colfer 1996; Prabhu *et al.* 1998) demonstrated the possibility and practicality of developing and adapting sets of criteria and indicators (C&I) for monitoring forest management and human wellbeing in specific local contexts. Such monitoring is central to the capacity to adapt to change while moving towards a shared vision of a desirable future. Such tools have proven useful at all levels, from communities to international processes, though their suitability in any context needs assessment and, if deemed useful, adaptation to local conditions. Examples of community-level testing of C&I and participatory monitoring are given in McDougall (2002), Hartanto *et al.* (2003), Guijt (2007) and Evans and Guariguata (2008).

### *Understanding diverse situations*

Mechanisms that maintain links and feedback from diverse local contexts to key decision makers are vital to ensure the continuing relevance and positive effects of policy interventions. One option, used in the Landscape Mosaics project (Pfund *et al.* 2008), is to select villages associated with forests of different quality and remoteness, to maximise the understanding of possible ecological and socioeconomic determinants. Another option could be to select communities along a likely climate change trajectory, for example, along a humidity gradient where drier or wetter conditions are likely to expand. For example, the intention could be to learn how the existing human systems are adapted to climate variability in the driest areas and share such understanding with people in places likely to face similar drier conditions in the future. Still another option is to examine the systems of different ethnic groups (e.g., Dounias and Colfer 2008), which often have totally different human systems even within the same ecological niche, or describe and work with different management and goals across gender lines (Shea *et al.* 2005).

Another approach involves linking particular communities with district-level government actors, as was done in Jambi, Sumatra, Indonesia (Komarudin *et al.* 2008) or underway in Landscape Mosaics sites in Guinea, Tanzania, Cameroon, Lao PDR, Indonesia and Madagascar (Pfund *et al.* 2008). The use of multistakeholder forums can serve a similar function of maximising communication and collaboration among levels and actors (e.g., Yuliani *et al.* 2008a, b).

These models build on the ACM approach described above, conducting participatory action research at both community and district government levels. Shared concerns are then identified between the two levels, and collaboration is encouraged as both villagers and officials struggle with addressing the shared goals.

### Linking local and national scales

The need for linking local and national scales has justified the development of learning mechanisms that foster exchanges of information between the different scales. An example is the National Policy Learning Group approach, used in Indonesia and Nepal for bringing together government and non-government actors who are genuinely committed to addressing national problems (see Box 2). To date, ACM facilitators have played leadership roles in these groups, inculcating a systematic learning approach within the groups. Climate change issues are perfect 'problems' for such groups to address, which should ideally maintain close links with the community level (whether through shared trials, frequent field trips, direct community involvement, or other mechanisms).

Another broad-scale approach is 'shared learning workshops' (see Box 3). These bring together individuals from all levels and various settings to share what has worked in their respective localities. Such workshops have been quite successful in providing a mechanism for districts in Indonesia (newly empowered after the 2001 decentralisation law) to learn from each other's successes and failures. Another approach for developing scenarios of the future with stakeholders is described in Box 4. These approaches can also contribute to climate change adaptation.

**Box 2. National Policy Learning Group in Nepal**
*(by Ganga Ram Dahal)*

In order to establish linkage between policy research and implementation, the National Policy Learning Group (NPLG) Nepal was initiated in 2005 as an outcome of CIFOR-led action research on Adaptive Collaborative Management (ACM). Although it is a loose network of multiple stakeholders representing government, NGOs and civil society groups, there has already been impact on the ground in terms of transforming research findings into action. One example is the formulation of government policy to give more authority to the local community in the development of enterprises based on non-timber forest products (NTFPs). This policy was formulated on the basis of the findings and recommendation of policy research undertaken in Nepal. Organising a periodic meeting of the network members provides space for shared learning on the one hand, and creates an environment for synergy on common agendas (e.g., pro-poor policy development, climate change and environmental issues) on the other. Other significant issues of common interest in the forestry sector in Nepal include community forestry, transborder illegal timber transportation, tenure reform, and equity, all of which are regularly discussed by this group.

Rights and Resources Initiative (another action research in Nepal, 2006–2008) used this network to increase members' participation in research and their use of research findings in practice. The research has been looking at the impacts of forest tenure reform on livelihoods, income, forest condition and equity (known by the acronym, LIFE).

The changed political context in Nepal has further increased the significance of NPLG. The network is now engaged in providing some valid inputs to the government on the forestry sector reform process and forest-related policy formulation. The politically unbiased, democratic and inclusive nature of the forum helps to influence the policy process in Nepal. The network includes the Federation of Community Forestry Users Nepal (FECOFUN), Nepal Foresters Association, and some NGOs and bilateral organisations.

Recently, NPLG Nepal has been linked with the global Forest Governance Learning Group (FGLG), which may further strengthen its role and effectiveness in transforming policy into practice.

**Box 3. Shared learning** *(by Moira Moeliono)*

Between 2005 and 2007, CIFOR and PILI (Green Network: A Bridge for Sustainability, an Indonesian NGO)—organised seven workshops with a focus on collaborative management of natural resources in protected areas in Indonesia. These workshops adopted the principle of 'levelling the playing field', where every participant was to be teacher and student. The activity itself built on similar learning approaches described as action learning, participatory action research, participatory learning and action, and social learning. The goal of these workshops evolved from being a channel for policy information to learning for policy change. We tried to use shared learning to develop, utilise and share information and knowledge. More importantly, shared learning was meant to encourage learning in and among groups to foster social change.

The informal settings, the variety of methods used, the focus on experience, and learning arising from participants' experience all made these workshops very popular. A network was developed through which learning continued and collaborative efforts emerged.

All of these approaches are useful and needed. But another important change is in order—and it is a tall order: *the standard operating procedures in government forest bureaucracies will need to change*. Genuine, meaningful attention to local human and ecological variation will require two difficult but key changes. First, the knowledge and potential contribution of rural dwellers will have to be more widely recognised and allowed to influence official decision making. This means changing officials' attitudes and strengthening feedback mechanisms within bureaucracies.

Second, greater flexibility and 'freedom to fail' will be needed, particularly for field personnel. Genuine capacity to adapt policies as needed requires the ability to experiment locally; and the greatest learning often comes from failures. Bureaucratic norms need to change to encourage experimentation and to accept occasional failure, in pursuit of desired goals.

**Box 4. Future scenarios: learning together how to plan and prepare for the future** *(by Kristen Evans and Peter Cronkleton)*

In Bolivia, recent decentralisation and forest devolution reforms have provided communities with opportunities to gain title to their forests and access more resources for community development, through local budgeting and planning processes. However, in the heavily forested area of Pando, local people—both communities and local government officials—had little experience with participatory planning methods and were often at odds over how to manage these new opportunities together. Communities thought that local officials were arrogant and corrupt; local officials were frustrated at the inability of the communities to present practical requests and negotiate reasonably. CIFOR researchers involved in the BMZ Poverty and Decentralization research project suggested that they experiment with 'future scenarios' as a method for planning and preparing for the future. Future scenarios are workshop-based activities where people with diverse interests can come together to anticipate, envision and plan for the future. The methods stimulate reflection and dialogue among stakeholders—essential elements of participatory planning and productive collaboration—and they create interest in continued involvement in planning processes (Evans *et al*. 2008). The methods can also help participants think about an ideal future, articulate hopes and desires, share them in a group setting, and arrive at a consensus about a common vision (Wollenberg *et al*. 1999; Evans *et al*. 2006). In Pando, future scenarios workshops were first carried out in the communities, facilitated by CIFOR researchers. Community members developed a vision of an ideal future for their community and presented it to the local government. Although initially sceptical, by the second presentation, the mayor saw that the methods could serve as a mechanism for planning for the future in a way that was fair, transparent and inclusive. He requested that the methods be used in all of the communities and then at the municipal level as the formal participatory planning process. Local leaders were also trained as facilitators. The result was a more productive, fair, transparent and democratic municipal planning process, where community members and local officials learned how to plan and prepare for the future together.

# 3 Tropical forests for adaptation

Tropical forests provide essential services at different scales, from local communities to the world, and can contribute to reducing the vulnerability of society to climate change. Thus, they need to be included in adaptation policies. The role of ecosystem services for human wellbeing is introduced in section 3.1 and the contribution of tropical forests to the adaptation of society to climate change is detailed in section 3.2. The insertion of forest in adaptation policies is discussed in section 3.3.

## 3.1. Ecosystem services and human wellbeing

### The concept of ecosystem services

The Millennium Ecosystem Assessment (2003) defines ecosystem services as the benefits people obtain from ecosystems. Three types of ecosystem services directly contribute to human wellbeing: *provisioning services* (also called ecosystem goods), such as food and fuel wood; *regulating services*, such as regulation of water, climate or erosion; and *cultural services*, such as recreational, spiritual or religious services. In addition to these three types, *supporting services* represent a fourth type of service and include the services that are necessary for the production of other services; for example, primary production, nutrient cycling and soil formation (see Figure 3).

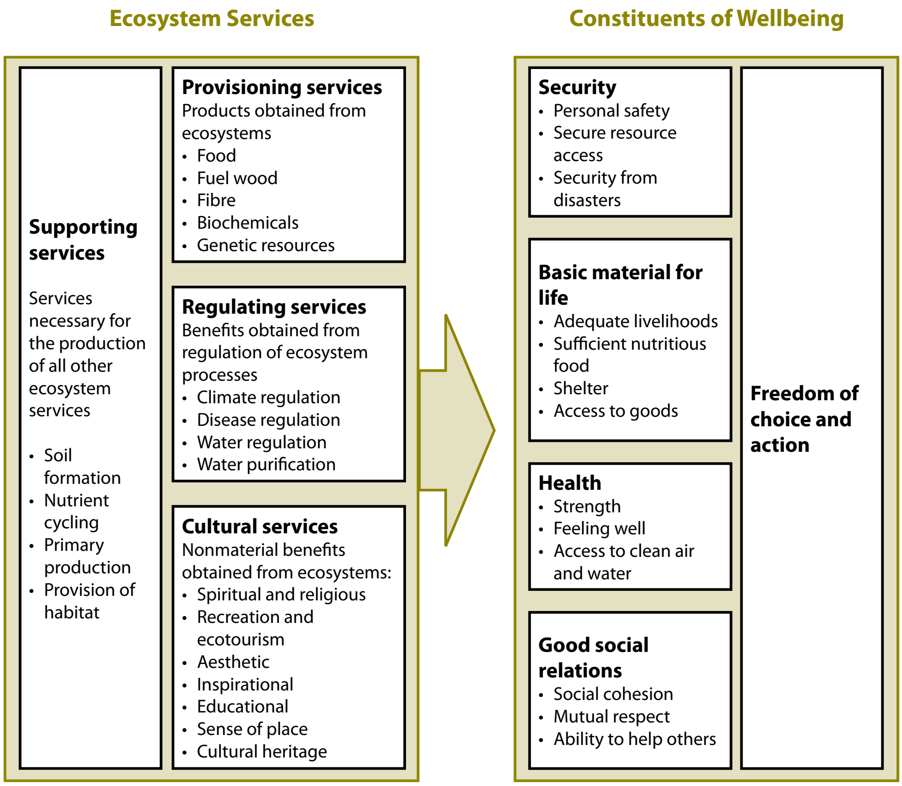



**Figure 3. Examples of ecosystem services and their links to human wellbeing** (after Millennium Ecosystem Assessment 2003).

Tropical forests cover less than 10% of the world's land area, but are very important providers of ecosystem services at various scales, from local (e.g., non-timber forest products, pollination and scenic beauty) to regional (e.g., hydrological services) and global (e.g., carbon sequestration). The biological richness of tropical forests (50–90% of Earth's terrestrial species) contributes to the supply of many ecosystem services (WRI *et al.* 1992).

Tropical forests produce diverse goods for local people, as documented in Asia (Kusters and Belcher 2004), Africa (Sunderland and Ndoye 2004) and Latin America (Alexiades and Shanley 2005). Wood is currently an important economic forest commodity for many tropical countries. Fuel wood is also important, especially in developing countries where it meets about 15% of energy demand—and more than 90% in 13 countries (Shvidenko *et al.* 2005). Non-wood forest products are extremely diverse, from fodder for animals and food for people to medicines and cosmetics. The livelihoods of 250 million to one billion people depend on these products (Byron and Arnold 1999). Edible forest products are of utmost importance in developing countries; for example, bushmeat and fish, which are major sources of protein for local people (Nasi *et al.* 2008). Tropical forests also produce traditional medicines, widely used locally in developing countries and for the development of modern medicines (Shvidenko *et al.* 2005).

Many regulating services are provided by tropical forests. Tropical forests play an important role in regulating the global climate as they store a large amount of carbon, around 212 Gigatonnes in the vegetation (i.e., 45% of the carbon stored in the world's vegetation) and 216 Gt in the soils down to a depth of one metre (i.e., 11% of the carbon in the world's soils) (Watson *et al.* 2000).

Other regulating services are local or regional, such as the purification of water, the mitigation of floods and drought, detoxification and decomposition of wastes, generation and renewal of soil, pollination of crops and natural vegetation, control of agricultural pests, dispersal of seeds, and moderation of temperature extremes and the force of winds and waves (Daily 1997). Of particular importance in a context of climate change is the role of forest for regulating water volumes and quality. Even if forests are not a panacea for all water-related problems (such as drought in dry areas or large-scale flooding), their contribution to the conservation of baseflow, the reduction of stormflow, the preservation of water quality, and the reduction of sediment load has been demonstrated in many places (Chomitz and Kumari 1996; Calder 2002; Bruijnzeel 2004; Bonell and Bruijnzeel 2005; FAO and CIFOR 2005).

For many local communities, tropical forests have a spiritual and religious value, and ecosystem changes can affect cultural identity and social stability (De Groot and Ramakrishnan 2005; Ramakrishnan 2007). Other services, such as aesthetic, recreation and heritage, are enjoyed by local people, visitors and people for whom the ecosystem has a symbolic importance.

## Ecosystems and human wellbeing

Ecosystem services influence all the components of wellbeing presented in Figure 3 (Millennium Ecosystem Assessment 2005). Ecosystem services increase the security of people living in the vicinity—for example, through the protective role played by regulating services against natural disasters. Ecosystem services are directly linked to incomes, food security and water availability that are basic materials for life (Levy *et al.* 2005). Human health is also linked to forests, as many case studies and syntheses have shown (e.g., Colfer *et al.* 2006; Colfer 2008). Social relations also depend on ecosystems, through the ability to realise aesthetic and recreational activities and express cultural values if they are linked to some habitats or species (Levy *et al.* 2005). Ecosystem services are also linked to freedom—the ability to decide on the kind of life to lead. For example, the degradation of hydrological services or fuel wood resources can increase the time spent by local communities in collecting sources of energy and water, resulting in less time for education, employment or leisure (Levy *et al.* 2005).

Many valuation studies have tried to give an economic value to ecosystem services, even when they have no market price, using a wide array of methods (e.g., Costanza *et al.* 1997; Ludwig 2000; Farber *et al.* 2002; National Research Council 2004; Norton and Noonan 2007; Nijkamp *et al.* 2008). Economic valuations have been undertaken in order to show the links between ecosystems and human welfare, to identify important ecosystems, and to guide decision making regarding ecosystem conservation (Bingham *et al.* 1995; Pritchard *et al.* 2000). These studies have shown the high value of ecosystem services at different scales (e.g., Costanza *et al.* 1997; Pattanayak 2004).

## Vulnerability of ecosystem services

Ecosystem services are threatened by various human-induced pressures other than climate change, such as land use change, landscape fragmentation, degradation of habitats, overextraction of resources, pollution, nitrogen deposition and invasive species. Climate change will exacerbate these pressures over the coming decades (Fischlin *et al.* 2007). Current climate change trends will impact species and ecosystems and result in declining ecosystem services (Leemans and Eickhout 2004). The loss of ecosystem services will reduce human wellbeing at all scales.

Increasing degradation of ecosystems is a major concern for sustainable development (Mäler 2008), and this concern will be more pressing in the future as human demands on ecosystem services are increasing (Millennium Ecosystem Assessment 2005). The links between forests and the alleviation of poverty should be emphasised in development programmes (Angelsen and Wunder 2003; Innes and Hickey 2006). There is an urgent need to include ecosystem services in planning and prioritisation for meeting different conservation objectives and focusing on human wellbeing (Egoh *et al.* 2007). All institutional levels are affected by the loss of ecosystem services, from households, through local communities and local firms, to national and international organisations (Hein *et al.* 2006). Because of the role of ecosystems in the regulation of the global climate, international organisations are increasingly looking for solutions to reduce deforestation and forest degradation (see Box 5).

**Box 5. Vulnerability of carbon storage and the links between adaptation and mitigation**

The vulnerability of ecosystems to climate change brings important consequences for the climate system, as ecosystem changes may release carbon into the atmosphere (amplifying global warming) or remove carbon from the atmosphere (reducing global warming). This vegetation–climate feedback has been studied widely; however, many uncertainties remain (Canadell *et al.* 2004). At a global scale, increasing atmospheric $CO_2$ concentration, combined with longer growing seasons at high latitudes, could cause an increase in ecosystem productivity, thus an increase in carbon removal from the atmosphere. However, the magnitude of this effect remains uncertain, as nutrient availability may become limiting, and $CO_2$ has secondary effects on ecosystem water balance and species composition (Fischlin *et al.* 2007). In the tropics, ecosystems are currently a net source of greenhouse gases because of deforestation. Cramer *et al.* (2004) used climate and deforestation scenarios and estimated that the impacts of climate change and deforestation would add between 29 and 129 ppm of $CO_2$ to the atmosphere by 2100, deforestation being responsible for the major part of these emissions. For the tropics, some models show that the Amazon forest could collapse (Cox *et al.* 2004) or that some tropical forest areas could become a source of carbon resulting from a combination of changes in climate and $CO_2$, especially because of drought stress (Berthelot *et al.* 2002).

International discussions are underway to include avoided tropical deforestation under the international climate regime. Reducing emissions from deforestation and forest degradation (REDD) in developing countries is an important measure for climate change mitigation. However, the potential of a REDD mechanism could be counteracted by the impacts of climate change on forests (Fischlin *et al.* 2007). This justifies exploring options that promote synergies between adaptation and mitigation (Nabuurs *et al.* 2007). In addition, REDD activities could affect the vulnerability of society at a local or regional scale. The conservation of ecosystem services can be beneficial for adaptation, but badly designed REDD activities could also deprive local people of their main sources of livelihood. Thus, the impacts of mitigation on adaptation are of major significance. It appears therefore necessary to promote synergies between mitigation and adaptation in forestry management and in the sectors that depend on forest ecosystem services (Murdiyarso *et al.* 2005; Klein *et al.* 2007; Ravindranath 2007).

## 3.2. Tropical forests for the adaptation of society

### Ecosystem services and societal vulnerability to climate change

In the conceptual framework for understanding the links between ecosystem services and human wellbeing (Figure 3), many components of wellbeing can also be interpreted as dimensions of vulnerability to climate change. For instance, personal safety and security is clearly related to the human vulnerability to disasters. Adequate livelihoods and good health may also determine the sensitivity and adaptive capacity of a population facing a climate-related threat.

Some criteria often used in quantitative studies of social vulnerability are related to income or wealth, education, health, social capital and networks, safety nets, or access to water (e.g., Cutter *et al.* 2003; Sullivan and Meigh 2005; Eakin and Bojórquez-Tapia 2008). These criteria of sensitivity or adaptive capacity of households, communities or countries are clearly linked to ecosystem services (Millennium Ecosystem Assessment 2003, 2005).

In addition to these similarities between vulnerability indicators and constituents of wellbeing, we propose to link ecosystem services and vulnerability to climate change (see Figure 4), using the components of vulnerability defined by the IPCC: exposure, sensitivity and adaptive capacity (see Appendix, Figure 7 for definitions). Ecosystem services may contribute to reducing exposure, sensitivity or vulnerability of coupled human–environmental systems in various ways.

The exposure of a system to climate change can be reduced by mitigation policies, in which the ecosystem service of carbon sequestration has a role to play (see Box 5). However, local practices of carbon sequestration will not have a measurable impact on the exposure of the locality to climate change, as carbon sequestration activities should be conducted at a global scale to have impacts on mitigation. Local or regional ecosystem services are more relevant for adaptation. Supporting services contribute to the adaptive capacity of an ecosystem, because nutrient cycling and primary production are important components of the functioning, resistance and resilience of the ecosystem. Regulating services can decrease the sensitivity of a coupled human–environment system; for example, the water regulation services

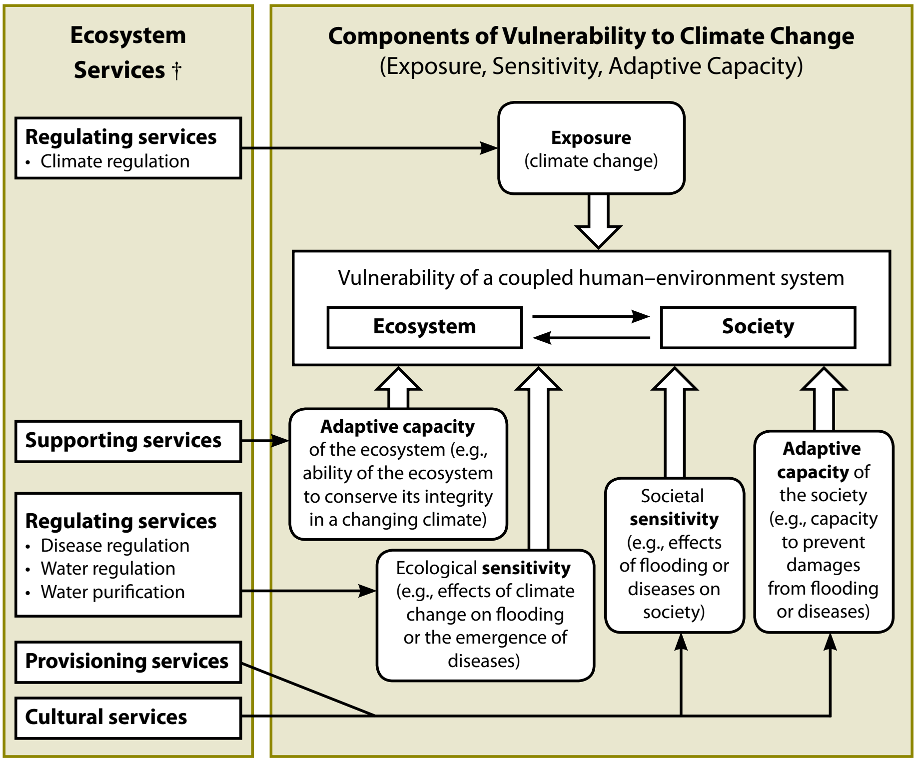



**Figure 4. Ecosystem services and their links to vulnerability to climate change.**

† See also Figure 3.

provided by a forest determine the response of a watershed to rainfall events. The vulnerability of the social system is also linked to provisioning and cultural services, as nutrition, access to goods, health and social cohesion contribute to sensitivity and adaptive capacity.

All sectors described as vulnerable to climate change by the IPCC (Parry *et al.* 2007) benefit from diverse ecosystem services (see Table 2). The vulnerability of these sectors depends on the vulnerability of the ecosystems they rely on. However, most vulnerability assessments use a sectoral approach, which overlooks the links between sectors and with ecosystems. We argue that, if ecosystem services are relevant for a given sector, the vulnerability assessment should deal with the vulnerabilities of both natural and human systems at the same time and consider the links between them. Two examples of such approaches are given below and an application is shown in Box 6.

**Table 2. Examples of relevant ecosystem services for vulnerable sectors**

| Ecosystem services | Vulnerable sectors† | | | | | |
|---|---|---|---|---|---|---|
| | Freshwater resources | Ecosystems ‡ | Food, fibre and forest products | Coastal systems and lowlying areas | Industry, settlement and society§ | Health |
| *Provisioning* | | | | | | |
| – Food | | | x | | x | x |
| – Wood, fuel wood, other fibres | | | x | | x | |
| – Biochemicals and genetic resources | | | x | | x | x |
| *Regulating* | | | | | | |
| – Moderation of floods, landslides, soil erosion, force of wave and wind | x | x | x | x | x | x |
| – Water purification, decomposition of wastes, control of diseases | x | x | x | | x | x |
| – Moderation of drought and temperature extremes | x | x | x | | x | x |
| – Pollination of crops and natural ecosystems, control of agricultural pests, dispersal of seeds | | x | x | | | x |
| – Regulation of global climate | x | x | x | x | x | x |
| *Cultural* | | | | | x | x |

† According to IPCC (Parry *et al.* 2007).
‡ Ecosystems outside the forests providing services.
§ Energy, transportation, tourism, insurance, etc.

## Assessing vulnerability of coupled natural and human systems

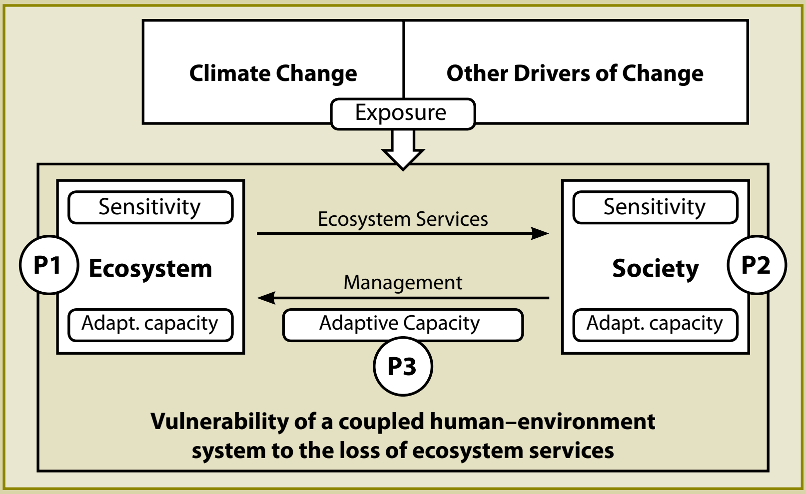
The ATEAM project (Advanced Terrestrial Ecosystem Analysis and Modelling, http://www.pik-potsdam.de/ateam) developed an approach to assess where people or sectors may be vulnerable to the loss of ecosystem services, as a consequence of climate and land use change. This approach highlights that the societal vulnerability to global change also results from impacts on ecosystems and the services they provide (Metzger *et al.* 2005, 2006).

The Research and Assessment Systems for Sustainability Program (http://sust.harvard.edu) developed a vulnerability framework for the assessment of coupled human–environment systems (Turner *et al.* 2003). Some essential

**Box 6. Principles and criteria for assessing the vulnerability of coupled human–environment systems**

Vulnerability assessments provide critical information for policy makers who need to prioritise adaptation efforts (Luers *et al.* 2003). Participative multicriteria assessments are effective in terms of policy impacts as they enable policy makers and local stakeholders to be engaged in the definition and valuation of criteria (Mendoza and Prabhu 2005).

A general framework was developed by the TroFCCA project (Tropical Forest and Climate Change Adaptation, CIFOR–CATIE, http://www.cifor.cgiar.org/trofcca) and is currently applied to diverse ecosystem services in various contexts, such as non-timber forest products (NTFPs) in West Africa and forest hydrological services in Central America. This framework is voluntarily broad, as it must serve as a guide for discussion during its application in specific cases (see figure).




The conceptual framework is inspired by the works of Turner *et al.* (2003) and Metzger *et al.* 2005), and emphasises the role of ecosystem services for society. Three main principles are defined (see circles in the figure). The first principle (P1) deals with the vulnerability of ecosystem services to climate change or variability and other threats. It can be described by criteria related to exposure and sensitivity to climate change or variability, and ecosystem adaptive capacity as a function of current degradation or other pressures.

The second principle (P2) deals with the human system and its vulnerability to the loss of ecosystem services. The sensitivity of the system (e.g., dependence on NTFPs or clean water) and its adaptive capacity (e.g., availability of substitutes for the lost services) can be used as criteria for P2. External drivers of changes, such as macroeconomic policies or energy prices, must also be taken into account in characterising this principle.

The third principle (P3) considers the adaptive capacity of the system as a whole. It refers to the capacity of the human systems to reduce the loss of ecosystem services. Criteria can refer to the capacity of removing practices that increase pressures on ecosystems and the capacity to implement forest adaptation.

elements considered in the framework are the linkages between human and biophysical vulnerability, and the complex dynamics of human–environment systems.

As vulnerability assessment should consider the vulnerability of sectors jointly with the vulnerability of ecosystems they depend on, adaptation policies should do the same. The adaptation measures should not be limited to technical and socioeconomic actions within the sector, but be broadened to consider ecosystem management as an adaptation option. For example, a hydropower plant or a drinking water facility facing problems of siltation or water quality could participate in upstream forest management, instead of investing in technical filtration or treatment solutions. The adaptation policy responses linking forests with other sectors are discussed in the next section.

## 3.3. Mainstreaming tropical forests into adaptation policies

Adaptation policies are needed to facilitate the adaptation of tropical forests and enhance the role of forests for the adaptation of society. The mainstreaming of tropical forests in adaptation policies should follow these two objectives: first, promoting adaptation for tropical forests, by encouraging the adaptive management of forest; and second, promoting tropical forests for adaptation, by linking forests with the sectors that benefit from forest ecosystem services.

### The need for mainstreaming forest adaptation into policies

As highlighted in previous sections, technical and societal adaptation is needed to reduce the vulnerability of human–environment systems to climate change. Even with the well documented need for adaptation of forests and people to climate change, there is still a lack of adaptation policy processes at the national level. Hesitation in the design of adaptation policies and programmes is often linked to a lack of information, uncertainties about the ‘exact’ direction of climate change and a ‘cascade of unknowns’. It is also related to political preferences for short-term economic gains, and perceived tradeoffs between the different sectors. Threats like climate change and variability have been insufficiently incorporated into national strategies (Mortimore and Manvell 2006).

There is a strong argument that governance—with its structures, mechanisms and institutions—is a key determinant of adaptive capacity (Adger *et al.* 2004; Brooks *et al.* 2005), as it sets the frame in which adaptation is happening or where adaptation is needed. In this context, revised national development policies and governance structures should enable adaptation at multiple scales. Therefore, we need to mainstream adaptation into national development policies, programmes and interventions to reduce the vulnerability of ecological and social systems (Huq *et al.* 2003; DFID 2006; UNFCCC 2007; see Appendix for a discussion of pros and cons of mainstreaming adaptation into development).

## Place of forests in adaptation policies

The need for mainstreaming forests into adaptation policies becomes even more obvious when reviewing the national communications and action plans for adaptation prepared under the UNFCCC (see Appendix for an introduction to national communications and adaptation plans under the UNFCCC), in which the role of forests for adaptation and the importance of adaptation for forests to reduce vulnerability have not been well reflected (UNFCCC 2008). Forests play a secondary role (if any at all) in adaptation policies (Kalame *et al.* in press), despite their importance for livelihoods and their interlinkages with other sectors. In most cases, forests and forestry are not a priority in the National Adaptation Programmes of Action (NAPAs). However, there are examples of adaptation strategies that do include forestry, such as reduction of climate change hazards through coastal afforestation in Bangladesh, forest fire prevention in Samoa, catchment conservation with reforestation in Haiti, and several examples in West Africa (see Box 7).

In the NAPAs and national communications submitted to the UNFCCC, the identified adaptation needs in the forest sector are related to technical (e.g., information systems for forest inventories) and societal adaptation (e.g., capacity building for community and state bodies). Proposed activities are often related to market-based improvements—for example, the development of non-timber forest products (NTFPs)—and to the review or setting up of new forest management and conservation plans. Most national communications and action plans for adaptation identify the lack of human and financial capacity as a constraint to successful adaptation.

**Box 7. Afforestation and reforestation policies and adaptation to climate change in West Africa** *(by Fobissie Kalame)*

West Africa experiences recurrent droughts, desertification and deforestation with accelerating forest and environmental degradation, sometimes leading to poor soil, crop and forest productivity, famine and extreme poverty, thereby increasing the vulnerability of ecosystems and communities.

Most West African governments have responded to forest degradation by developing strategies for afforestation and reforestation with two objectives: (1) to provide ecosystem services for combating desertification and environmental degradation, and (2) to replenish the dwindling forest and tree-based assets that local communities depend on (e.g., for non-timber forest products, timber or fire wood).

In Ghana, for example, the 1994 'Forest and Wildlife Policy' emphasises the necessity of state, private and community level reforestation initiatives to restore degraded forest resources. Similarly, Burkina Faso's 1997 'Forestry Code' describes degraded areas to be reforested, afforested and regenerated to protect forests and the environment. The '8000 villages-8000 forests' project (1994–1997) and the 'National Reforestation Campaign' (2003–2012) are examples of large-scale reforestation programmes in Burkina Faso.

Most of the afforestation/reforestation programmes use multipurpose, fast growing, drought tolerant, and fire resistant tree species. Major challenges remain at the level of implementation with issues of local participation, and insufficient human, material and financial resources.

Though not labelled as climate change adaptation measures, afforestation/reforestation activities promoted by forest policies can contribute to reducing local vulnerability. Recently, the NAPAs in some countries (e.g., Burkina Faso and Mali) have recommended afforestation/reforestation as an adaptation measure. Hence, national forest policies need to re-align their objectives with a clear climate change adaptation focus (Kalame *et al.* in press).

To achieve these identified needs and activities, a policy mix is proposed in NAPAs and national communications, using regulatory (e.g., revision of existing forest laws, enforcement of laws for protection and conservation of forests), incentive-based and economic (e.g., market instruments for NTFPs, payments for forest ecosystem services, taxes), and information-based policy instruments (e.g., capacity building activities for state bodies and forest users). The emphasis is on regulatory and information-based instruments and measures, depending under which modes of governance (hierarchies, markets and networks) and in which governance structures (traditional, bottom up, comanagement, decentralised, centralised, private structures) adaptation should be applied.

However, national adaptation policies propose traditional policy instruments and measures without analysing the 'lessons learned' of past pitfalls in the forest sectors. There are also other factors that may explain why national adaptation policies are not yet successful in mainstreaming adaptation and integrating forests, in spite of the efforts made in the national communications and NAPAs.

First, regulatory approaches have often failed as a result of shortcomings in or total lack of implementation and enforcement of such laws in the often weak political and institutional context of developing countries. The transfer of forest resources to the local scale has also faced major pitfalls (Agrawal and Ribot 1999; Colfer 2005; Ribot *et al.* 2006; Tacconi 2007). In his paper on the history of forest management in West Africa, Ribot (2001) showed that, even under a decentralised government, forest management and its profits could remain centralised when local participation was limited to responsibilities without rights. Actors and structures from other scales (e.g., the donor community) also seem to have confirmed centralised management, accepting government's monopoly in defining the right way to manage and use forests, thereby rejecting local rights and hindering the development of local adaptive capacity (Ribot 2001).

Second, linkages are rarely made between adaptation policies and other ongoing political process and issues of high political relevance, such as land tenure reforms, property rights and access to natural resource, even if rights over and ownership of natural resources are considered a key feature for forest governance and adaptive capacity (Agrawal *et al.* 2008). The complexity of the policy arena of forests and adaptation may contribute to the lack of linkages between forests and adaptation.

Finally, and perhaps most important, horizontal and vertical coordination is lacking among the institutions involved in the design of adaptation policies, often disconnected from the local scale, where adaptation should take place (Agrawal 2008; Brockhaus and Kambire forthcoming).

Failures and shortcomings in forest governance for sustainable forest management—observed in the past even without a now obvious driver like climate change and the resulting need for adaptation—are not yet considered in national adaptation policies, which may result in even higher vulnerability for forests and forest-dependent people and sectors.

Therefore, innovative policy approaches are needed to recognise both the need for adaptation policies that encourage the adaptive management of forest, and the need for policies that engage other sectors which benefit from forest ecosystem services in forest adaptation.

## Policies promoting adaptation for forests

National policies that aim to promote the adaptation of forests to climate change should follow multiple objectives. First, they should reduce non-climatic threats to forests; for example, land use change, fragmentation or degradation by unsustainable harvesting practices. Removing maladaptation policies goes in that direction and aims at identifying other policy instruments that increase forest vulnerability; for example, incentives to biofuels or other crops competing with forest lands. Second, policies should encourage large-scale decision making for the management of forest or more generally biodiversity. Large landscape approaches are needed for designing and implementing forest adaptation measures (Hansen *et al.* 2003). Third, conservation policies must explicitly include climate change as a driver of change (Hannah *et al.* 2002; Killeen and Solórzano 2008). For instance, the design of national systems of protected areas and biological corridors must consider the vulnerability of the protected ecosystem and the role of corridors for facilitating migration of species under scenarios of climate change (IUCN 2003). Fourth, policies should try to promote information sharing about forest adaptation and establish monitoring systems for the impact of climate change on forests. The public should be included as a target for information dissemination and awareness raising. Fifth, forest policies must promote partnerships in the forestry sector in a broad sense (local forest stakeholders, forest private sector, forest governmental agencies, forest scientists from natural and social sciences, development and conservation NGOs, international agencies dealing with forestry issues). Sixth, as adaptation options at the local scale are often limited by financial and institutional capacities (Agrawal 2008), policies should have the objectives of strengthening local institutions, through capacity building and funding.

Many obstacles can be identified on the road towards implementing such policies, as past experience with forest policies has shown. However, climate change threats can be a catalyst for achieving better forest management or conservation, especially if the actors benefiting from forest ecosystem services at different scales are involved in the process.

## Policies promoting forests for adaptation

As highlighted earlier, forest ecosystem services are of great importance for the livelihoods of local populations, for sectoral and cross-sectoral national and subnational development, and for the international community. The sectors depending on forest ecosystem services are currently not involved in forest adaptation. Natural resources management is often done by stakeholders with few (if any) links with those benefiting from ecosystem services or bearing the consequences of the loss of ecosystem services. In watershed and coastal area management, sectors or stakeholders benefiting from water quality provided by upstream forests or protection from storms provided by mangroves should be involved in decision making and in ecosystem management (see Box 8).

In a multiscale view, from global to local, many institutions and sectors are concerned about forest adaptation: for example, international adaptation funds (see Appendix), mitigation funds and mechanisms for protecting carbon stored in forests, international biodiversity funds, national agencies involved in disaster prevention or poverty reduction, conservation and development NGOs, private sector benefiting from scenic beauty or biodiversity for ecotourism or from clean water for industrial purposes, and local users of water and forest products. Adaptation policies should aim at linking these actors with those engaged in forest management or conservation. The participation of non-forest actors may take many forms; for example, participation in decision making, capacity building, monitoring and financing.

The financial contribution of the non-forest actors to forest adaptive management is essential. Incentive-based policy instruments like payments

**Box 8. Mainstreaming forest into adaptation and development policies in The Philippines** *(by Rodel Lasco)*

There had been little consideration of an overall climate change adaptation strategy and its various options for Philippine forest ecosystems. The 1999 Philippines Initial National Communication contains adaptation options for watershed management that partly apply to forest ecosystems. These are mainly regulatory policies governing the use and conservation of forest resources in The Philippines.

Watershed management, forest conservation and greater local community participation could help in climate change adaptation. For example, protecting existing forests allows for natural adjustment to a new climate regime. Greater local community involvement could minimise the financial cost of adaptation (borne by state agencies). However, climate change is hardly being considered at all in the government's planning process for forest resources. The more urgent concern is to save remaining forests from human exploitation—the imminent threat.

In response to these shortcomings, initiatives in The Philippines highlight the importance of individual actors as brokers and catalysers in the policy arena of climate change and adaptation, as well as the need for linking the local governance structures to national and global processes to support mainstreaming adaptation and forests: the World Agroforestry Centre (ICRAF) in partnership with Luntiang Pilipinas (Green Philippines, a nationwide organisation chaired by active environmentalist and influential senator, Loren Legarda), with initial funding from GTZ, launched the Trees for Life programme in 2008. This programme is designed to promote trees and agroforestry for climate change adaptation and mitigation nationwide, with local government units (LGUs) as the main target. A key objective of the programme is to enhance the awareness and capacity of LGUs and NGOs nationwide in the use of trees and agroforestry in promoting climate change adaptation and mitigation. This is in recognition of the role of trees and agroforestry in enhancing resilience of small-scale farmers to climate change impacts.

In addition, Senator Legarda filed a bill in The Philippines Senate in August 2008, called An Act Mainstreaming Climate Change Adaptation, among the provisions of which is the promotion of forests and tree planting for climate change mitigation and adaptation.

for environmental services (PES) can have positive impacts on conservation or sustainable management efforts, and contribute to the adaptation of both forests and the users of ecosystem services. However, PES also face challenges related to the provision of services (problems of measurement), the payments themselves (monetary and non-monetary), the identification of buyers and sellers (private, public), the procedures, institutions and governance (Wunder 2005). Even though experiences of PES specifically for adaptation have not been well documented, this instrument may have potential for innovative financing of adaptation measures integrating conservation of forests, adaptive management, reforestation and afforestation.

## Which institutions?

Besides the need for revising national development policies to achieve both objectives (adaptation for forests and forests for adaptation), and the need for new policies specifically designed and integrated to achieve these objectives, existing governance structures need to be revised in order for these policies to be successfully implemented.

Mainstreaming forest into adaptation policies requires cross-sectoral approaches. However, the integration of adaptation policies across sectors remains a challenge (Adger *et al.* 2005b). To overcome obstacles in the design and implementation of adaptive policies and processes, there is a need for multilayered institutions and mechanisms to address cross-scale interactions, without undermining the capacity to self-organise at any particular scale (Cash *et al.* 2006; Lebel *et al.* 2006). However, unbalanced power relations in cross-scale networks or institutions can disturb the sustainable management of natural resources at the local scale and hinder change for adaptation; for example, when power is used to maintain the status quo (Adger *et al.* 2005a, b; Paavola and Adger 2006; Armitage 2008).

There is also a need to develop adaptive, flexible and learning institutions at all scales to respond to the nonlinear dynamics of natural resource and human systems (Folke *et al.* 2005). To achieve that objective, attention must be paid to building capacity and learning. Attributes of governance and individual, organisational or community capacities for adaptation determine the success of adaptation to climate change, and learning and flexibility are seen as key features for adaptation (Pelling and High 2005). The importance of knowledge, shared learning and reflection as key features for adaptive capacity is confirmed by broader work on change outside the climate debate; for example, in literature on adaptive comanagement of forests (Colfer 2005; Armitage 2008). Networks, collective action and inherent social capital are also key determinants for responding to change and for achieving sustainable management of natural resources (Adger 2003; Tompkins and Adger 2004; Pelling and High 2005).

The support and strengthening of those features of governance can be one way forward to achieving adaptive forest governance under climate change, as Boyd (2008) showed for the Amazonian forest.

## The role of policy-relevant science

Science should play a fundamental role in mainstreaming forests into adaptation policies, as it can inform policy makers about assessing vulnerabilities, identifying response options and designing adaptation strategies. Assessment of vulnerabilities should prioritise places or sectors with the highest vulnerabilities and demonstrate how forest adaptation can contribute to reducing the vulnerability of non-forest actors.

Building a policy–science dialogue is essential. Evidence based on rigorous research needs to be translated into policy-relevant language and placed into the policy process. However, it is well documented that policy making is not always solution oriented and evidence based. In addition, scientific research does not always fulfil quality criteria like credibility, solution orientation and, especially, timely delivery (Sutcliffe and Court 2006).

To achieve this science–policy dialogue and design a good adaptation policy, scientists must analyse structures and paths in a specific institutional and policy context to identify feasible policies and to support successful processes of change and adaptation. An adequate approach should enable work on both key obstacles in this science–policy dialogue simultaneously—inappropriate science and maladaptive policy processes. A policy research framework encompassing actors and policy networks should help in analysing the content and structure of specific decision making arenas. Such a framework should consider biophysical and socioeconomic research activities and actions at the same time to actively inform the policy process itself (see example in Box 9).

Identified paths should enable structural obstacles to be overcome, and identified brokers could assist in reducing institutional constraints (see Box 10). Science itself acts as a policy broker, and scientific networks in a specific region can make use of these opportunities to ensure that the results gained by interdisciplinary research are translated into policy.

**Box 9. A policy research framework on actors, decision making and policy networks**

In the TroFCCA project (Tropical Forests and Climate Change Adaptation http://www.cifor.cgiar.org/trofcca), policy research activities focus strongly on the adaptive capacities of the stakeholders involved in the decision and policy making processes across scales and across sectors that are relevant for forests and adaptation to climate change. The framework consists of a coupled human–ecological approach, where three partially simultaneous phases of research are applied.

Phase 1 – Identification of evidence on exposure and sensitivity of a specific system: biophysical research on forest ecosystems and their services affected by climate change is combined with research on the social system affected by climate change directly and indirectly via changes in the provision of such services.

Phase 2 – Identification of the adaptive capacity of the system: the institutional and policy frame is analysed by applying policy content analysis and stakeholder analysis (perceptions, risk awareness, belief systems, personal and organisational learning capacity/flexibility, policy preferences), including an analysis of networks in which actors operate in the policy or decision making arena for forests and adaptation (networks of information and influence).

Phase 3 – Contribution to mainstreaming adaptation and forest by identifying adaptation options and by supporting the design of adaptation strategies.

The first two phases will facilitate the design of adaptation strategies together with other stakeholders and mainstreaming of adaptation into development policies.

First results from Burkina Faso, Costa Rica, Indonesia, Mali and The Philippines confirm that several activities can assist in identifying feasible paths for mainstreaming adaptation into policy, and simultaneously animate an improvement of adaptive capacity. These activities are:

- Analysing the structures and content of the policy arena
- Identifying brokers and bridges, existing groups and coalitions
- Understanding actors' belief systems.

**Box 10. Hydropower, forests and adaptation in Costa Rica: supporting adaptive decision making processes** *(by Raffaele Vignola)*

Hydropower production is a development priority of Costa Rica and is highly vulnerable to the effects of climate change. A case study in Reventazon watershed shows that the increase in extreme precipitation events is bound to increase the erosion rate and thus siltation of dams important for hydropower generation. In this context, the current inappropriate management of steep uplands threatens to increase the already high budget (over $4 million per year) spent on keeping a convenient useful volume for hydropower production.

Current policies are inadequate to enforce a programme for sustainable soil management, and maintain and enhance the services provided by forest. Indeed, the actual payment for ecosystem services scheme does not cover broad landscape land uses, including agriculture, and so fails to have a significant impact in terms of erosion control.

However, in order to establish innovative institutions for financing and managing the forest services for soil protection, we first needed to understand the biophysical context and characterise potential scenarios. At the same time, we characterised stakeholders' interests, objectives and constraints, and then used scenarios and objectives to perform a structured decision process around the available alternatives. Additionally, analysing the role and position of the various actors in the information network helped identify key actors to catalyse the adoption of response measures.

The complex system of drivers with multiple external and internal factors for change is not amenable to oversimplified answers based on single causalities. Understanding the complexity of climate change, forest ecosystem services and adaptation is a challenge to science as it is a challenge to policy makers and civil society (see Box 11). Further efforts are needed by all actors in the national and subnational policy arena for implementing efficient adaptation policies.

**Box 11. The role of science in coordinating and supporting adaptive processes in West Africa** *(by Houria Djoudi, Hermann Kambire and Maria Brockhaus)*

The first results of an ongoing policy network analysis in Burkina Faso indicate information gaps between the coordinating agency for adaptation at national scale and the subnational governance structures. Additionally, there is no horizontal coordination for adaptation and forests at either national or local level, and local institutions (customary, elected institutions and state bodies like the extension services) are often disconnected. Windows of opportunity—like the decentralisation process and the transfer of forest resources to the local scale—remain unused for supporting adaptation efforts at local scale (Brockhaus and Kambire forthcoming).

A workshop on local governance, forests and adaptive capacities in a municipality in southwest Burkina Faso, with actors from different scales, established a platform for shared knowledge and learning on forests and adaptation to climate change. Efforts to contribute to vertical coordination of adaptation, as well as support for local governance and horizontal coordination in decision making processes related to climate change adaptation and forests, are ongoing. However, a maladaptive institutional and policy context can hinder successful adaptation through lack of capacities and structures for learning, and lack of knowledge (emphasised during this and other workshops in Burkina Faso and Mali). Comparative research in two municipalities in Burkina Faso has shown that individual understandings determine what can be realised in the space for adaptation that a specific governance structure is offering. Disconnected institutional and legal realities at different layers, and perceived tradeoffs among sectors may lead to marginalised regions, sectors and parts of the population (Brockhaus and Kambire forthcoming).

Ongoing research on adaptation at the interface of forest ecosystem services with livestock systems in Mali shows the difficulties for successful adaptation in remote areas and areas with no state representation, especially in a context where development programmes and interventions have yet to take climate change into account and have not mainstreamed adaptation in the project design (Brockhaus and Djoudi 2008). In this situation, project activities at the interface of forest ecosystem and livestock systems can counteract and nullify existing local adaptation strategies and efforts. Therefore, an integrated research approach is applied, where science can bridge the national and local scales.

# 4 Conclusions

- As tropical forests are vulnerable to climate change, management and conservation practices should integrate climate change threats and aim to reduce vulnerabilities. Adaptation options have already been defined for buffering forests from perturbations or for facilitating a shift or 'evolution' of forests towards new states adapted to changing climate conditions. The need for flexible and diversified approaches in forest adaptation is heightened by uncertainties.
- Tropical forests provide important provisioning, regulating and cultural services that contribute to human wellbeing at scales from local to global. The increasing degradation and reducing capacity of ecosystems to provide services are major concerns for sustainable development and the vulnerability of society to climate change, as ecosystem services help reduce exposure or sensitivity and increase adaptive capacity of most sectors of the society. Therefore, vulnerability assessment should consider the vulnerability of these sectors as well as the vulnerability of the ecosystems they depend on.
- Adaptation measures need to be implemented and policies need to be designed to facilitate the adaptation of tropical forests and to enhance the role of forests for the adaptation of society. In addition to mainstreaming adaptation into development, forest needs to be taken into consideration in adaptation strategies. National policy should promote adaptation for forests—adaptation policies that encourage the adaptive management of forests. At the same time, they should promote forests for adaptation—

recognising the role of forests in reducing societal vulnerability and by including the sectors that benefit from forest ecosystem services in forest adaptation (i.e., by involving *all* stakeholders in forest adaptation planning and implementation).

– Mainstreaming forest into adaptation policies requires cross-sectoral approaches; however, the integration of adaptation policies across sectors is still a challenge. To achieve adaptation across scales and sectors, adaptive, flexible and learning institutions are needed at all scales to respond to the nonlinear dynamics of natural-resource and human systems. A number of institutional changes will be needed. Managers at all levels need to understand the mechanisms that allow local people to adapt their own systems. Implementing forest adaptation should not start from scratch, but be built on the variety of experiences that have aimed at building adaptive and collaborative management, recognising the need for links and mutual support among levels. For successful mainstreaming of forests into adaptation policies, science should play a fundamental role in this policy arena.

# Appendix: Understanding adaptation

This appendix introduces general information about climate scenarios (section A.1), defines the concepts of vulnerability (A.2) and adaptation (A.3), and describes the international policies and funds for adaptation (A.4).

## A.1. Climate change scenarios in the tropics

The combined global land and marine surface temperature record in the time series from 1850 to 2005 shows an increasing trend of the global average surface temperature (see Figure 5) (Brohan *et al.* 2006). Twelve of the thirteen warmest years in the series occurred between 1995 and 2007, and the 2000s decade is *very likely*[1] to be warmer than the 1990s, the warmest complete decade in the series. The total temperature increase from 1850–1899 to 2001–2005 was 0.76 ± 0.19° (IPCC 2007). According to the IPCC Fourth Assessment Report (IPCC 2007), increased concentration of anthropogenic greenhouse gases (GHG) is *very likely* the cause of warming in the 20th century. With current development trends and climate change mitigation policies, global GHG emissions will continue to grow for several decades. Climate models predict an average warming of about 0.2° per decade up to the mid-2020s for a range of emissions scenarios (IPCC 2007).

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1 Following the IPCC Fourth Assessment Report (IPCC 2007), the following terms have been used to indicate the assessed likelihood of the occurrence/outcome: *Virtually certain* >99% probability of occurrence, *Extremely likely* >95%, *Very likely* >90%, *Likely* >66%, *More likely than not* >50%, *About as likely as not* 33–66% probability, *Unlikely* <33%, *Very unlikely* <10%, *Extremely unlikely* <5%.

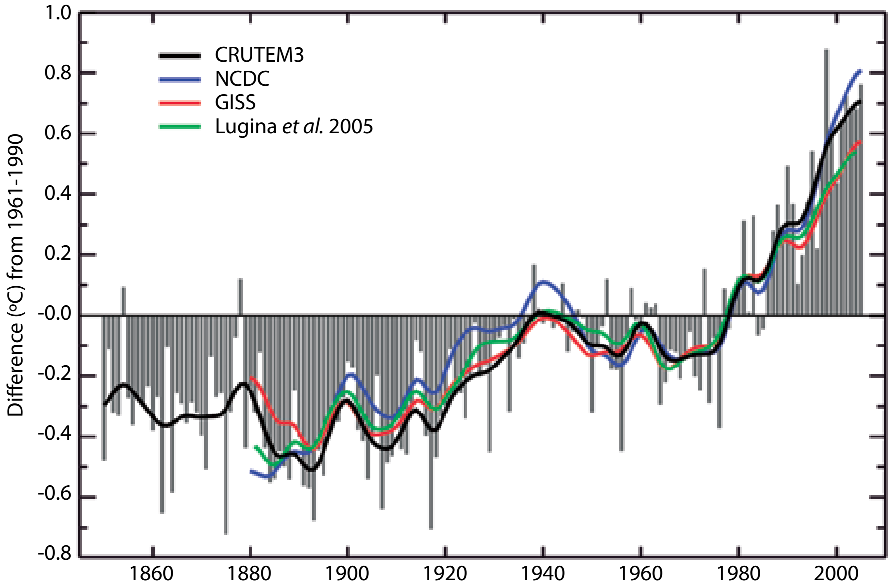


**Figure 5. Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961–1990 mean for CRUTEM3 (updated from Brohan *et al.* 2006).** The smooth curves show decadal variations according to different datasets (Trenberth *et al.* 2007).

Predicting future climate is necessary for assessing the impact on and the vulnerability of environmental, economic and social systems. The future climate depends largely on GHG emissions, which depend upon many uncertain factors like demography, consumption, technology, policy and attitudes towards environment. For this reason, future climate patterns are simulated using estimates of plausible future socioeconomic conditions and associated GHG emissions. Complex numerical climate models representing the physical processes of the climate system are the only credible tool currently available for simulating the response of the global climate system to increasing concentration of GHGs (Randal *et al.* 2007).

According to IPCC (2007), projected global average earth surface warming at the end of the 21st century is 4.0° (*likely* range 2.4–6.4°) for high emission A1FI scenario[2] and 1.8° (*likely* range 1.1–2.9°C) for low emission B1 scenario,

[2] A1FI and B1 are scenarios from the IPCC Special Report on Emission Scenarios (SRES) (Nakicenovic and Swart 2000). There are many such scenarios, which are grouped into six designations that are commonly used as markers, from the highest to the lowest emission scenarios: A1FI, A1T, A1B, A2, B1 and B2.

relative to the end of the 20th century. Projected global sea level rise at the end of the 21st century varies from 0.18 to 0.59 m for the same scenarios. All models show an increase in global mean precipitation (IPCC 2007). Increases in the amount of precipitation are *likely* in the tropical and high latitude regions (see Figure 6), while decreases are *likely* in the subtropical and mid-latitude regions as the consequence of a general intensification of the global hydrological cycle (Solomon *et al.* 2007).

Tropical regions in Africa, South Asia and Central America at the end of the 21st century are *likely* or *very likely* to be warming at a faster rate than the global annual mean warming (Christensen *et al.* 2007). Projected changes in annual rainfall vary across the tropical regions (see Figure 6). Rainfall in East Africa and during the summer monsoon of South and Southeast Asia is *likely* to increase (Christensen *et al.* 2007). Annual precipitation in most of Central America is *likely* to decrease—this region is the most prominent

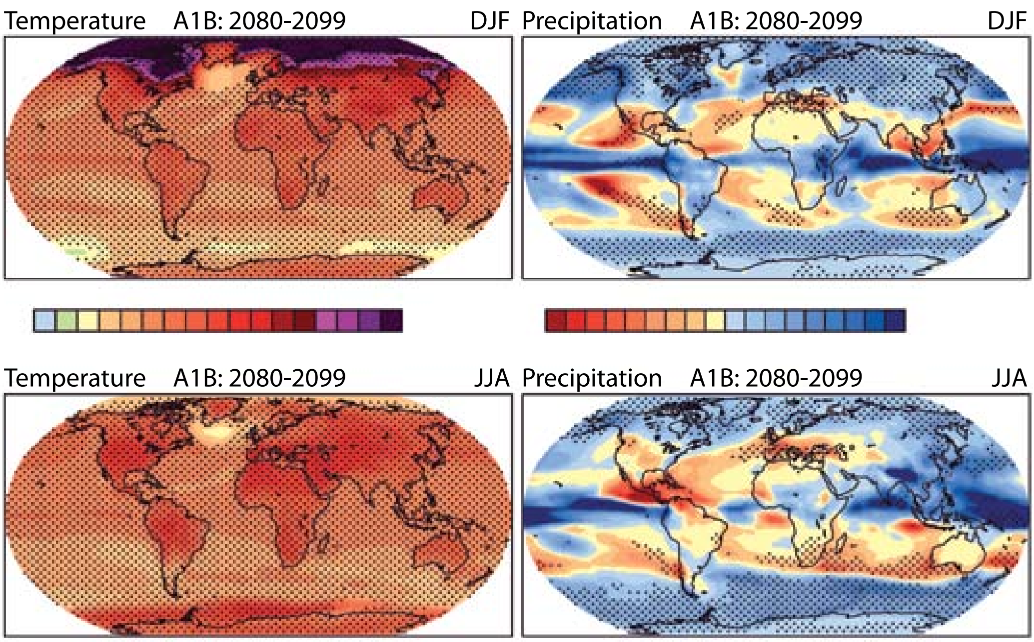


**Figure 6. Multimodel mean changes in surface air temperature (°C, left) and precipitation (mm/day, right) for boreal winter (DJF, top) and summer (JJA, bottom).** Changes are given for the SRES A1B scenario, for the period 2080 to 2099 relative to 1980 to 1999. Stippling denotes areas where the magnitude of the multimodel ensemble mean exceeds the intermodel standard deviation (Meehl *et al.* 2007).

tropical hotspot of climate change as defined by Giorgi (2006). It is unclear how the rainfall in the African Sahel and the Amazon will change (see Table 3). In many places, the intensity of precipitation events is projected to increase, even for the regions where mean precipitation decreases—here there would be longer periods between rainfall events.

Peak wind intensities of tropical cyclones are *likely* to increase—as revealed by embedded high-resolution models and global models (9 km to 100 km grid spacing)—particularly in tropical Southeast Asia and South Asia, bringing extreme rainfall (Christensen *et al.* 2007). The projections indicate a decrease in weak tropical storm frequency and an increase in the number of strong tropical cyclones, but with *low confidence*[3] (Meehl *et al.* 2007).

El Niño is an important climate phenomenon generated in the Pacific Ocean that causes variability to many tropical and subtropical regions on interannual timescales. Different large-scale mechanisms also drive the Indian Ocean Dipole Mode (Saji *et al.* 1999; Vinayachandran *et al.* 2002) and the North Atlantic Oscillation (Salinger 2005). Past climate records show that El Niño events have been more frequent and stronger since the mid-1970s (Trenberth and Hoar 1996). Despite significant advancements in climate modelling, there are still large uncertainties about the amplitudes and variability of El Niño (Meehl *et al.* 2000, 2007). The repeatability of this phenomenon is still not predictable, because what triggers the mechanism of this event is still not well understood (Cuny 2001).

Climate models have improved, and the latest Atmosphere-Ocean General Circulation Models have resolutions finer than 2.5° × 2.5° latitude/longitude. However, some impact assessments require finer resolutions, especially when the topography is likely to affect the climate. There are also improved nested regional climate models which offer a dynamic 3D simulation with high resolution commonly up to 50 km × 50 km or 25 km × 25 km.

There are multiple sources of uncertainties of climate scenarios, for example, uncertainties with the emission scenarios and the climate model itself, especially

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[3] Following the IPCC Fourth Assessment Report (IPCC 2007), the following terms have been used to indicate the level of confidence in being correct: *Very high confidence* represents at least 9 out of 10 chance of being correct; *High confidence* represents about 8 out of 10 chance of being correct; *Medium confidence* represents about 5 out of 10 chance of being correct; *Low confidence* represents about 2 out of 10 chance being correct; *Very low confidence* represents less than 1 out of 10 chance being correct.

**Table 3. Climate change trends in three continents, according to IPCC**
(Christensen *et al.* 2007)

| Varia† | Place | Confi-dence | Trend |
|---|---|---|---|
| | **Africa** | | |
| Temp | Throughout the continent | Very likely | Warming greater than the global annual mean warming in all seasons |
| Temp | Drier subtropical regions | Very likely | Warming more than the moister tropics |
| Prec | Much of Mediterranean Africa and the northern Sahara | Likely | Decrease in annual rainfall |
| Prec | Southern Africa | Likely | Decrease in rainfall in much of the winter rainfall region and western margin |
| Prec | East Africa | Likely | Increase in annual mean rainfall |
| Prec | The Sahel, the Guinean Coast and the southern Sahara | Unclear | Unclear trends in precipitation |
| | **Asia** | | |
| Temp | Central Asia, the Tibetan Plateau and northern Asia | Likely | Warming well above the global mean |
| Temp | Eastern Asia and South Asia | Likely | Warming above the global mean |
| Temp | Southeast Asia | Likely | Warming similar to the global mean |
| Prec | Northern Asia and the Tibetan Plateau | Very likely | Increase in precipitation during boreal winter |
| Prec | Eastern Asia and southern parts of Southeast Asia | Likely | Increase in precipitation during boreal winter |
| Prec | Northern, East and South Asia, most of Southeast Asia | Likely | Increase in precipitation in summer |
| Prec | Central Asia | Likely | Decrease in precipitation in summer |
| Extr | East Asia | Very likely | Heat waves/hot spells of longer duration, more intense and more frequent |
| Extr | East Asia and parts of South Asia | Very likely | Increase in the frequency of intense precipitation events |
| Extr | East, Southeast and South Asia | Likely | Increase in extreme rainfall and winds associated with tropical cyclones |
| | **Central and South America** | | |
| Temp | Southern South America | Likely | Warming similar to the global mean warming |
| Temp | All areas except southern South America | Likely | Warming greater than the global mean warming |
| Prec | Most of Central America and in the southern Andes | Likely | Decrease in annual precipitation (with large local variability in precipitation response in mountainous areas) |
| Prec | Tierra del Fuego | Likely | Increase in winter precipitation |
| Prec | Southeastern South America | Likely | Increase in summer precipitation |
| Prec | Northern South America, including the Amazon forest | Unclear | Unclear trends in annual and seasonal mean rainfall, but qualitative consistency in Ecuador and northern Peru (increasing rainfall) and at the northern tip of the continent and in southern northeast Brazil (decreasing) |

† Var (variables): Prec = precipitation, Temp = temperature, Extr = extreme events.

for regional climate scenarios (Mitchell and Hulme 1999). Precipitation trends in the tropics are particularly uncertain (see Figure 6, right, where stippling corresponds to lower variability among scenarios and hence higher confidence). Despite their limitations, climate scenarios are useful for better understanding the response to plausible climate (Price and Flannigan 2000), assessing a range of potential impacts and risks associated with climate hazards, and for better planning and decision making processes.

IPCC (2007) indicates several key impacts on different sectors that are correlated with climate change when adaptations are not considered: freshwater resources and their management; ecosystems; food, fibre and forest products; coastal systems and lowlying areas; industry, settlement and society; and health. Availability of fresh water is expected to increase in temperate regions and in the humid tropics, but decrease in the dry tropics and subtropics. Droughts and floods are expected to increase globally, which makes water management more difficult. Some ecosystems could change, being either shifted or destroyed, under climate change stress in conjunction with existing or enhanced disturbances such as fires, landslides, land use change and pollution. Agriculture could be under threat due to increasing water stress in many countries, and disasters such as flood and drought that could hit food crop production. Forest production may increase in the short term, but the trends are uncertain in the long term. Coastal and lowlying areas are at risk of flooding due to sea level rise and soil erosion, while extreme temperatures could harm corals. In some areas, infrastructures such as settlement and industries are at risk of disasters such as floods and landslides. Projected climate exposure could affect people's health with low adaptive capacity because of bad nutrition, more disasters causing deaths and injuries, and altered spatial distribution of infectious disease vectors.

## A.2. Concepts of vulnerability

In order to understand how to adapt to climate change, we must first define the central concept of adaptation, which is *vulnerability*. Understanding and assessing vulnerabilities to climate change is necessary to inform policy makers and develop policies for reducing risks associated with climate change. It contributes to increasing the scientific knowledge about climate-sensitive socioeconomic or ecological systems, targeting policy to the most vulnerable places or sectors, and defining adaptation options (Füssel and Klein 2006). Understanding vulnerability is not easy, in part because of the diversity of definitions and associated terms used in the literature, such as risk, hazard, sensitivity, exposure, adaptive capacity, resilience and potential impacts (Brooks 2003). Moreover, the ordinary definition of vulnerability ('exposed to being attacked or harmed' according to Oxford dictionary) is not precise enough for guiding vulnerability assessments.

## Different interpretations

Several scientific communities working on vulnerability—for instance, those dealing with livelihoods, food security, disasters, health and climate change—have built different definitions (Eakin and Luers 2006). Within this diversity of definitions, two distinct interpretations of vulnerability can be observed. First, a technical interpretation developed mainly by the risk and disaster management community considers vulnerability as the likelihood of occurrence of an exogenous hazard (e.g., a cyclone or a storm) and the associated impacts on a system, without taking into account the role of social factors in coping with the hazard (Carter *et al.* 1994). Second, a social interpretation, developed by political economists and human geographers, emphasises the socioeconomic and political factors that explain why a system is or is not able to cope with an external threat (Dow 1992; Adger and Kelly 1999). In this case, vulnerability is described by the internal state of the system and not by the characteristics of the threats (Brooks 2003).

Several authors have stressed the importance of defining vulnerability for a particular situation, i.e., the vulnerability of specified variables of a specified system to specified hazards within a specified time horizon, instead of assessing the vulnerability of a place to climate change in general (Brooks 2003; Füssel 2007a; Luers *et al.* 2003). For example, an assessment can deal with the vulnerability of forest-based livelihoods in the Sahel to drought over the next 30 years. In particular, specifying hazards is important, as a system may be able to adapt to some hazards (e.g., drought) and not to others (e.g., flooding). Three broad categories of hazards have been identified by Brooks (2003): category 1 (discrete recurrent hazards, such as storms or drought), category 2 (continuous hazards, such as increase in mean temperatures), and category 3 (discrete singular hazards, such as abrupt climate change events).

## The IPCC definition

Between these two interpretations of vulnerability, the definition proposed by IPCC is now widely used in the climate change community and is considered as a third school of thought (Füssel and Klein 2006). According to IPCC, vulnerability is 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity' (McCarthy *et al.* 2001). This definition explicitly includes external (exposure) and internal factors (sensitivity and adaptive capacity) and allows consideration of both socioeconomic and biophysical factors (see Table 4).

**Table 4. Categories of vulnerability factors** (from Füssel 2007a)

| Sphere | Domain | |
|---|---|---|
| | **Socioeconomic** | **Biophysical** |
| Internal | Household income, social networks, access to information | Topography, environmental conditions, land cover |
| External | National policies, international aid, economic globalisation | Severe storms, earthquakes, sea level change |

According to the IPCC definition, the three main components of vulnerability are exposure, sensitivity and adaptive capacity (see Figure 7 for definitions). This definition is useful for vulnerability assessment and has been applied widely; for example, by Metzger *et al.* (2005) in an operational framework for studying the vulnerability of ecosystem services and their users to global change (see Box 12). The IPCC definition is also compatible with other approaches, such as the framework for vulnerability analysis in sustainability science elaborated by Turner *et al.* (2003).

## Components of vulnerability

In the IPCC definition, exposure is external to the system, while sensitivity and adaptive capacity are internal. As an example, the three factors E, S and AC explaining vulnerability of forest growth to temperature changes could be, respectively, the increase in temperature, the sensitivity of tree dynamics to temperature, and the changes of ecosystem composition following changes in tree dynamics. In climate change studies, exposure is generally climatic, as expressed in the IPCC definition, but can be extended or modified to include other factors. First, socioeconomic exposure can also be considered in addition to climate, for instance globalisation (O'Brien *et al.* 2004). Second, depending on the system under study, exposure can combine climate change

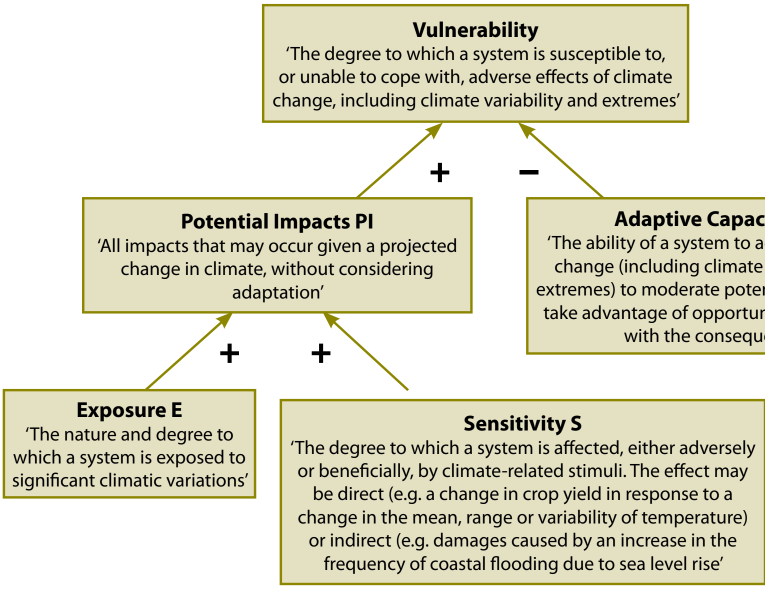



**Figure 7. The components of vulnerability** (definitions are from IPCC: McCarthy *et al.* 2001). The signs under the arrows mean that high exposure, high sensitivity and low adaptive capacity induce high vulnerability.

## Box 12. The ATEAM framework for assessing vulnerabilities

Developing metrics for quantifying vulnerability can facilitate policy–science dialogues on adaptation and the use of vulnerability assessment in policy making. Several sets of indicators have been developed for various components of vulnerability (e.g., Moss *et al.* 2001; Cutter *et al.* 2003; Brooks *et al.* 2005; Eakin and Bojórquez-Tapia 2008).

Elaborating on the IPCC definitions of vulnerability, exposure, sensitivity and adaptive capacity, the ATEAM project (Advanced Terrestrial Ecosystem Analysis and Modeling, www.pik-potsdam.de/ateam) developed a spatially explicit and quantitative framework for vulnerability assessment (Metzger *et al.* 2005). Ecosystem models are used for assessing the changes in the supply of different ecosystem services under scenarios of climate change in Europe. Then scenario-based changes in adaptive capacity are used to assess vulnerability for different sectors: agriculture, water management, energy, and nature conservation. The vulnerability maps allow identification of the most vulnerable regions, the most vulnerable sectors in a given region, and the least harmful scenarios for regions and sectors (Metzger *et al.* 2006).

Combining indicators of potential impacts and adaptive capacity in a vulnerability index is not straightforward. Because of the limited empirical basis of some adaptive capacity indices, Metzger *et al.* (2006) created maps of vulnerability displaying the two components of vulnerability, potential impacts and adaptive capacity, without aggregating them in a single dimension.

**Box 13. Vulnerable countries**

Several authors have proposed indicators of sensitivity and adaptive capacity to climate change at a national scale and used them to rank countries according to their vulnerability (or sensitivity and adaptive capacity according to the IPCC definition). Although these studies may provide inputs for policy makers at national or global scale, they have been criticised for the non-consideration of important vulnerability factors observable only at subnational scales (Adger and Vincent 2005) and the ambiguity about what is assessed as vulnerable and to what nations are considered vulnerable (Luers 2005).

Those using an inductive data-driven approach define a set of indicators and select the indicators that are the most correlated with proxies of vulnerability (e.g., using data on past disasters) or that are perceived by experts to be best indicators of vulnerability (e.g., Moss *et al.* 2001). For instance, Brooks *et al.* (2005) build a wide array of potential vulnerability indicators related to economy, health and nutrition, education, infrastructure, governance, geography and demography, agriculture, ecology and technology. They select 11 indicators having a strong correlation with mortality from climate-related disasters (population with access to sanitation, literacy rate of those aged 15–24 years, maternal mortality, literacy rate of those over 15 years old, calorific intake, voice and accountability, civil liberties, political rights, government effectiveness, female to male literacy ratio, life expectancy at birth). They then rank countries using these indicators and show that the most vulnerable countries are those situated in Sub-Saharan Africa and those that have recently experienced conflict.

Conversely, theory-driven studies start from assumptions about the link between vulnerability and various environmental and development factors (e.g., Cutter *et al.* 2003, at the scale of US counties). Adger and Vincent (2005) apply the social vulnerability index (SVI)—an aggregate index of human sensitivity and adaptive capacity to climate change-induced changes in water availability—to rank the vulnerability of African countries. The SVI is composed of five composite subindices: economic wellbeing and stability, demographic structure, institutional stability and strength of public infrastructure, global interconnectivity, and dependence on natural resources (Vincent 2004).

and ecosystem factors. For instance, a study on the vulnerability of society to floods could express exposure as a function of rainfall intensity and the hydrological response of a watershed or forest.

Sensitivity is a characteristic of a system and represents the 'dose–response' relationships between the exposure and the impacts. For example, the likelihood of infrastructure destruction because of flooding, or the changes in crop productivity caused by a decrease in precipitation. The adaptive capacity describes the ability of a system to modify its characteristics (e.g., an ecosystem changing its composition towards species more adapted to the new climate) or behaviour (e.g., a farmer choosing new crops better adapted to drought). Determinants of sensitivity and adaptive capacity can be endogenous to the system (e.g., the biological richness of an ecosystem; or wealth, social networks, technology and education for a human community) or exogenous (e.g., landscape connectivity at the margins of an ecosystem; national policies or global markets for a human community). Box 13 provides examples of indicators of sensitivity and adaptive capacity at the country scale.

In addition to the potential impacts defined in Figure 7, other types of impacts are considered by the IPCC and other authors (see Figure 8). While potential impacts are the result of exposure and sensitivity without considering adaptation, the expected impacts are those that would occur after an autonomous adaptation of the system and the residual impacts after planned adaptation (Füssel and Klein 2006).

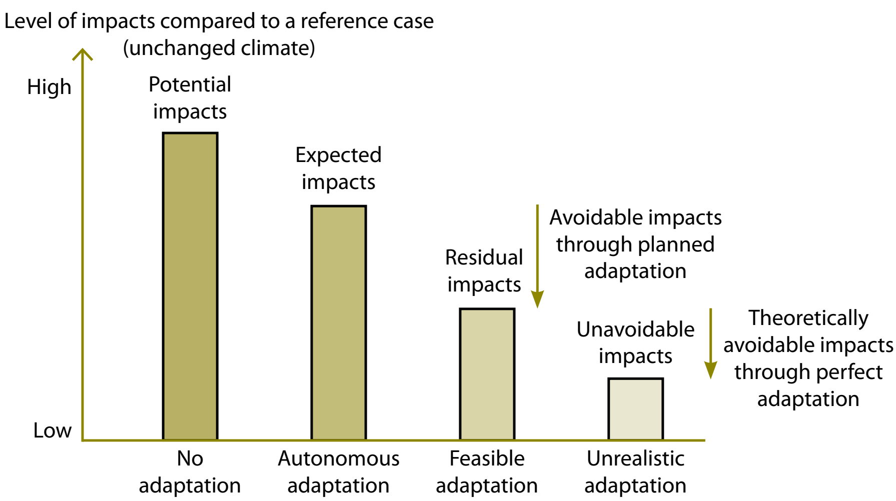



**Figure 8. Various conceptualisations of impact and adaptation** (after Füssel and Klein 2006).

## Vulnerability assessments

Depending on the purpose of climate change studies, the focus of vulnerability assessments can be placed on different components of vulnerability. Füssel and Klein (2006) distinguish four distinct types of vulnerability assessments: impact assessments (estimating the impacts of climate change on a system), first generation vulnerability assessments (including non-climatic factors and possible adaptation measures), second generation assessments (giving attention to the adaptive capacity and its determinants), and adaptation policy assessments (involving stakeholders in the analysis of current vulnerability, recommending adaptation measures in phase with other policies).

Exposure and sensitivity are key components in impact assessment studies, even though potential adaptive capacity may also be included (Carter *et al.* 1994). The results of these studies are useful for designing technical adaptation measures, as well as for the debate on mitigation, as they provide information about the potential impacts of different levels of GHGs (Smit *et al.* 1999). Guidelines for impact assessment include the *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations* (Carter *et al.* 1994).

Conversely, adaptive capacity is the key component of adaptation policy studies, which focus on understanding internal vulnerability (sensitivity and adaptive capacity) or analysing how to increase adaptive capacity. These studies are relevant for designing adaptation projects and policies and for broad development issues (Burton *et al.* 2002). An example of guidelines for adaptation policy studies is the UNDP–GEF Adaptation Policy Framework (Lim and Spanger-Siegfried 2004).

Even though impact assessments have provided scientific results and inputs for designing technical adaptation options that are both useful and valuable, they have generally not been useful in the design of adaptation policies, because they rarely consider policy context. Moreover, because of the uncertainties inherent to impact assessment and climate scenarios at local scale, scientific results do not provide clear messages to policy makers (Burton *et al.* 2002). For this reason, vulnerability assessments aiming at policy impacts have been evolving towards adaptation policy studies, with better integration of key stakeholders in the process and a better understanding of policy processes and non-climatic issues (Füssel and Klein 2006). Box 14 provides an example approach for vulnerability assessment.

**Box 14. An eight step approach for assessing vulnerabilities** *(from Schröter* et al. *2005)*

In response to the need to assess the vulnerability of coupled human–environment systems, Schröter *et al.* (2005) developed a methodological framework for 'place-based' vulnerability assessments. The framework comprises eight steps:

1. Define study area together with stakeholders
   - Choose spatial and temporal scale.
2. Get to know place over time
   - Review literature. Contact researchers. Spend time in field with stakeholders. Explore nearby areas.
3. Hypothesise who is vulnerable to what
   - Redefine focus on stakeholder subgroups. Identify drivers.
4. Develop a causal model of vulnerability
   - Examine exposure, sensitivity and adaptive capacity. Formalise into model(s).
5. Find indicators for the elements of vulnerability
   - Exposure, Sensitivity, Adaptive capacity.
6. Operationalise model(s) of vulnerability
   - Apply model(s) to weight and combine indicators. Validate results.
7. Project future vulnerability
   - Choose scenarios with stakeholders. Apply model(s).
8. Communicate vulnerability creatively
   - Be clear about uncertainty. Trust stakeholders. Use multiple, interactive media.

The first three steps take place before a modelling approach is implemented. By models, the authors mean a formalised description of a system, which can be numerical and computationally processed, but not necessarily. The framework should be applied by involving stakeholders and various scientific disciplines, engaging varied and flexible knowledge, recognising multiple global change drivers and differential adaptive capacity, and using both prospective and historical information. The authors present two example applications of the framework on agriculture vulnerability in the USA and Zimbabwe.

## A.3. What is adaptation?

According to the IPCC, adaptation is an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (McCarthy *et al.*

2001). Following the IPCC definition of vulnerability, three cornerstones of adaptation can be defined. First, *exposure* can be reduced where possible; for example, by relocating a community from a flood-prone area or implementing an emergency alert system. Second, *sensitivity* can be reduced; for example, by planting new crops resistant to drought or creating construction norms for building in hazard-prone areas. Third, *adaptive capacity* can be increased; for example, by raising population wellbeing and education or designing insurance schemes (Adger *et al.* 2005a).

A distinction is generally made between autonomous (or spontaneous) adaptation and planned adaptation. According to the IPCC, autonomous adaptation does not constitute a conscious response to climatic stimuli, while planned adaptation is a 'result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state' (McCarthy *et al.* 2001). Evidence of past and current autonomous adaptations to climate change or variability has been reported widely (e.g., Mortimore and Adams 2001; Orlove 2005), but such adaptations may not be sufficient to adapt to current and expected rates of climate change. Planning adaptation that goes beyond autonomous adaptation is now seen as a priority, because science has generated evidence about current and future climate change, and many natural resource managers and policy makers have to deal with vulnerability issues (Füssel 2007b; Agrawal 2008).

## Planning adaptation

There is no universal recipe for designing and implementing adaptation (Füssel 2007b), because adaptation concerns a wide array of sectors with distinct objectives and vulnerabilities to different climatic threats—for instance, agriculture, human health, water management, ecosystem management (including forestry), disaster prevention, human settlements, industry and energy. Moreover, a large diversity of adaptation options is available, with different timings, actors, functions and forms (see Table 5). These options must be tailored to the local economic, environmental, political and cultural conditions of the area, and institutional arena relevant for the sector.

In some cases, an individual adaptation can be sufficient to reduce individual vulnerability; however, collective interventions are often required (Adger *et al.* 2005a). Collective adaptation decisions are taken by a wide array of actors at

**Table 5. Types of adaptation (after Smit *et al.* 1999; definitions from IPCC, McCarthy *et al.* 2001)**

| Differentiating concept | Types of adaptation |
|---|---|
| Timing | – Anticipatory (or proactive) adaptation takes place before impacts of climate change are observed<br>– Responsive (or reactive) adaptation takes place after impacts of climate change have been observed |
| Temporal scope | – Short term (or tactical)<br>– Long term (or strategic) |
| Spatial scope | – Localised<br>– Widespread |
| Actors | – Private adaptation: initiated and implemented by individuals, households or private companies. Private adaptation is usually in the actor's rational self interest<br>– Public adaptation: initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs |
| Function or effects | Retreat. Accommodate. Protect. Prevent. Tolerate. Spread. Change. Restore |
| Form | Structural. Legal. Institutional. Regulatory. Financial. Technological |

different scales; for example, individuals, firms, civil society, and local, regional, national and international public institutions. The different scales of decision making are interrelated; for instance, individual decisions are constrained by national institutions, and national adaptation policies are influenced by international processes such as the UNFCCC.

Adaptation actions can be influential at different spatial scales (from farms to regions or countries) and involve actors and institutions with different spheres of influence (from a firm or a community to a national or international organisation). An essential step in adaptation planning is to understand the scales that are relevant for the actors concerned by adaptation and the cross-scale interactions (Adger *et al.* 2005a). In particular, understanding local institutions is a key component of local adaptation planning, as these institutions mediate impacts and vulnerability, and determine the possible individual and collective adaptation responses, as well as their outcomes (Agrawal 2008).

Local stakeholders and communities must be placed at the centre of adaptation planning. As communities choose and implement adaptive strategies on the basis of their resources, their formal organisations, and their informal social relations and values (Pelling and High 2005), valuing local knowledge and building on social capital should be a priority of planned adaptation (Allen 2006). For instance, such planning includes understanding the strategies that local communities have developed for adapting to climate variability in the past and their local perceptions and knowledge on climate and vulnerability (Agrawal 2008). In addition to understanding community structure and values, planned adaptation should also aim to empower local stakeholders (including women and other marginalised groups) and build social capital at various levels (Allen 2006).

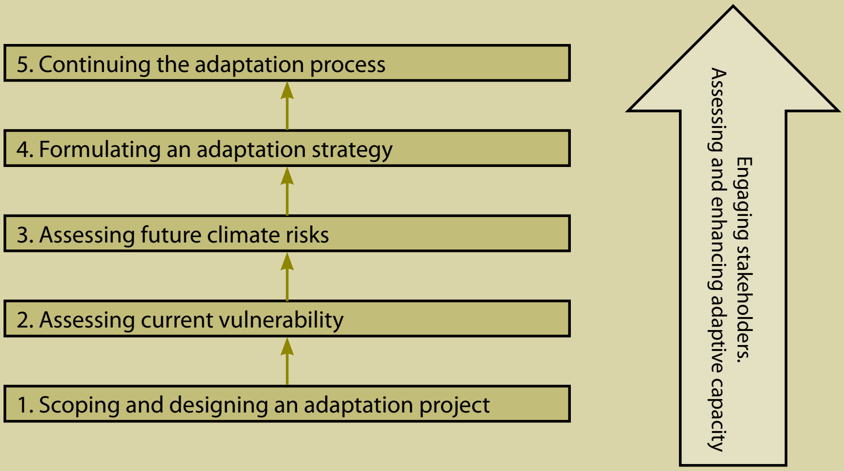
For achieving successful collective adaptation, decision makers of public and private institutions, local stakeholders, natural resource managers, scientists, policy analysts and economists should specify adaptation priorities based on the wider political, social and economic context, define and evaluate adaptation options, and decide how to implement these options (see example approach in Box 15).

Some approaches to vulnerability assessment and adaptation planning (e.g., the Adaptation Policy Framework, see Box 15) start from the current vulnerability. In many developing countries, adaptation to current threats is the most immediate task to be implemented. The current threats, related to climate variability and other drivers (e.g., policy, markets), are to be addressed before climate change issues can be considered. Reducing current vulnerability is essential in the process of adaptation to climate change, because a society less vulnerable to current threats will more likely be adaptive to future changes.

The evaluation of adaptation options must not be limited to their effectiveness, i.e., their capacity to achieve the expressed objectives of vulnerability reduction (Adger *et al.* 2005a), but other criteria must also be considered, especially equity, economic efficiency, legitimacy, flexibility, feasibility and environmental sustainability (Smit *et al.* 1999). As short-term or local successes may cause failures in the longer term or in other places, the outcomes of an evaluation of adaptation options depends on the temporal and spatial scale of analysis (Adger *et al.* 2005a). What we need is an analysis that goes beyond scales to

**Box 15. The Adaptation Policy Framework** *(from Lim and Spanger-Siegfried 2004)*

The Adaptation Policy Framework (APF) aims at guiding the design of adaptation strategies, policies and measures. The APF is composed of five components:



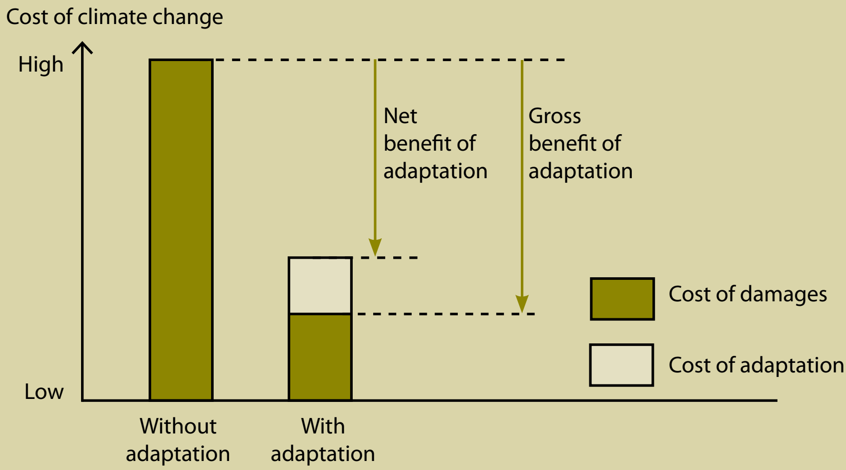

These five components are supplemented by two cross-cutting processes: engaging stakeholders in all components through a sustained dialogue for successful implementation of an adaptation strategy, and assessing and enhancing adaptive capacity so that societies can better adapt to climate change, including variability.

Users can apply the five components and two cross-cutting processes with different intensities depending on their needs and the available information. The APF does not require abundant data or research, but emphasises thoughtful assessments and robust stakeholder processes.

evaluate adaptation options more comprehensively. In terms of economic efficiency and cost–benefit analysis, the evaluation should also take into account funding mechanisms for adaptation, especially from international funds. However, international adaptation finance is still a challenge due to the dilemma of financing services with global benefits (mitigation) versus services with local benefits (adaptation measures) and uncertainties about costs and benefits of adaptation (see Box 16).

**Box 16. Costs and benefits of adaptation**

The costs and benefits of adaptation are hard to estimate because of the uncertainties regarding the costs of climate change impacts, the adaptation measures to be implemented, the costs of these measures, and their contribution to reduce impacts (see figure, after Stern 2007).




According to several global assessments of climate change impacts (reviewed by Hitz and Smith 2004), the average cost of damage in 2100 for a 2–3° warming varies between 0 and 2.7% of global GDP. Assuming a higher warming, Stern (2007) provided estimates between 5% and 20%, depending on the assumptions of impacts and outcomes. In April 2008, Stern said that the 2007 IPCC report provided data for a higher estimation of the costs of damage.

Few estimates have been given for the global costs and benefits of adaptation. The World Bank (2006) estimates very roughly that protecting the investments from development finance could cost $9–41 billion. Global estimates of adaptation costs are largely uncertain and mask heterogeneity of local situations where adaptation is a priority; however, local estimates can be very useful for policy makers (Callaway 2004).

Local costs–benefits of adaptation are important issues because costs of adapting or costs of failing to adapt can perpetuate poverty and environmental degradation in developing countries (Kates 2000). Stern (2007) reports the large benefits of several successful experiences of disaster management. For example, the $3.15 billion spent in China on flood control between 1960 and 2000 reportedly avoided $12.8 billion in losses. In Vietnam, a project aimed at protecting a coastal population with mangrove planting had a benefit–cost ratio of 52 (Stern 2007).

### Mainstreaming adaptation into development

Because climate change will impact all aspects of sustainable development and because vulnerability depends strongly on development, policy makers must strive to mainstream adaptation to climate change into national and sectoral development (Huq *et al.* 2003; Lemos *et al.* 2007; UNFCCC 2007). Development interventions that do not address adaptation to climate change may worsen the socioeconomic situation (Agrawal 2008). Policy makers should also identify and remove maladaptive practices, i.e., existing policies that increase vulnerability (for instance, incentives to natural resource overexploitation) or adaptation measures that fail to achieve their objectives (UNFCCC 2007). Another argument for mainstreaming adaptation into development policies is that climate change threats and the need for adaptation can be a catalyst for achieving sustainable development (UNFCCC 2007). However, some concerns have been raised about the risk of mainstreaming adaptation into development (Klein 2006). Funding for adaptation is scarce—if adaptation and development are not differentiated, there is a risk that adaptation funds will be used for any development activities, regardless of their impacts on adaptation. The funds would be used for development activities and the impacts on adaptation could be unclear or impossible to monitor. Another risk is that the funding for climate policy could reduce the official development assistance (ODA) flows that serve more immediate development needs (Klein 2006). Regarding national policies and the international funds on adaptation, mainstreaming adaptation into national development will make adaptation into 'business as usual' and mask the incremental costs of adaptation efforts, thus preventing developing countries from claiming international funding for adaptation.

## A.4. International policies and funds

Policy makers around the world have—some 15 years after signing the UNFCCC in Rio de Janeiro—finally recognised the need to integrate thinking about climate change into all areas of public policy making. Although most of the efforts have been directed towards mitigation, the need to develop polices and funding mechanisms for adaptation to a changing climate is now widely acknowledged. It is also becoming evident that adaptation and mitigation are interlinked in many ways; for instance, any substantial new mitigation commitments in the post-2012 climate regime may be politically feasible only if they are accompanied by stronger support for adaptation (Burton *et al.* 2006).

## Adaptation under the UNFCCC

In principle, adaptation was established as a priority right at the start of the international climate effort. In the UNFCCC signed in 1992, all parties committed generally to undertake national adaptation measures and to cooperate in preparing for the impacts of climate change. In the UNFCCC process, adaptation measures are intertwined with future commitments on climate mitigation, making the UNFCCC negotiating process the most obvious venue for structuring long-term global agreements for both adaptation and mitigation.

Specific elements of a convention-based adaptation approach include: (a) support to vulnerable countries for the development of comprehensive national adaptation strategies; (b) funding to assist countries with approved national strategies to implement high-priority measures, with priority given to those addressing impacts reasonably attributable to climate change; and (c) establishment or designation of an international body to provide technical support, judge the adequacy of national strategies, and select high-priority projects for funding (Burton *et al.* 2006).

However, there are constraints on what can be achieved within a convention-based regime created specifically to address climate change. First, the regime's inherent focus on climate change may not easily lend itself to a comprehensive effort addressing both climate change and natural climate variability. Second, the climate change regime has not traditionally engaged many of the agencies and actors whose participation in adaptation is essential.

Even if the regime assigned a higher priority to adaptation, it still might not be the best channel for engaging relevant policy makers and stakeholders (Burton *et al.* 2006). Thus, a convention-based adaptation regime would tend to focus more on policies and measures that are designed as a direct response to climate change than on policies for building general adaptive capacity of the society or addressing issues such as vulnerability to climate variability or local environmental benefits of adaptation. Funding for adaptation measures under the UNFCCC is designed mainly to cover the full incremental costs of adaptation (Bouwer and Aerts 2006) and are channelled through various mechanisms (see Box 17).

**Box 17. UNFCCC adaptation funds**

The UNFCCC secretariat estimated that the investment and financial flows needed for adaptation are likely to be tens of billions of dollars per year within several decades and could be more than $100 billion per year.

The Adaptation Fund under the Kyoto Protocol is intended to fund concrete adaptation projects and programmes in developing countries that are particularly vulnerable to the adverse effects of climate change. The source of this funding is intended to be from a 2% levy on proceeds from Clean Development Mechanism (CDM) projects (excluding those undertaken in least developed countries), as well as from other voluntary sources. The Adaptation Fund is in the process of being operationalised. The actual amount of money that will be available from this fund is uncertain, as it depends on the extent of the CDM and on the price of carbon.

Article 4 of the Convention highlights that developed country Parties shall provide financial resources to assist developing country Parties adapt to climate change. To facilitate this, the Convention gave GEF the responsibility of operating its financial mechanism. GEF enables a transfer of financial resources from developed to developing countries by establishing operational programmes, providing programming documents and allocating resources. Based on guidance from the UNFCCC, GEF operates three funds: (1) the GEF Trust Fund, (2) the Least Developed Countries Fund (LDCF), and (3) the Special Climate Change Fund (SCCF).

The GEF Trust Fund and its Strategic Priority on Adaptation (SPA) support enabling activities, pilot and demonstration projects that address adaptation *and* generate global environmental benefits.

The SCCF is partly designed to finance adaptation activities that increase resilience to the impacts of climate change, through a focus on adaptation responses particularly in water resources, land, agriculture, health, infrastructure development, disaster preparedness, and in fragile ecosystems and coastal zones.

The LDCF was partly established to support projects addressing urgent and immediate adaptation needs in the least developed countries as identified by their NAPAs.

The funds that are currently available under the Convention and the Kyoto Protocol are small compared to the magnitude of the needs identified by the UNFCCC. The financial resources available for adaptation in the funds currently operated by GEF amounted to about $275 million in August 2007. The Adaptation Fund could receive $80–300 million per year for the period 2008–2012. Assuming a share of proceeds for adaptation of 2% continues to apply after 2012, the level of funding could be $100–500 million per year for a low demand for the CDM, and $1–5 billion per year for a high demand. However, there is still a deficit in funding that needs to be filled.

## Other policy and funding options for adaptation

Other options at the international level essentially involve working through existing channels of multilateral and bilateral assistance to integrate adaptation considerations across the full range of development support. A development-centred strategy could closely complement the convention-based approach described above, helping to ensure that the national adaptation strategies prepared are in fact implemented, and could over time leverage far more resources than would likely be forthcoming under the climate regime (Burton *et al.* 2006).

Since the UNFCCC will only meet incremental costs, basic funding for adaptation will have to come from other sources, mostly from development banks, other conventions, and ODA. Other options include designing specific measures aimed at 'climate proofing' development projects or risk management measures and insurance policies (Mills 2005; Bouwer and Aerts 2006). Burton *et al.* (2006) and Müller (2008) present a comprehensive review of these 'innovative' approaches for international adaptation funding.

## National communications and NAPAs

Under the UNFCCC, countries are committed to submitting national communications to the secretariat of the Convention. In their national communications, developing countries provided information on their vulnerabilities to climate change in a wide range of sectors, and highlighted sectoral adaptation options and responses. These include both proactive and reactive responses to climate change. The sectoral approach to adaptation raises at least two questions—equity and fairness—in defining the priority sectors for a country (Paavola and Adger 2006), and highlights potentially weak coordination of national measures at the highest political level (Glantz 2001).

The 7th Conference of the Parties of the UNFCCC, acknowledging specific situations of least developed countries (LDCs), established an LDC work programme including NAPAs. The NAPAs focus on urgent and immediate needs of LDCs—those for which further delay could increase vulnerability or lead to increased costs at a later stage. NAPAs use existing information; they are action oriented and country driven, flexible and based on national circumstances. Up to October 2008, some 39 countries had prepared their NAPAs. Funding for implementation of NAPAs has been channelled through the Global Environment Facility's (GEF) initiatives (see Box 17) (Huq and Burton 2003; Bouwer and Aerts 2006).

NAPAs aim at defining the strategic goals and objectives of future adaptation mechanisms for a country to reduce the adverse effects of climate change, including variability and extreme events, and to promote sustainable development. Future strategies and mechanisms are suggested based on existing processes and practices, while keeping the main essence of adaptation science, which is a process to adjust to the adverse situation of climate change.

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The most prominent international responses to climate change focus on mitigation (reducing the accumulation of greenhouse gases) rather than adaptation (reducing the vulnerability of society and ecosystems). However, with climate change now inevitable, adaptation is gaining importance in the policy arena, and is an integral part of ongoing negotiations towards an international framework.

This report presents the case for adaptation for tropical forests (reducing the impacts of climate change on forests and their ecosystem services) and tropical forests for adaptation (using forests to help local people and society in general to adapt to inevitable changes).

Policies in the forest, climate change and other sectors need to address these issues and be integrated with each other—such a cross-sectoral approach is essential if the benefits derived in one area are not to be lost or counteracted in another. Moreover, the institutions involved in policy development and implementation need themselves to be flexible and able to learn in the context of dynamic human and environmental systems. And all this needs to be done at all levels from the local community to the national government and international institutions.

The report includes an appendix covering climate scenarios, concepts, and international policies and funds.

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