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FORESTS AND SOCIETY – RESPONDING TO GLOBAL DRIVERS OF CHANGE

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2 Forests and Adaptation to Climate Change: Challenges and Opportunities

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Abstract: Climate change is an important driver of changes in forests. As forests and forest-dependent societies are likely to be affected by climate change and its associated disturbances, adaptation is needed for reducing the vulnerability of forests to climate change. New challenges arise from the need to understand the vulnerability of forests and forest-dependent communities to climate change and to facilitate how they adapt to the changes. Forests also play a role in how the broader society adapts to climate change because forests provide diverse ecosystem services that contribute to human well-being and reduce social vulnerability. For this reason, forests should be considered in planning the adaptation of the society beyond forests. Ecosystem-based adaptation, an emerging approach to dealing forests in a changing climate, offers opportunities for forest and forest-dependent communities and supports the conservation or sustainable management of forests. This chapter presents an overview of climate change as a driver of changes in forests, the challenges and opportunities of adapting forests and the use of forests in adaptation practices, as well as the associated policy issues.

Keywords: climate change, adaptation, vulnerability, impacts, adaptive capacity, resilience, biodiversity, ecosystem services, ecosystem-based adaptation, adaptation policy

■

2.1 Introduction

Since the publication of its first assessment report in 1990, the Intergovernmental Panel on Climate Change (IPCC) has gathered incontrovertible evidence of human-induced climate change and the impacts it will have on ecosystems and on human societies (IPCC 2007). For tackling the resulting problems, two broad categories of responses have been defined: (1) mitigation (reducing the accumulation of greenhouse gases in the atmosphere) and, (2) adaptation (reducing the vulnerability of societies and ecosystems facing the impacts of climate change). So far, the prominent international responses – the United Nations Framework Convention on Climate Change and the Kyoto Protocol – have focussed on mitigation rather than adaptation. However, with some degree of global temperature increase now recognised as inevitable, adaptation is gaining importance in climate policy arenas at global and national levels.

While forests have a place in mitigation science and policy, their place in the emerging science of adaptation and in new climate-related policies is still to be built up. The linkage between forests and adaptation is two-fold: first, adaptation is needed for forests and forest-dependent people; second, forests play a role in adaptation of the broader society. In the first instance, because climate change is an important driver of changes in forests, new challenges arise from the need to understand both how the forests will change and what will be the impacts of those changes on forest-dependent people. We will need to assess the vulnerability of forest-dependent communities to the changes in forests, as well as determine successful ways of adapting to those changes (see definitions of vulnerability and adaptation in Box 2.1).

In the second instance, because forests provide ecosystem services that contribute to human well-

Box 2.1 Adaptation and vulnerability: Definitions

According to the 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). According to the IPCC definition, the three components of vulnerability are exposure, sensitivity, and adaptive capacity (see definitions in the figure, where the signs under the arrows mean that high exposure, high sensitivity, and low adaptive capacity induce high vulnerability).

Adaptation is defined by the IPCC as “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.” Various types of adaptation are distinguished, such as anticipatory or proactive adaptation (“that takes place before impacts of climate change are observed”), reactive adaptation (“that takes place after impacts of climate change have been observed”), autonomous or spontaneous adaptation (“that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems”) and planned adaptation (“that is the 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”).

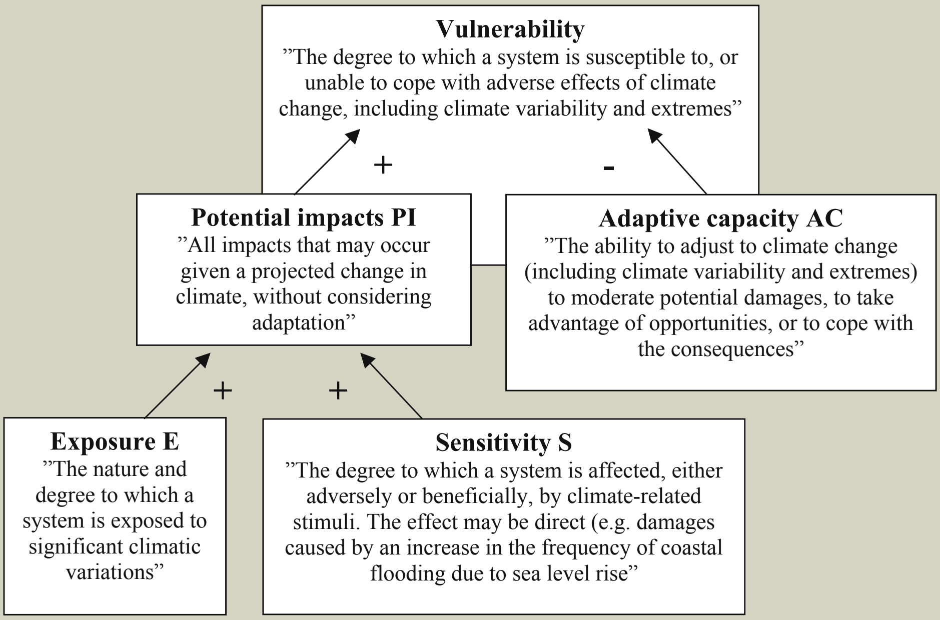


Figure 2.1 Definitions.

being and reduce social vulnerability, forests should be considered when planning adaptation policies and practices in sectors outside of the forest sector. This presents new opportunities for the forest sector.

This chapter presents an overview of climate change as a driver of changes in forests, the challenges and opportunities of adapting forests and using forests for adaptation, as well as the associated policy issues.

2.2 Forests are Vulnerable to Climate Change

Many 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 drivers of change (e.g., land use change, pollution, over-exploitation of resources).

According to the IPCC definition of vulnerability (see Box 2.1), the potential impacts of climate change on forests result from exposure and sensitiv-

Exposure

- Climate change and variability
  - Increase in temperature
  - Changes in precipitation
  - Changes in seasonal patterns
  - Hurricanes and storms
  - Increase in CO_2 levels
- Sea level rise
- Other drivers
  - Land use change
  - Landscape fragmentation
  - Resource exploitation
  - Pollution

Sensitivity

- Changes in tree level processes
  - e.g. productivity
- Changes in species distribution
- Changes in site conditions
  - e.g. soil condition
- Changes in stand structure
  - e.g. density, height
- Changes in disturbance regimes
  - e.g. fires, pests and diseases

Figure 2.2 Components of the exposure and sensitivity of forest ecosystems (after Johnston and Williamson 2007).

ity. Forests are exposed to different factors of climate change and variability, as well as other drivers, such as changes in land use or pollution, that may exacerbate the impacts of climate change (see Figure 2.2). Sensitivity refers to the degree to which a forest will be affected by a change in climate, either positively or negatively, such as through changes in tree level processes, species distribution, or disturbance regimes (see Figure 2.2).

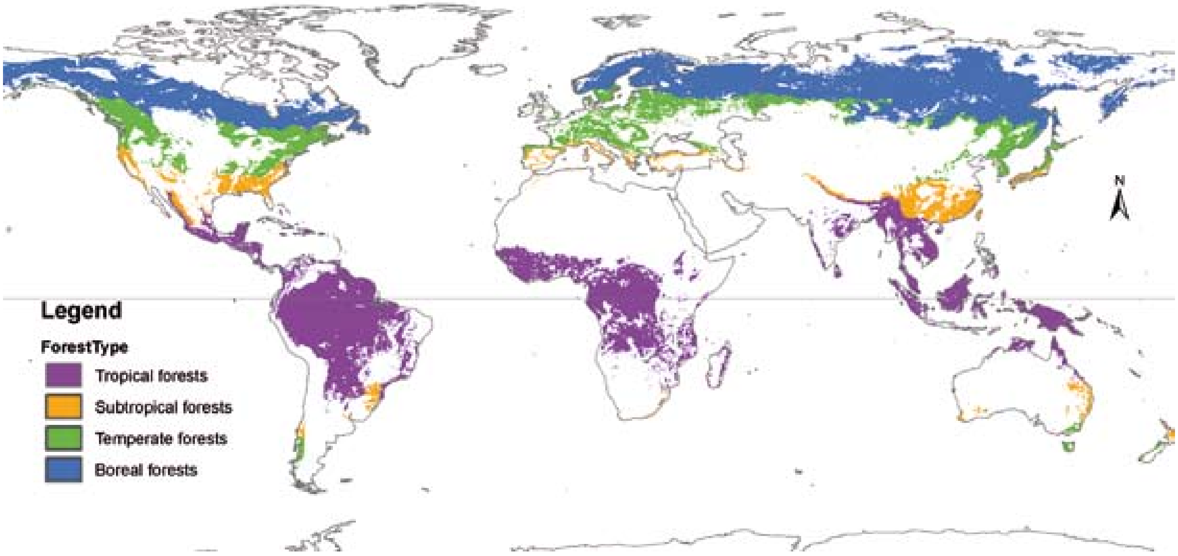
The vulnerability of a forest also depends on its adaptive capacity (see definition in Box 2.1). Even if the adaptive capacity of forests remains uncertain (Julius et al. 2008), many scientists are concerned that this innate capacity will not be sufficient to enable forests to adapt to unprecedented rates of climatic changes (Gitay et al. 2002, Seppälä et al. 2009). Species can adapt to climate change through phenotypic plasticity (commonly termed acclimatisation), adaptive evolution, or migration to suitable sites (Markham 1996, Bawa and Dayanandan 1998). The adaptive capacity of an ecosystem is related to the diversity of functional groups within the ecosystem and the diversity of species within groups, the most compelling explanation being the redundancy provided by multi-species membership in critical functional groups (Walker 1992, 1995; Peterson et al. 1998; Thompson et al. 2009). Several studies suggest that successful adaptation to climate change may require migration rates much faster than those observed in the past, such as during postglacial times (Malcolm et al. 2002, Pearson 2006).

In the following sections, we present some evidence of impacts and vulnerability of forests, according to biomes. Various forest classifications have been derived to describe the large diversity among global forest types. Here we use four forest biomes (boreal, temperate, subtropical, and tropical) (see FAO 2001 and Map 2.1).

We describe climate change impacts for two clusters of climate scenarios: growth and stable (Fischlin et al. 2009). The growth cluster includes scenarios in which emissions continue to increase over the course of the current century at rates similar to those in the second half of the last century (i.e., "business as usual") due to the absence of stringent climate policy, as in, for instance, the IPCC reference scenarios A1FI, A1B, and A2. The stable cluster includes scenarios in which emissions decline during the course of the current century as a result of major socio-economic changes that allow atmospheric carbon dioxide (CO_2) concentrations to approach a new equilibrium by the year 2100, as in, for instance, the IPCC reference scenarios A1T, B2, and B1.

We also describe how the impacts of climate change will affect biodiversity. According to the IPCC, roughly 20–30% of vascular plants and higher animals on the planet are estimated to be at an increasingly high risk of extinction as temperatures increase by 2–3°C above pre-industrial levels (Fischlin et al. 2009). Even small changes in climate could affect phenological events (such as flowering and fruiting) that may escalate into major impacts on forest biodiversity. This is because co-evolution has produced highly specialised interactions among specific plant and animal species in natural forests.

Overall, it is very likely that even modest losses in biodiversity would cause consequential changes in the ecosystem services that forests provide, such as the service of sequestering carbon. Climate feedbacks from local climate to the global carbon cycle may have major implications for the global climate and may contribute to an acceleration of climate change. Several climate change models project that the carbon-regulating services of forests could be severely degraded under climate scenarios in the growth cluster (Cramer et al. 2004).



Map 2.1 Distribution of the world's forests by major ecological zone (FAO 2001).

2.2.1 Tropical Forests

Impacts of climate variability and change have already been observed in tropical forests, for instance, on ecosystem structure and functioning, and carbon cycling (Root et al. 2003, Fearnside 2004, Malhi and Phillips 2004). 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). Climate variability and associated events, such as the El Niño Southern Oscillation, have caused drought and increased the frequency of fire in humid tropical forests in Indonesia and Brazil (Barlow and Peres 2004, Murdiyarso and Lebel 2007). Some species extinctions linked to climate change have already been reported for tropical forests. For example, Pounds et al. (1999, 2006) reported that climate change and a fungal pathogen were important causes of recent extinctions of the golden toad (*Bufo periglenes*).

Climate change is expected to cause significant shifts in the distribution of tropical rainforests and disturbance patterns. The possibility that climate change could enhance drought in the Amazon is of major concern because it would cause increased wildfire, climate-induced forest dieback, and large-scale conversion of tropical rainforest to savannah, which has important implications for the global climate (Cox et al. 2004, Scholze et al. 2006, Nepstad et al. 2008). 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°C warming, and most types are sensitive to changes in precipitation (Hilbert et al. 2001).

Tropical cloud forests are an important subset of tropical forests from a climate change perspective. Even small-scale shifts in temperature and precipitation are expected to have serious consequences because cloud forests are located in areas having steep gradients. The highly specific climatic conditions of cloud forests (Foster 2002) that justify monitoring these forests for possible effects of climate change (Loope and Giambelluca 1998). Atmospheric warming raises the altitude of cloud cover that provides tropical cloud forest species with the prolonged moisture they receive by being immersed in the clouds (Pounds et al. 1999). The habitats they require will shift up the slopes of mountains, forcing species into increasingly smaller areas (Hansen et al. 2003). In East Maui, Hawaii, the steep microclimatic gradients combined with increases in interannual variability in precipitation and hurricanes are expected to cause replacement of endemic biota by non-native plants and animals (Loope and Giambelluca 1998).

Tropical dry forests are very sensitive to changes in rainfall, which can affect vegetation productivity and plant survival (Hulme 2005, Miles 2006). Studies conducted in Tanzania and Costa Rica show that tropical dry forests may be particularly sensitive to life zone shifts under climate change (Mwakifwamba and Mwakasonda 2001, Enquist 2002). A slight annual decrease in 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 lead eventually to a decrease of fires due to the reduction of fuelbeds over time (Goldammer and Price 1998, Hansen et al. 2003).

Tropical mangroves are also highly 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 of sediment accumulation, which is necessary for the survival of mangroves, and erosion will reduce the size of mangroves (Hansen et al. 2003). Mangroves may be affected by other atmospheric changes as well, including temperature, increased carbon dioxide, and storms.

The vulnerability of tropical forests is also increased by non climatic pressures, such as forest conversion and fragmentation. In the Amazon, the interactions between agricultural expansion, forest fires, and climate change could accelerate the degradation process (Nepstad et al. 2008). The ability of species to migrate will be limited by forest fragmentation, and their ability to colonise new areas will be affected by invasive species (Fischlin et al. 2007). Climate change could be the biggest cause of increased extinction rates in tropical forests (Fischlin et al. 2007), exacerbated by the continued loss of forest cover and forest degradation.

However, many dimensions of the vulnerability of tropical rainforests remain uncertain (Morgan et al. 2001, Wright 2005). Integrated research about these various drivers and their interactions is lacking, particularly in the tropics, which impedes the assessment of climate change impacts and vulnerabilities.

2.2.2 Subtropical Forests

Many subtropical forests regularly experience high temperatures and extended droughts, making them particularly susceptible to forest fires. Greater fire frequencies have already been observed in the Mediterranean basin (Fischlin et al. 2009). According to the IPCC Fourth Assessment Report, drought stress has affected vegetation and reduced gross primary production by as much as 30% in southern Europe, resulting in a net carbon source, particularly during the heat wave of 2003 (Fischlin et al. 2007).

Under climate scenarios in the growth cluster, subtropical forests are projected to experience higher evapotranspiration and lower rainfall. Productivity in most subtropical forests is projected to decrease under a wide range of climate-change scenarios due to increases in temperatures above physiological optimum (Fischlin et al. 2009). Higher temperatures and longer droughts are likely to increase vegetation flammability, leading to more frequent forest fires. However, contrary to the pattern expected in boreal and temperate forests, fire frequencies may reach saturation after an initial stage, or may even diminish when conditions become so dry that decreased production leads to less fuel accumulation (Fischlin et al. 2009). Under more frequent disturbance, especially fire and drought, carbon stocks are expected to be greatly reduced (Bond et al. 2005).

The subtropics contain some of the most prominent biodiversity hotspots in Latin America, Australia, and South Africa. These biodiversity hotspots are highly sensitive to changing climatic conditions under a wide range of climate-change scenarios. Projections suggest that 40% of biodiversity in subtropical forests could be lost even under climate scenarios in the stable cluster (Fischlin et al. 2009). Many subtropical forest species exist in highly fragmented environments and are at particular risk of extinction, with subsequent negative impacts on the livelihoods of forest-dependent people.

2.2.3 Temperate Forests

There is no evidence yet of widespread change in temperate forest types (Fischlin et al. 2007), although local changes have been reported in southern Switzerland (Walther 2000) and in British Columbia (Hebda 2008), and tree lines have advanced in alpine areas (Kullman 2001, Danby and Hik 2007). Lack of major change in temperate forest types should not be surprising, however, as trees in temperate regions are long-lived and most are slow-growing. Physiological responses to warmer temperatures have been observed in trees, including longer growing season (Menzel and Fabrian 1999, Piao et al. 2007) and higher production (Boisvenue and Running 2006, Martinez-Vilalta et al. 2008), except where moisture limitation occurs.

Largely based on Sitch et al. (2003), Fischlin et al. (2007) reported broad temperate forest decline and forest type change under the growth (+3.8°C) climate change scenarios. Whereas under the stable (+2°C) scenario, Fischlin et al. (2007) reported relatively less decline, but still considerable forest change was predicted. These conclusions are broadly supported in the literature for all forested continents (Sykes and Prentice 1996, Bugmann 1997, Iverson and Prassad 2002, del Rio et al. 2005, Goldblum and Rigg 2005, Frumhoff et al. 2007, Kellomäki et al. 2008).

The three main disturbances in temperate forests include fire, wind, and herbivory (Frelich 2002), along with various pathogens. These will all change in severity, frequency, and in their interactions with climate change (Meehl et al. 2007). Where fire is a factor, it is expected to increase (Cary 2002, Garzon et al. 2008). Temperate forests will also be affected by an increased number of invasive species (Ward and Masters 2007).

Broad range changes in tree species and novel forest types can be expected during the next 70–100 years in temperate forests (Sitch et al. 2003, Fischlin et al. 2007, 2009). Temperate forest communities will change; species will migrate pole-ward, up mountains, or be replaced by grasslands and savannahs in drier areas, including areas of the Mediterranean zone (Sykes and Prentice 1996, Bugmann 1997, Iverson and Prassad 2002, Malcolm et al. 2002, del Rio et al. 2005, Fei and Sen 2005, Goldblum and Rigg 2005, Frumhoff et al. 2007, Keinast et al. 2007, Garzon et al. 2008, Koca et al. 2008, Martinez-Vilalta et al. 2008, Fischlin et al. 2009) and in North America (Hamann and Wang 2006, McKenney et al. 2007). High uncertainty is associated with these predictions owing to interactions among increased fire, invasive species, pathogens, and storms (Dale et al. 2001).

Marked species migration and novel ecosystem development is also likely under climate change in temperate forests. There is concern that climate change may exceed the capacity of species with heavy seeds (such as *Quercus* spp.) to migrate (Malcolm et al. 2002). Original forest species communities are unlikely to reassemble owing to differential species migration capacity and responses to disturbances, and anthropogenically altered landscapes. Migration of species to surrogate habitats may be impeded by the fragmentation of temperate forest landscapes owing to 20th century anthropogenic activity, as well as natural barriers (e.g., mountain ranges, lakes, and seas).

Some research suggests increased productivity in temperate forests in response to climate change (Joyce and Nungesser 2000, Parry 2000) as moderated by moisture, and driven by nitrogen levels (Magnani et al. 2007) and soil type (Rasmussen et al. 2008). While nitrogen and CO_2 levels may fertilise these systems (Milne and van Oijen 2005), any net positive effects in total carbon sequestration may be lost through increased soil respiration or drought (Gough et al. 2008, Noormets et al. 2008, Piao et al. 2008). Under growth scenarios, there is likely to be reductions in carbon sequestration owing to high system respiration and reduced production (Sitch et al. 2003).

2.2.4 Boreal Forests

Current marginal expansion of the boreal forest northwards has been reported, consistent with predictions (Lloyd 2005, Caccianga and Payette 2007, Soja et al. 2007, Devi et al. 2008, MacDonald et al. 2008), but expansion may be slower than expected because of poor soils, fires, and oceanic cooling effects (MacDonald et al. 2008, Payette et al. 2008). The growing season has lengthened (Soja et al. 2007, Kellomäki et al. 2008), and increased growth has been found for some species (Briffa et al. 2008). For other species, temperature threshold effects and important interactions with moisture may occur and affect individual species responses to climate change (Brooks et al. 1998, Wilmking et al. 2004, Kellomäki et al. 2008). Fire was predicted to increase (Flannigan et al. 1998) and has been confirmed in North America and Russia (Gillett et al. 2004, Soja et al. 2007). Warming climate has been implicated as a cause for extensive outbreaks of mountain pine beetle (*Dendroctonus ponderosae*) in western Canada and the USA (Taylor et al. 2006), and of spruce beetle (*Dendroctonus rufipennis*) in Alaska and northwestern Canada (Berg et al. 2006).

The boreal biome is expected to warm more than other forest biomes (Christensen et al. 2007). Under both growth and stable climate change scenarios, Fischlin et al. (2007) and Sitch et al. (2003) reported predicted broad gains northward for boreal forests, although with conversion to temperate forests and grasslands at southern and central areas of Canada and Russia. This is supported in Price and Scott (2006) for Canada, where the biome is expected to increase in area under the growth scenario. Kellomäki et al. (2008) modelled a 44% increase in production from the boreal biome in Finland under the growth scenario.

Soja et al. (2007) summarised published predicted changes for the boreal forest as: increased fire, increased infestation, northward expansion, and altered stand composition and structure. To that list we add less old-growth forest and conversion of southern-central dry forests to grasslands (Thompson et al. 1998, Price and Scott 2006). Flannigan et al. (2005) suggests that the area of boreal forests burned in Canada may increase by 74–118% by the end of this century, depending on scenario, but also depending on the frequency of drought years (Fauria and Johnson 2008). Other estimates suggest increases of more than five times current levels in some areas under growth climate change scenarios (Balshi et al. 2008).

Levels of infestation are uncertain but expected to rise owing to drought and warm conditions (Ward and Masters 2007, Fischlin et al. 2009). The tree line should continue to shift northwards, but new communities may develop owing to differential response capacity among species (MacDonald et al. 2008). Other threats include the potential for severe insect infestation, and loss of forest cover in southern areas in response to drought and fire.

The estimated total carbon stored in boreal forests is much higher than previously thought and, depending on how the accounting is done, is likely in the range of 25–33% of the total global carbon (Bhatti et al. 2003, Bradshaw et al. 2009), much of it as peat. Climate change may result in increased emission of greenhouse gases through fire and decomposition (Kurz et al. 2008). Greenhouse gases emitted from all Canadian forest fires are estimated to increase from 162 Tg/year of CO_2 equivalent in the $1xCO_2$ scenario to 313 Tg/year of CO_2 equivalent in the $3xCO_2$ scenario, including contributions from CO_2, CH_4, and N_2O (nitrous oxide) (Amiro et al. 2009). While productivity is expected to rise, net carbon losses are likely to occur owing to increased disturbances and higher respiration (Kurz et al. 2008), depending to a large degree on rates of disturbance and forest management actions (Chen et al. 2008).

2.3 Adaptation for Forests and Forest-Dependent People

In the context of changing economic, social, and global political environments, adaptation to climate change adds new challenges to forest stakeholders (defined as people who depend directly on forests or participate in their management, such as forest communities, forest managers and companies, conservationists, forest policy makers, development organisations, and scientists). The need to include adaptation into forest management and policies is becoming increasingly recognised by these stakeholders, especially in temperate and boreal areas. In particular, forest stakeholders face challenges related to understanding vulnerability, identifying adaptation options, and implementing adaptation.

2.3.1 Understanding Vulnerability

Understanding the vulnerability of forests and forest-dependent people is a first step towards designing effective adaptation. Vulnerability assessments include analysing the determinants of vulnerability and prioritising interventions for reducing the vulnerability of forests and forest-dependent people. Two main approaches to vulnerability assessments are generally applied to social-ecological systems: “impact-based approaches” (or impact studies) and “vulnerability-based approaches.” Impact-based approaches start with assessing the potential impacts of climate change on forest or forest people under different climate scenarios. Vulnerability-based approaches start with assessing social sensitivity and adaptive capacity to respond to stresses and, if necessary, combine this information with impact studies (Kelly and Adger 2000). With vulnerability-based approaches, vulnerability is determined by the existing capacity rather than by any predicted future impacts (Ribot 2009).

For understanding forest vulnerability, many impact studies are available at global or continental scales (e.g., Scholze et al. 2006). However, the coarse resolution of these studies limits their usefulness for informing decisions on adaptation measures at a local scale. Impact studies can facilitate decision-making if they are conducted at a relevant scale (e.g., national or sub-national) and if they assess uncertainties (e.g., by considering several climate scenarios) (see Box 2.2). It is also important for impact studies to address the factors that enhance or limit the adaptive capacity of forests, such as the process of species migration and the role of landscape connectivity in adaptation (Pearson 2006).

To facilitate adaptation processes for forest-dependent people, vulnerability-based approaches seem more adequate than impact studies (Burton et al. 2002). Most impact-based approaches have failed to facilitate social adaptation processes because the future of both climate and societies is uncertain, because climate scenarios do not necessarily capture the local climatic specificities and relevant variables for local people (e.g., extreme climatic events), and because impact studies operate at a time horizon much further than the ones relevant for people and decision-makers (Mitchell and Hulme 1999, Burton et al. 2002). Some authors argue that vulnerability-based approaches are more likely to identify policy-relevant recommendations for social adaptation because they address immediate needs and are consistent with a precautionary approach to climate change. Reducing social vulnerability to current stresses should help people adapt to the future climate whatever the future will be (Heltberg et al. 2009).

Impact-based and vulnerability-based approaches are complementary in the process of planning the adaptation of forests and forest communities. If attention is paid only to reducing current vulnerability in general, the conclusions could easily lead to recommendations related to a conventional development approach (e.g., with more education and equity, more stable and diversified livelihoods, or better infrastructure) without addressing future climate risks. While reducing vulnerability to current exposures is relevant, it may not be sufficient for addressing future risks (Lim and Spanger-Siegfried 2005). Impact studies give insights into the potential risks that forests would face in the future and to which societies should be empowered to adapt.

Some issues are important to consider when assessing vulnerability. First, cross-scale issues are crucial. Adaptation is fundamentally local (Adger et al. 2005a, Agrawal and Perrin 2008), but is influenced by factors from higher scales (e.g., national policies or management at the landscape scale). Assessing the vulnerability of forests and forest-dependent people therefore requires that such cross-scale factors be taken into account. Second, time horizons must be relevant for the decision to be taken (e.g., long term for a long rotation plantation, or more short term for local social adaptation) (Füssel 2007). Third, as the vulnerability of forest people to climate change

Box 2.2 Using future tree suitability projections for adaptation

Trevor Murdock

Favouring the establishment of tree species that will be suited to future climate is an important adaptive response (see Section 2.3). It is challenging to make use of projected future forest impacts in vulnerability assessments because of large uncertainties. The case study in this box illustrates how uncertain projections may be used for adaptation in a temperate forest setting. The example is for spruce in British Columbia, Canada.

The resolution (~350 km × 350 km) of GCM (Global Circulation Model) projections is too coarse for assessing impacts in British Columbia due to large climatic gradients over small distances. Simple empirical downscaling to high resolution (~4 km × 4 km) was performed by applying projected climate change from GCMs to high resolution historical climatology (Wang et al. 2006). Tree species suitability was approximated using climate envelope techniques (Murdock and Flower 2009).

The difference in projected suitability between climate scenarios in the "growth" and "stable" emissions clusters is considerable. With higher emissions (A2), much of the current spruce distribution becomes unsuitable (see figure, left), but with lower emissions (B1), there is little change (see figure, centre). Also, because future emissions are unknown, it is uncertain which of these projections should be used for adaptation. Additional uncertainty arises from differences in GCMs. The range in projected annual temperature and precipitation changes over British Columbia from five GCMs is +1.8 to 2.6°C and +2 to 11% for A2, and +1.7 to 1.9°C and +6 to 8% for B1.

For adaptation, a set of policies is needed (Section 2.3). Projected impacts may inform these policies if uncertainty is quantified. For example, the percentage of projections that indicate spruce suitability in the future is shown in the figure (right). This illustrates the level of (dis)-agreement among the different GCMs and emissions. Thus, in areas that are projected to become unsuitable for most or all cases (dark brown), there is a strong indication to favour species other than spruce as part of an adaptation strategy. Where there is low agreement (light/grey), other factors may be relatively more important to planting decisions and a more complex set of adaptation strategies may be required

Figure 2.3 Projected spruce suitability for 2080s in British Columbia: (left) Average for "growth" (A2) scenarios from five GCMs. Light green areas were suitable in both 1961–1990 and in the 2080s, dark green areas become suitable, and dark brown areas lose suitability by 2080s (centre); same for "stable" scenarios (B1). The frame on the right shows the percent of projections from a combined set of ten GCMs following both growth and stable scenarios; dark green indicates agreement between models that the climate will be suitable and brown that it will not be suitable. Reprinted with the permission of Pacific Climate Impacts Consortium.

depends on the state of their forests, and the vulnerability of forests depends on the people's decisions, vulnerability assessment should integrate social and biophysical dimensions and be interdisciplinary (see Box 2.3). Fourth, the participation of forest stakeholders is essential in vulnerability assessments. Vulnerability assessments performed only by scientists are likely to fail to facilitate adaptation processes (Füssel 2007) because stakeholders involved in vulnerability assessment are more likely to participate in adaptation planning and implementation. Participatory vulnerability assessments are a way to engage stakeholders into a process of adaptation and, therefore, can be a means as well as an end. Participation can also help to integrate different views on vulnerability, especially the perception of local indigenous

Box 2.3 Vulnerability assessment of Chilean forests and landowners

Carlos Bahamondez

This case study aimed at assessing the vulnerability of forests and forest landowners to climate change. It adopted the IPCC definition of vulnerability and the approach to vulnerability assessment proposed by Luers et al. (2003). This approach enables differentiating between different types of forest owners, technological developments, and geographical locations. For assessing the impact of climate change on forest productivity, especially the impact of changes in day-time high (maximum) and night-time low (minimum) annual mean temperatures, we applied the ecophysiological model 3PG (Physiological Principles Predicting Growth) (Landsberg et al. 2001). Two forest plantation species were studied (*Eucalyptus* spp. and *Pinus radiata*) under four main management regimes and two types of landowners (small and large). We created vulnerability maps based on spatial distance inverse interpolation method with the A2 climatic scenario downscaled at 25 km by 25 km by PRECIS (Providing Regional Climate for Impact Studies) (Universidad de Chile 2007). Results showed the negative impacts of climate change on plantations productivity, highlighting the current needs for adaptation measures, especially genetic. Results also showed that small landowners are more vulnerable than large landowners due to their low technological development (Bahamondez et al. 2008).

people and their knowledge on adaptation (Vedwan and Rhoades 2001, Deressa et al. 2009).

In a perspective of implementing adaptation, vulnerability assessments and impact studies also contribute to raising awareness about the need for adaptation. There is often the lack of a sense of urgency among forest stakeholders because the effects of climate change are assumed to be gradual (Chapin et al. 2004). Even when stakeholders are well-aware that climate change is happening, they may not see an immediate need to develop adaptation strategies. For instance, in boreal countries, Roberts et al. (2009) reported little evidence of adaptation policies for forests and noted that Finland suggested that a long lead time will be required for any adaptation program. Ogden and Innes (2007a) found that economic conditions, timber supply, trade policy, and environmental regulations had a greater influence on perceptions of sustainability among forest resource users than did climate change. However, as highlighted by Innes et al. (2009), a laissez-faire attitude to forest management under climate change is not an option because the natural resilience of forest stands is likely to be exceeded globally by 2100. That time scale is well within the life spans of trees planted now in boreal regions.

Nevertheless, some governments have recognised science-based predictions for changes in forests and have identified a need for adaptive action. For instance, in boreal regions, socio-economic impacts, such as changes in timber supply, loss of forest stock and non-market goods, altered land values, social stress from economic restructuring, and effects on protected areas have been recognised (e.g., Natural Resources Canada 2004). While the implications of climate change are anticipated, there is a high level of uncertainty that affects the capacity of decision-makers to act. For example, Price and Scott (2006) found a lack of concordance among models and scenarios in their predictions of future forest vegetation communities.

Uncertainty should not be a reason for inaction (Dessai and Hulme 2004). Better handling of uncertainties in decision-making is essential for improving adaptation policies and practices because uncertainties are inherent to climate change adaptation. Approaches exist that provide flexibility to adjust the course of action in accordance with the accumulating scientific knowledge and experience (see Section 2.3.3).

2.3.2 Identifying Adaptation Options

Adaptation measures for forests have been proposed, particularly for temperate and boreal forests (e.g., Noss 2001, Hansen et al. 2003, Spittlehouse and Stewart 2003, Fischlin et al. 2007, Millar et al. 2007, Guariguata et al. 2008, Ogden and Innes 2008). Regarding adaptation in general, Smithers and Smit (1997) distinguish two broad kinds of adaptation measures: measures that aim to buffer a system from perturbations by increasing its resistance and resilience[1] to change, and measures that facilitate a shift or an evolution of the system towards a new state that meets altered conditions (see Figure 2.4).

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[1] 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).

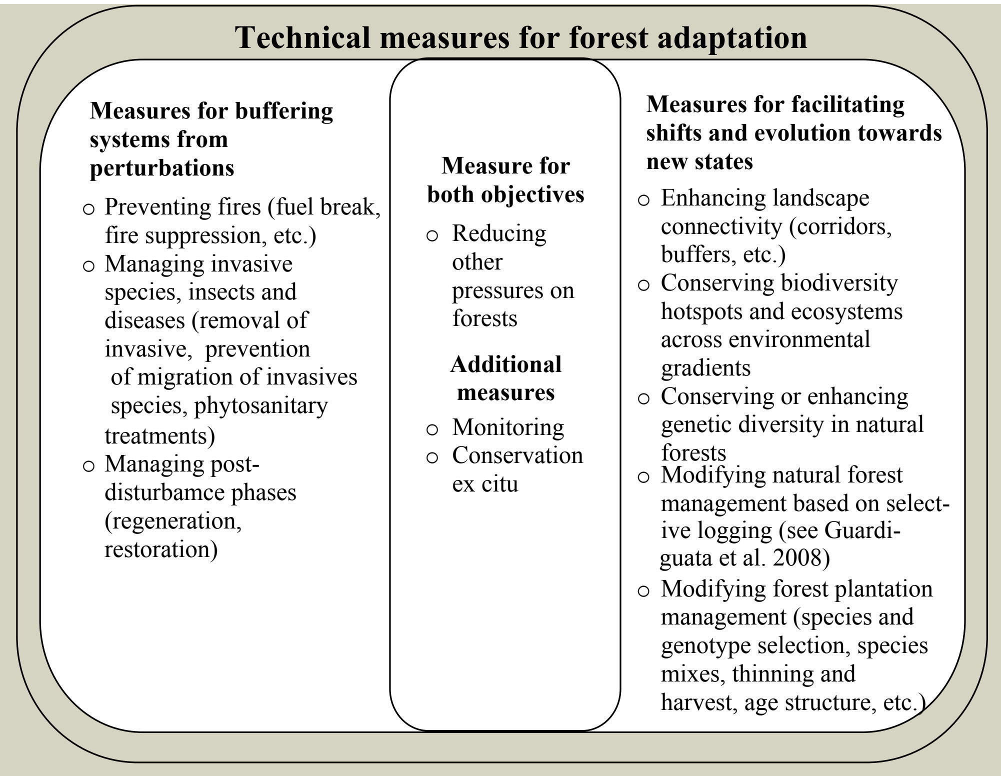

Figure 2.4 Examples of technical measures for forest adaptation (Locatelli et al. 2008).

In the case of forests, some buffering measures focus on preventing perturbations, such as fire (managing fuel, suppressing or controlling fires), invasive species (preventing or removing invasive species), and insects and diseases (applying phytosanitary treatments). Other buffering measures include managing the forest actively after a perturbation; for instance, favouring the establishment of adapted and acceptable species.

Buffering measures that try to conserve forests in their current or past state are not a panacea. Such measures may only be effective over a short term and will eventually fail with increasing changes in environmental conditions. Furthermore, there are high costs associated with these measures due to the intensive management required for implementation. For the above mentioned reasons, these measures should be applied to high value forests (e.g., high priority conservation forests for biodiversity) or to forests with low sensitivity to climate change (Millar et al. 2007).

Measures that facilitate a shift or evolution of a system do not aim to resist changes, but rather to ease and manage natural adaptation processes. The resilience of the ecosystem is crucial, not necessarily to keep the ecosystem in the same state after a disturbance, but to help it evolve towards a state that is acceptable for the manager or the society. An example of facilitating measures is the reduction of landscape fragmentation. This is because connectivity between habitats eases species migration; corridors established in the direction of the climate gradient could help forests to adapt (Noss 2001). Another facilitating measure consists of conserving a large spectrum of forest types for their value and their possible higher resilience (Noss 2001); for instance, ecosystems across environmental gradients or biodiversity hotspots. As genetic diversity is a key element of the adaptive capacity of an ecosystem, some authors propose measures for maintaining or enhancing it in managed forests (Guariguata et al. 2008). For forest plantations, management can be modified to adapt to climate change, for example, by adopting species and genotypes that are adapted to future climates, planting mixed species and uneven age structure, or by changing rotation length (Guariguata et al. 2008).

Measures that reduce non-climatic pressures, such as forest conversion, fragmentation, and degradation, can contribute to both buffering and facilitating (Noss 2001, Hansen et al. 2003, Malhi et al. 2008). Climate change adds to other stresses, some of which are currently more pressing than the climate; for example, forest conversion in the tropics. If non-climatic threats are not addressed, adaptation to climate change may be irrelevant or purely academic (Markham 1996). In places where threats to forest sustainability are mostly non-climatic (e.g., land-use conversion, overharvesting), implementing forest conservation or sustainable forest management is essential for reducing the vulnerability of forests and is an important first step towards forest adaptation.

Bruno Locatelli

Photo 2.1 Climate change is likely to have negative effects on forest-dependent communities, particularly in developing countries, where these communities lack adaptive capacity because of poverty, marginalisation, and location far from the centres of power (Sandrakatsy, Madagascar).

In places where forest conservation and sustainable management are already being implemented, specific adaptation measures can be incorporated into those practices.

The uncertainties about climate change and forest vulnerability intensify the need for flexible and diverse approaches that combine measures selected from an adaptation toolbox, or a list of possible measures (Millar et al. 2007). Selecting a limited number of measures is relevant for systems with less complexity (e.g., monoculture plantations) and exposed to clear trends in climate change. However, in most cases, a high degree of uncertainty will justify selecting a portfolio of measures to reduce the risk of choosing one or just a few inadequate measures.

2.3.3 Implementing Forest Adaptation

Implementing forest adaptation at the local scale should not start from scratch but be built on previous experiences. In various contexts over the last decade, researchers have been experimenting with approaches that emphasise collaborative and adaptive management, and that are relevant for forest adaptation (e.g., Buck et al. 2001, Tompkins and Adger 2004, Colfer 2005, Armitage et al. 2008). These approaches are compatible with the sustainable forest management (SFM) framework, which should guide the implementation of adaptation for forests and forest-dependent people.

Focus on Local Specifics

A challenge in the implementation of forest adaptation comes from geographical and human diversity. The need to pay attention to local specifics has become increasingly obvious because adaptation processes should be adjusted to the local ecological or social contexts (Agrawal 2008). However, attention to local variation is typically seen as too difficult, too costly, or impractical. Institutional changes are needed to allow building adaptation at the local level, rather than trying to make broad-scale plans. A number of institutional challenges need to be overcome in order to successfully address adaptation in populated forests; for example, increasing local ownership and access to forests, and building institutional responsibility for adaptation (Macqueen and Vermeulen 2006). Agrawal (2008) emphasises the importance of assessing and strengthening local institutions, and developing locally appropriate solutions.

Adaptation must be based on local practices and knowledge. Many forest communities have a detailed knowledge of their environment, and have developed strategies for adapting to interannual and longer-term climate variability (Roberts et al. 2009). Even if unprecedented rates of changes may challenge this knowledge and the capacity of learning and developing new strategies, local knowledge systems should be integral to local adaptation plans (Innes et al. 2009).

Further, while adaptation will be about managing local problems, it is also a national issue and so requires collaboration at multiple levels and across sectors (Ogden and Innes 2007b). Local adaptation is affected by institutions that operate on a regional, national, or global level. Because the adaptive capacity of a local system can be weakened by inappropriate policies and programs (Herrmann and Hutchinson 2005), policy-makers at different levels need to develop mechanisms that allow people to adapt their own systems more effectively as the climate changes.

Collaborative Adaptation

Forest stakeholders have a central role to play in forest adaptation because they manage forests and depend directly on them. The projected environmental impacts of climate change on forests will have far-reaching social and economic consequences on forest-dependent people (e.g., forest communities) and sectors (e.g., forest sectors). For forest sectors, many studies have projected a global increase in the supply of timber, but the trends are not homogeneous among regions (Osman-Elasha and Parrotta 2009).

Many communities in both developed and developing countries are sensitive to changes in forests because they depend on forests products for their livelihoods, food security, and health, especially non-timber forest products (e.g., medicinal plants). Drawing on traditions from First Nations and settler communities in Canada, for example, many subsistence harvesters collect non-timber forest products (NTFPs) for food (Duchesne and Wetzel 2002). In an analysis of seven studies conducted in Latin America, around 35% of the incomes of indigenous communities were found to come from forest products (Vedeld et al. 2004). Changes in the provision of forest goods and services induced by climate change could affect forest communities. In many places, particularly in developing countries, forest-dependent communities lack adaptive capacity because of poverty, marginalisation, and location far from the centres of power (Ribot 2009).

An important component of, and challenge for, forest adaptation is determining roles and responsibilities in adaptation. The forest industry, various levels of government, and local and indigenous communities will all need to adjust their activities to adapt to the effects of climate change on forests. Among these groups, differing perceptions of risk and levels of responsibilities may create barriers in the negotiating and decision-making processes for adaptation. For example, conflicting priorities and mandates could lead to future problems that will have to be resolved before formal adaptation policies can be developed and acted on (Natural Resources Canada 2004). Resolution of these kinds of problems will also require behavioural changes (Krankina et al. 1997).

Adaptive Management

Implementing forest adaptation often means thinking in the context of adaptive management; this may be a challenge. Forest adaptive management is defined as "a dynamic approach to forest management in which the effects of treatments and decisions are continually monitored and used, along with research results, to modify management on a continuing basis to ensure that objectives are being met" (Helms 1998). Adaptive management is a systematic process for improving policies and practices that can be used by forest stakeholders to adjust their activities as they progressively learn while the environment is changing (Innes et al. 2009). Adaptive management enables stakeholders to face the challenges of complexity and uncertainty related to climate adaptation (Arvai et al. 2006, Roberts et al. 2009).

Forest stakeholders can implement different adaptation measures and observe the outcomes. As monitoring must be in place to enable reflecting and making new decisions, sets of criteria and indicators for monitoring forest management and human well-being (e.g. Prabhu et al. 1996, 1998) could be applied to forest adaptation. Within the framework of adaptive management, science and local knowledge systems play an important role for understanding forest dynamics and the effects of the actions carried out (Innes et al. 2009).

Sustainable Forest Management

Sustainable forest management (SFM) can provide an effective framework for addressing forest adaptation in an integrated manner. A widely agreed definition of SFM is "a dynamic and evolving concept aiming to maintain and enhance the economic, social, and environmental values of all types of forests for the benefit of present and future generations"[2]. The specific management practices and policies for SFM largely depend on the specific ecological and socio-

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[2] General Assembly of the United Nations, resolution 62/98 adopted in December 2007

Box 2.4 Adaptation for forests in the NCs and NAPAs

Many NCs and NAPAs identify management and policy measures for adapting forests to climate change (Roberts 2008). Although such measures may not be aimed solely at adapting to climate change, some include:

- Afforestation, reforestation, and forest restoration with species suited to the future climate (e.g., NC India, Sierra Leone), with short rotation species and management practices that enhance forest resilience (e.g., NC India) or with fast-growing tree species resistant to possible disturbances, such as insect, disease, and fire (e.g., NAPA Bhutan, Burundi, Eritrea, Samoa, Tanzania; NC Sierra Leone).
- Changes in forest species and composition (e.g., NC Austria, Belgium, Belarus, Finland, Slovenia), and promoting mixed species forests (e.g., NC Bulgaria, Czech Republic, France).
- Changes in thinning and harvesting patterns and techniques (e.g., NC Bulgaria, Spain, Canada, China, Finland, Sweden).
- Community-based forest management and forestation (e.g., NAPA Bhutan, Ethiopia, Cambodia, Tanzania, Zambia; NC Fiji, Nepal, Rwanda, Sierra Leone).
- Forest conservation in the form of Sustainable Forest Management and formal protection areas (e.g., NAPA Djibouti, D.R. Congo, Guinea, Guinea-Bissau, Senegal, Samoa, Tanzania; NC Brazil, Cameroon, India, Nepal, Rwanda), and the establishment of forest corridors (e.g., NC Belgium, China, Poland, Sweden, Switzerland).
- Near-nature forest management (e.g., NC Austria, Denmark, Switzerland, and Ukraine).
- Genetic management: seed selection or maintenance of genetic diversity (e.g., NC China, Bulgaria, France, Spain, Ukraine, Uruguay).
- Monitoring and management of disturbances: fires, pests, and diseases (e.g., NC Bulgaria, Canada, France, Ukraine, Switzerland).
- Mapping and risk assessment as an important aspect of adapting to climate change (e.g., NC Australia, France, New Zealand).

economic context; nevertheless, it can be argued that adaptive management practices and policies that promote SFM principles are essential for reducing the vulnerability of forest ecosystems (Seppälä et al. 2009). In many developing countries, failure to manage forests sustainability reduces the capacity of forests to provide ecosystem services to forest-dependent societies in the long term. In these cases, the potential of SFM to enhance the adaptive capacity of both forests and people remains unused.

SFM practices adopt a holistic approach to forest management, including social, economic, and environmental goals. The seven thematic areas of SFM, as defined by the United Nations Forum on Forests (UNFF 2004), are similar to the main elements that should be considered in adaptation plans: extent of forest resources; biological diversity; forest health and vitality; productive functions of forest resources; protective functions of forest resources; socio-economic functions; and the legal, policy, and institutional framework. Adaptation to climate change can thus be incorporated into the thematic areas of SFM as an additional goal (Glück et al. 2009), or SFM practices can be implemented with an adaptive management approach (Innes et al. 2009).

Existing Forest Adaptation Policies

In many countries, adaptation policies are increasingly addressing the need for adapting forests to climate change. Roberts (2008) reviewed the forest management measures proposed in the National Communications (NC) and National Adaptation Programmes of Actions (NAPA) produced for the United Nations Framework Convention on Climate Change (UNFCCC) (see Box 2.4). In the tropical domain, community-based forest management and forestation are proposed in several NCs and NAPAs. In the subtropical domains, such adaptation measures propose the establishment of corridors for facilitating species migration, the reduction of perturbations, and additional management options related to mixed species forests and genetic selection. In the temperate and boreal domains, the NCs include measures for increasing the stability of forests in the face of climate change (e.g., near-natural forest management with mixed forests in terms of species and age classes), reducing disturbances (e.g., fire and pest management), and facilitating adaptation (e.g., establishment of corridors for migration) (Roberts et al. 2009).

In most countries, these adaptation measures are based on existing forest policies that aim for sustainable forest management rather than adaptation, which is relevant in places where SFM must be in place before adaptation can be addressed. The proposed policy instruments include a wide array of regulatory, economic, and informational instruments (see Roberts 2008). However, little information is available on the actual implementation of these instruments and their effects. Even though NCs and NAPAs propose adaptation measures, forest adaptation is still far from being implemented and mainstreamed into decision-making.

One concern related to the proposed adaptation policies comes from the limited applicability and success of some of the proposed instruments. Regulatory approaches have shown success in the implementation of principles of SFM mainly in temperate and boreal forests in developed countries (Roberts 2008). But their success in other regions is limited due to the lack of policy implementation and enforcement in the often weak political and institutional context of developing countries. Additionally, linkages are rarely made between these policies and other ongoing political processes and issues of high political relevance, such as land tenure reforms, property rights, and access to natural resources (Locatelli et al. 2008). This is especially important because rights to and ownership of natural resources are considered key features for forest governance and social adaptation (Agrawal et al. 2008).

2.4 Forests and Adaptation in a Broader Context

Forests provide ecosystem services that contribute to reducing the vulnerability of sectors and to society beyond the forestry sector. This broad perspective on the role of forests represents an opportunity for achieving better management or conservation of forests with the involvement of different sectors concerned with adaptation.

2.4.1 Forests Contribute to the Adaptation of Societies

Forests provide essential services across all scales, from local communities to the world. Forests contribute to reducing the vulnerability of society to climate change. The Millennium Ecosystem Assessment (2003) defines ecosystem services as the benefits people obtain from ecosystems. Three types of services directly contribute to human well-being: *provisioning services* (also called ecosystem goods), such as food and fuel; *regulating services*, such as regulation of water, climate, or erosion; and *cultural services*, such as recreational, spiritual, or religious services. In addition to these, *supporting services* represent a fourth type of service and include the services that are necessary for the production of other services, such as primary production, nutrient cycling, and soil formation (see Figure 2.5).

Ecosystem services influence all components of human well-being presented in Figure 2.5 (Millennium Ecosystem Assessment 2005). Ecosystem services increase the security of people, for example, because of the protective role played by regulating services, which provide a buffer against natural disasters (e.g., floods, violent storms, landslides). Ecosystem services are directly linked to the basic materials for a good life, such as income, food security, and water availability (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 are dependent on ecosystems through the ability to realise aesthetic and recreational activities, and express cultural values where they are linked to various habitats or species (Levy et al. 2005). Ecosystem services are also linked to freedom of choice, e.g., the ability to decide on the kind of life to lead. For example, the degradation of hydrological services or fuelwood resources can increase the time spent by local communities to collect water and energy sources, resulting in less time for education, employment, or leisure (Levy et al. 2005).

Forest ecosystem services contribute to reducing the vulnerability of society beyond the forests. Forest regulating services reduce the exposure of the society to climate-related extreme events: they can moderate the force of waves or wind (Adger et al. 2005b) and reduce temperatures during heat waves (Gill et al. 2007). Forest provisioning services can also provide safety nets to local populations, reducing their sensitivity to climate change. For instance, in Africa, many rural communities use non-timber forest products for direct consumption or for trading when agriculture or livestock is affected by climate events (Paavola 2008). In Costa Rica, current trends of higher rainfall intensity cause increasing concerns about erosion and siltation among hydroelectricity companies. Forest conservation in the watersheds upstream of the hydroelectric dams is seen as a measure to adapt to climate change (Vignola and Calvo 2008).

2.4.2 Forests and Ecosystem-Based Adaptation

Forest ecosystem services are threatened by various human-caused pressures other than climate change, such as land use change, landscape fragmentation, degradation of habitats, over-extraction of goods, pollution, nitrogen deposition, and invasive species. As these pose threats for people and economic sec-

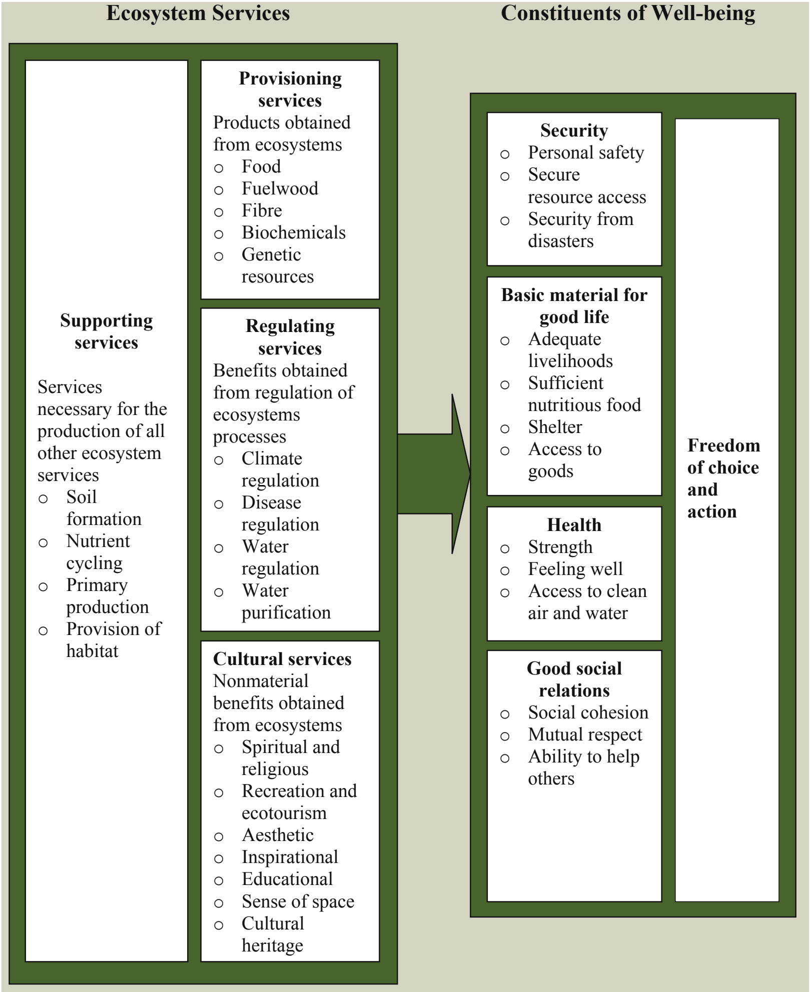

Figure 2.5 Example of ecosystem services and their links to human well-being (Locatelli 2008, adapted from Millennium Ecosystem Assessment 2005).

tors that depend on these services and that are vulnerable to climate change, forest conservation and management are an adaptation strategy.

The concept of Ecosystem-Based Adaptation (EBA) has recently emerged in the international arena on climate change adaptation, with proposals submitted by countries and non-governmental organisations to the UNFCCC in December 2008 (e.g., IUCN 2008) and 2009 (e.g., submissions by Brazil, Costa Rica, Panama, and Sri Lanka). EBA is a set of adaptation policies or measures that consider the role of ecosystem services in reducing the vulnerability of society to climate change in a multi-sectoral and multi-scale approach (Vignola et al. 2009). EBA policies and measures aim at reducing the vulnerability of ecosystems and their services to different threats (including climate change and land-use change). EBA can be cost-effective, sustainable, and generate environmental, social, economic, and cultural co-benefits (CBD 2009). According to the Economics of Ecosystems and Biodiversity (TEEB) study (2009), cost-benefit analyses indicate that public investment should support ecological infrastructure (forests, mangroves, wetlands, etc.) because of its contribution to adaptation to climate change.

EBA considers different kinds of ecosystems in landscapes, but forests have a primordial place in EBA because they are major providers of ecosystem services. For ensuring that forests will contribute to the adaptation of the broader society in the future, EBA aims to reduce current threats to ecosystem services (e.g., deforestation and forest degradation) by conserving forests or managing them sustainably. It also aims at reducing future threats by implementing adaptation to climate change. In this sense, EBA is an overarching framework to forest and adaptation in which "adaptation for forests" is needed to ensure the role of "forests for adaptation."

EBA can also aim at conserving specific forest ecosystem services that are crucial for societal adaptation, such as water-related services. Many forests are already managed for ensuring a reliable provision of clean water to the society, but management and priorities could be modified in the future in light of climate change. Forest management can evolve towards a better conservation of water in places where the population is particularly vulnerable to changes in water quantity or quality (Innes et al. 2009).

In addition to conserving ecosystem services through SFM and forest adaptation, EBA also deals with the use of forest ecosystem services for societal adaptation. This means, for instance, that access and rights to forest products are considered, and awareness is raised on the importance of forests for the adaptation of society. It means also that EBA links different sectors, especially sectors managing forests and sectors benefiting from forest ecosystem services. With EBA, sustainable forest management and forest adaptation are not only an issue for forest stakeholders, but for the whole society.

2.4.3 Forests for Adaptation: Challenges and Opportunities

Using forests for adaptation brings new challenges. A challenge comes from the need to understand and value the role of forest ecosystem services in the adaptation of society. This can be achieved by incorporating ecosystems and the users of ecosystem services into vulnerability assessments in order to achieve a deeper understanding of linkages and better targeting of adaptation responses. Such vulnerability assessments have been conducted by the ATEAM project[3] for assessing where people and sectors in Europe may be vulnerable to the loss of ecosystem services as a consequence of climate and land use changes (Metzger et al. 2005, 2006). The Research and Assessment Systems for Sustainability Program[4] developed a framework for assessing the vulnerability of coupled human-environment systems that focuses on the linkages between human and biophysical vulnerability (Turner et al. 2003).

Similar to vulnerability assessment, adaptation practices and policies should jointly consider the vulnerability of society and forests. Decision-making on adaptation can be integrative by combining forests and society, inclusive across scales and sectors, and participatory by incorporating different views and experiences (Tompkins and Adger 2004, Folke et al. 2005, Boyd 2008). Another challenge lies in the need to design cross-sectoral adaptation that considers sustainable forest management as an adaptation option in addition to technical and socioeconomic actions within one specific sector. For instance, a hydropower plant or a drinking water facility facing problems of siltation or water quality could participate in managing upstream forests instead of investing in technical filtration or treatment solutions. This means that adaptation strategies must be prioritised based on their effectiveness and efficiency, and their cross-sectoral effects, as adaptation based on forests may benefit many sectors. This poses a challenge in assessing adaptation strategies because economic valuations of EBA are lacking.

Using forests for adaptation will modify the costs and benefits of forest management. If the objective of providing ecosystem services to vulnerable sectors is added to the objectives of forest management, forest managers may face higher costs or lower benefits, while other sectors may receive benefits from ecosystem services (Glück et al. 2009). It means that EBA must include financial transfers from sectors benefiting from forests ecosystem services to sectors managing the forests. These financial transfers may help remove the financial barriers to SFM and forest adaptation in a cross-sectoral way, with payments for ecosystem services appearing as a natural instrument in addition to other instruments facilitating information sharing and technical assistance. The integration of forests in adaptation plans for other sectors could represent an opportunity for forest conservation because the role of ecosystem services would be recognised and, possibly, be rewarded by those benefiting from them.

So far, the importance of forests for the adaptation of society has not been adequately reflected in current policies. Even though there is growing awareness of the value of forest ecosystem services, adaptation policies and proposed projects tend to apply sectoral approaches; few decision-making processes incorporate forests into adaptation. In developing countries, where the links between livelihoods and forests are strong, several NAPAs consider forests as an adaptation measure. Most of them, however, propose forest projects for reducing the vulnerability of forest people rather than for the adaptation of the society beyond the forest (see Box 2.5). In addition, the role of forests in reducing social vulnerability is rarely explicit. The inclusion of forests in the NAPAs as an adaptation strategy is not surprising because it is recommended in the UNFCCC guidelines for the preparation of NAPAs (UNFCCC 2002). Neither is it a sign that forests are mainstreamed in decision-making processes on adaptation because many NAPAs are developed by experts in a marginal position vis-à-vis political decision making.

In theory, EBA represents an opportunity for achieving the dual purpose of better managing forests and facilitating sustainable processes of societal adaptation. In practice, EBA requires new modes of

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[3] Advanced Terrestrial Ecosystem Analysis and Modelling (Potsdam Institute for Climate Impact Research 2008)

[4] For more information see Harvard University web-page: http://sust.harvard.edu

Box 2.5 Forests for adaptation in the NAPAs

Jaime Webbe

Among the 41 NAPAs submitted as of 22 June 2009, all but four discuss forests within the framework of vulnerability or adaptation. Despite this, however, only 26 NAPAs identify priority projects specific to forests. Many of these projects refer to conservation, reforestation, and restoration as a tool to sustain local livelihoods and preserve or restore ecosystem services. For instance, the Tanzanian NAPA proposes tree plantations for improving the livelihoods of communities around Mount Kilimanjaro by providing alternative sources of income and food.

Forest-specific projects contained in NAPAs also include the expansion or establishment of forest protected areas, including in Djibouti, Mali, and Samoa. It is also worth noting the high proportion of forest adaptation projects with a community-based approach. In fact, 73% of NAPAs containing forest adaptation projects make explicit reference to community participation. For example, the Uganda NAPA includes a community tree-growing project, and the Madagascar NAPA prioritises a project for the transfer of the management of forests to the local level.

In addition to forest-specific projects, an additional nine NAPAs identify projects with elements related to forests. These include projects such as coastal protection in Mozambique and the Solomon islands that contain an activity on mangrove restoration. Other examples include agriculture promotion projects such as agroforestry in the Gambia, Sudan, and Vanuatu. Finally, in recognition of the value of forests in maintaining hydrological regimes, 12 different projects are listed with the main objective of basin management or flood control based on an integrated approach that includes forest-based adaptation. This includes a project in Rwanda for the conservation and protection of lands against erosion and floods at the district level that contains an activity for the reforestation of degraded lands.

local and national governance that include multi-sectoral processes, stakeholder participation, and flexible institutions, such as policy networks (or network governance) (Glück et al. 2009). EBA can also be facilitated by a better integration of international policies related to forests, climate change mitigation and adaptation, and biodiversity. For instance, a global mitigation mechanism such as REDD (Reduction of Emissions from Deforestation and Forest Degradation) has the potential to contribute to adaptation by improving local livelihoods, strengthening local institutions, and conserving ecosystem services. But REDD can also have negative effects on the adaptive capacity of local forest people by reducing their access to land and forest resources. Therefore, a better integration of policies for adaptation and mitigation in forests is necessary at the local, national, and international levels.

2.5 Conclusions

Many forests are likely to be affected by climate change and its associated disturbances, in combination with other drivers of global change. As a result, the forest sector and forest-dependent people in both developed and developing countries can be adversely affected. Adaptation to climate change in forests represents new challenges for forest stakeholders and decision-makers, in addition to current economic, social, and political challenges. These new challenges are related to assessing vulnerability, identifying adaptation measures, and implementing adaptation.

However, adaptation to climate change also represents opportunities for better management or conservation of forests because forests provide essential ecosystem services that contribute to reducing the vulnerability of the society beyond the forest. Ecosystem-based adaptation, an emerging approach to adaptation, represents several challenges related to linking different stakeholders (forest and non-forest related) and different scales (from local to national or international). However, this approach to adaptation may present opportunities for forest and forest-dependent people because it would recognise the role of forests in providing ecosystem services for the society and support the sustainable management and adaptation of forests.

Mainstreaming adaptation for forests and forests for adaptation requires new modes of governance, as traditional governance often fails to address the challenges of adaptation. National policies should promote forest adaptation into the framework of sustainable forest management, and promote intersectoral coordination for linking forest and other sectors in adaptation policies. International policies also have a role to play through better integration of processes related to forests, climate change adaptation and mitigation, and biodiversity.

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