4 Future Socio-Economic Impacts and Vulnerabilities

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Abstract: The projected impacts of climate change are significant, and despite the uncertainties associated with current climate and ecosystem model projections, the associated changes in the provision of forest ecosystem services are expected to be substantial in many parts of the world. These impacts will present significant social and economic challenges for affected communities and society as a whole, particularly among the forest-dependent poor, who are already highly vulnerable in many countries throughout the world. This chapter discusses how the likely effects of climate-induced changes on the provision of forest ecosystem services may affect the economic and social well-being of society, including forest-dependent people, with specific reference to the production of wood and non-wood products, hydrological regulation and water quality, human health and well-being, spiritual and cultural values, recreation and ecotourism. The role of governance is discussed as a key factor that will profoundly influence social and economic impacts and vulnerabilities, and the adaptive capacity of societies to deal with the effects of expected climate change-induced shifts in the quantity and quality of forest ecosystem services.

Keywords: climate change, socio-economic impacts and vulnerabilities, non-wood forest products, social resilience, forest-dependent, cultural services, traditional coping strategies, adaptive capacity and governance

4.1 Introduction

The expected impacts of climate change on forests and woodlands and their capacity to provide vital ecosystem services, as discussed in previous chapters of this report, will have far-reaching consequences for the well-being of people in affected areas. Modelling and analysis to date, as described in this chapter, has provided numerous insights for policy makers. As with any scientific endeavour, though, evaluations of the future socio-economic impacts and vulnerabilities of climate change are fraught with difficulties and uncertainties. As is widely recognized throughout the socio-economic literature, future projections of economic conditions are inherently uncertain. These uncertainties are compounded by the links economists make with the climate and ecological models that contain their own uncertainties, particularly when addressing impacts at subregional and local levels. These difficulties are compounded not only by the complexity of forest ecosystems and their responses to climate change, but also by the indirect nature of the links between provision of forest ecosystem services and human well-being.

Current projections of climate and ecological models indicate that forest productivity will increase over time in some regions (IPCC 2007, Fischlin et al. 2007), presenting new opportunities for forest industry and forest-dependent communities to capture economic benefits associated with these changes. In many other regions these same projections suggest significant declines in the capacity of forest ecosystems to provide production, provisioning, regulating and cultural services upon which a significant proportion of the world's population depends for their livelihoods.

Of particular concern are the potential impacts on forest-dependent communities in tropical and sub-

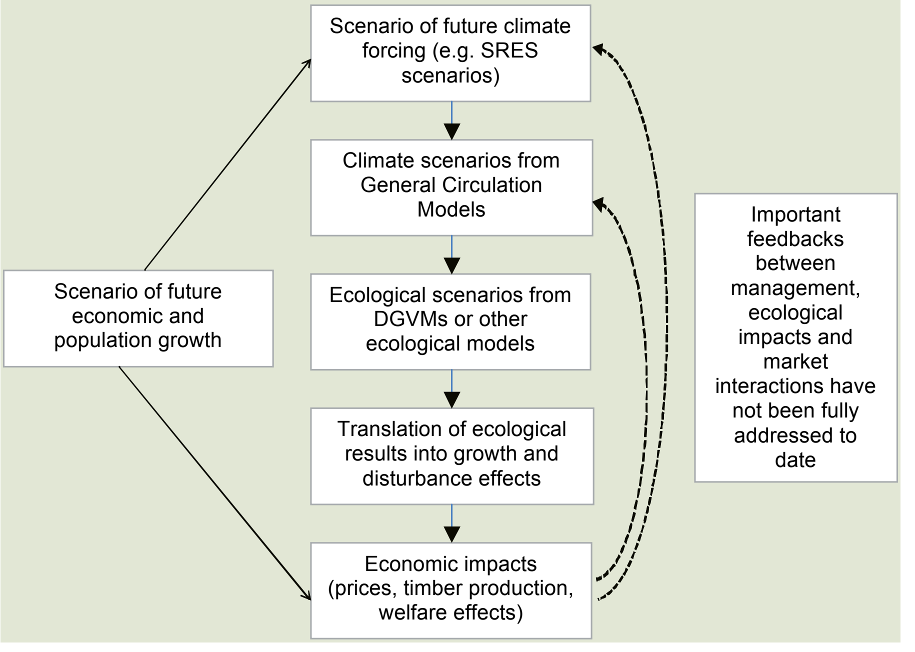

Figure 4.1 Stylized view of methods for assessing economic impacts of climate change.

tropical domains who are already suffering from the effects of ongoing deforestation and forest degradation. Projected increases in the frequency and severity of droughts, floods, other extreme weather events, forest disturbances such as forest fires and outbreaks of forest pests and diseases, and associated changes in forest structure and composition will further reduce the capacity of forests and woodlands to provide timber, fuelwood and essential non-wood forest products, sufficient clean water for consumptive use, and other services required to meet basic nutritional, health and cultural needs of forest-dependent people. In such regions, existing socio-economic vulnerabilities of these communities may be expected to worsen. As has been witnessed in the past, the inability of people to meet their basic requirements for food, clean water and other necessities which forest ecosystem services often provide can lead to deepening poverty, deteriorating public health, social conflict (as people seek to migrate to more hospitable areas, or already overcrowded urban centres) and other detrimental human impacts.

In this chapter, we consider how climate-induced changes on the provision of forest ecosystem services will impact the economic and social well-being of forest-dependent people. We consider these socio-economic impacts and vulnerabilities with reference to provisioning services (including production of wood and non-wood products, in sub-chapter 4.2); regulating services (hydrological regulation and water quality, human health and well-being, in sub-chapter 4.3); and cultural services (spiritual and cultural values, recreation and ecotourism, in sub-chapter 4.4). Supporting services are addressed in chapter 3. The role of governance is discussed in this chapter as a key factor that will profoundly influence social and economic impacts and vulnerabilities, and affect, positively or negatively, the adaptive capacity of societies to deal with the effects of expected shifts in the quantity and quality of forest ecosystem services as influenced by climate change.

Within social science research, many methods have been used to assess potential impacts of climate change in social systems. These methods either implicitly or explicitly account for adaptation. For a description of these methods see Box 4.1.

4.2 Provisioning Services

4.2.1 Wood and Wood Products

Models and Methods to Assess Impacts of Climate Change on Wood Product Markets

Any assessment of climate-change impacts in wood-product markets requires inputs from other disciplines. For timber-market impacts, these inputs include scenarios of future climate change from general circulation models, and scenarios of ecological impacts from ecological models (e.g. dynamic global vegetation models, or DGVMs), as discussed in chapter 3. The results from ecological models provide an indication about the implications of climate

Box 4.1 Assessing Potential Climate Change Impacts in Social Science

Climate change is only one factor that will affect forests and people dependent on forest goods and services in the future. Population and income growth, expansion or reduction of crop and pastureland, pest infestations, forest fires and industrial pollution (e.g. nitrogen deposition or acid rain) are other factors that will affect the structure and function of forests in the coming century. To assess the impact of climate change on forest goods and services, the methods used must disentangle the effects of climate change from these many other important influences. Further, as noted by Rosenzweig et al. (2008), humans will adapt, and it is difficult to separate adaptation from the impacts. Within social science research, many methods have been used to assess potential impacts of climate change in social systems. These methods either implicitly or explicitly account for adaptation.

First, researchers may use evidence from adaptation of human systems to other types of impacts, or to historic climate change, to make inferences about how climate change may affect these same, or other, human systems (see e.g. 'vulnerability assessment' proposed by Turner et al. 2003). With such analysis, researchers assess how other observable factors (such as population change, agricultural expansion, disturbances, etc.), influence forests and the flows of goods and services provided by forests. This information is then used to make inferences about how climate change may affect these same flows of goods and services provided by forests, and the individuals or groups of individuals who use them. Analysis like this can help researchers better understand the resilience of families, groups of people, political systems or other entities to the small- or large-scale disruptions possible with climate change. In regions where climate change is already occurring and having impacts, such as in high altitudes and high latitudes, researchers are already using these methods (e.g. Young and Lipton 2006, Ford et al. 2008).

Second, researchers may employ empirical, or statistical, data that compares responses of economic or social systems across climate variables (see e.g. Mendelsohn et al. 1994, Schlenker et al. 2006, Deschenes and Greenstone 2007). To make such analysis valid, one must have a large number of observations over a fairly wide spatial scale. Researchers may also supplement this cross-sectional data with data from different time periods to strengthen the results. If a large number of studies are available assessing impacts on a particular resource (e.g. forests, crops, land use), one may also conduct meta-analysis. Meta-analysis involves combining the results of many different studies, perhaps from different regions, to assess whether the results can be generalized.

Third, researchers can conduct survey or experimental research designed to elicit hypothetical individual (or community) responses to climate-change stimuli (see e.g. Layton and Brown 2003). Studies conducted with survey methods or with experimental techniques can isolate responses to climate-change stimuli from other types of stimuli. However, it is important to recognize that in the absence of actual observed climate change, this data will be hypothetical.

Fourth, researchers can construct models to assess impacts on specific variables. Researchers often rely on models sufficiently empirical or statistical data is not available. Much of the research on the impacts of climate change on timber-market outputs has been conducted with modelling studies (see e.g. Joyce et al. 1995, Sohngen and Mendelsohn 1998, Sohngen et al. 2001, and Perez-Garcia et al. 2002). The models simulate market activity 'without' and 'with' climate-change stimuli. The two cases are compared to determine impacts on economic outcomes (e.g. prices, outputs). Because other factors in the model are constant in the 'with' and 'without' cases (population, income, etc.), modelling exercises isolate the impacts of climate change relative to other influences.

change on different ecosystem types, but these results must often be translated into data that can be used in economic models.

A stylized view of the steps typically taken to conduct an economic assessment of climate-change impacts is shown in Figure 4.1. Most assessments to date have assumed a linear path of models, that is, from climate scenario to ecological scenario to economic model. Some links between vegetation models and General Circulation Models have been established, but important feedbacks between management, ecological impacts and market interactions have not been fully addressed to date. This point is important to recognize because most ecological models assume that there is little, or no, interaction between humans and ecosystems. In reality though, many of the world's ecosystems are affected by human management, and most forests utilized for timber production are in fact managed. Ecological models that do not account for land management by

Table 4.1 Other factors, besides climate change, that would affect the demand or supply of wood.

Factor	Demand side effects	Supply side effects
Energy demand	Affect demand for wood as an input into energy production	Affect supply of land for forests
Agricultural markets	–	Affect competition for land and affect supply of forestland
Governance	Affect income and population growth and thus demand	Affect land tenure
Economic growth	Affect demand for wood	Affect demand for land in other uses, such as environmental protection
Exchange rates	Alter the quantity demanded	Alter production costs across countries

humans likely overestimate the impacts of climate change on ecosystems because they do not capture human responses either directly to climate change phenomena, or to secondary market adjustments caused by climate change (Sohngen et al. 1998).

Quite a lot of other factors, besides climate change, also will affect forests and forest management in the future (e.g. Table 4.1). Economic models of course could be used to study the effects other exogenous impacts have on timber markets, but would constitute a different study than one on climate-change impacts. All the economic models make assumptions about how the other factors described in Table 4.1 affect markets when they analyse climate-change impacts. Analysts typically hold their assumptions about these other factors constant between the baseline scenario and their climate-change scenario. Some studies do conduct sensitivity analysis to consider the implications of changes in one or another of the 'other' factors.

Ecological Impacts Captured By Economic Models

As discussed in Chapter 3 of this report, climate change could have many influences on forest structure and function, including changes in productivity, changes in disturbance, and the movement of species and ecosystem types across the landscape. Economists account for these effects by using results from the ecological studies to perturb their underlying inventory models. Within the economic literature, three ecological impacts have been studied to date: yield effects, disturbance regimes and movement of species and ecosystem types.

Yield Effects: The inventory models used by economists typically contain yield functions, which provide information on the quantity of biomass per hectare at different age-class intervals. These models do not incorporate the influence of climate on the yield projections. Ecological models typically provide information on changes in productivity of different ecosystem types and in some cases age classes, under different transient climate scenarios, and these changes can be used to perturb the annual growth of forests within the inventory models (Joyce 2007).

One important uncertainty in modelling growth effects in forestry is the influence of increasing atmospheric concentration of carbon dioxide (CO_2). Most ecological models used by economists to date have incorporated this influence on plant growth. A recent study by Haynes et al. (2007) illustrates the importance of (CO_2) effects. Their study shows that under climate change and elevated CO_2, softwood and hardwood inventories expand steadily (relative to the base run of no climate change or elevated CO_2 influence), while under climate change only, some forest types increase in timber growth, while growth in other forest types declines. This area of research on CO_2 effects on plants is a rapidly changing area of science, and economic model development can lag behind the current understanding of the science.

Disturbance Regimes: Changes in disturbance regimes such as changes in forest fire outbreaks, severe storm and wind damage, disease outbreaks, or insect infestations that lead to large areas of dead, dying and decaying trees – can have more immediate effects on markets than changes in forest yields. If forest dieback and disturbance occurs in managed forest zones, losses of existing stocks of trees could have immediate impacts in markets. The full range of economic impacts will depend on how extensive the damage to trees is and how much salvage can be conducted.

Movement of Species and Ecosystem Types: Ecological models indicate that ecosystem types will shift pole-ward and up-slope. Accounting for movement of species is the most difficult aspect of economic modelling due to the long time lags between regeneration and harvest of trees. The movement of tree species by humans is inherently a trial and error process. Natural migration rates within ecological models account for the natural trial and error process. Through active management, humans can speed this up, although investments will depend on prices. Humans may also make errors that will slow migration. There are many genetic studies showing the adaptability of commodity species across large geographical areas, but there is currently little research on the adaptability of non-commodity forest tree species.

Economic Estimates of Impacts in Timber Markets

There is a long history of modelling timber markets, both within countries and internationally. These models have been developed to assess the relationship between changing demand for wood products and the supply of timber. One example is the TAMM model (Adams and Haynes 1980), which was used widely throughout the 1980s and 1990s for timber supply analysis in the United States. More recently in the USA, the FASOM model (Adams et al. 1996) has been developed and employed for forest policy analysis in the USA. Whereas TAMM and FASOM models only consider the United States, The Center for International Trade in Forest Products Global Trade Model (CGTM; described in Kallio et al. 1987) and the Timber Supply Model (Sedjo and Lyon 1990) account for global demand and supply conditions. EFISCEN is a forest-sector projection model similar to TAMM and CGTM which has been applied widely to the European forest sector (Nabuurs et al. 2001). In the past 10–15 years, all of these models have been applied to assess climate change.

The recent IPCC report indicates that by the end of this century global warming could cause large-scale changes in the structure and function of ecosystems globally (Fischlin et al. 2007). While the most dramatic changes appear to occur later in the century, significant adjustments in forest stocks could occur within the next 20–50 years (Fischlin et al. 2007). Taking the ecological results into account, economic studies have thus far concluded that the global supply of timber is not likely to be adversely affected by climate change, and in fact could be increased (Easterling et al. 2007). The results in this chapter support this general conclusion from the IPCC, but the results here recognize as well that there are potentially large regional and local effects from climate change that will have important implications for citizens living and working within those affected forested areas.

Given the results in Easterling et al. (2007) and other economic assessments of climate change, consumers worldwide are expected to benefit from climate change due to expanding global timber supply and falling prices. Producers and landowners, on the other hand, could gain or lose welfare during climate change depending on relative productivity versus price effects. The results in this sub-chapter focus on impacts of climate change on output and timber producers.

Global Results

As a result of projected increases in the productivity of forested ecosystems due to climate change, a number of studies have projected that climate change will increase the long-run supply of timber globally (Perez-Garcia et al. 1997, Sohngen et al. 2001, Perez-Garcia et al. 2002, Lee and Lyon 2004). With the exception of Perez-Garcia et al. (2002), the other studies utilized earlier, static General Circulation Models. As a consequence, those authors had to make assumptions about the timing of the effects of climate change, assuming that the effects occurred linearly over a 50–100 year period.

Authors of existing studies also have focused on different types of ecological effects in their analyses. Perez-Garcia et al. (1997, 2002) used changes in either net primary productivity or total ecosystem carbon to adjust the annual growth of timber in different regions of the world. Because the ecological results suggested either more net primary productivity or ecosystem carbon in the long run in most ecosystems, the supply of timber expanded and timber market welfare increased.

Sohngen et al. (2001) used changes in net primary productivity to adjust annual growth as well, but they also accounted for disturbance and movement in species over time. To capture disturbance, they assumed that any change in ecosystem type from the baseline to the climate scenario resulted in dieback of the existing species. They then allowed the timber model to choose whether to regenerate new forest types in regions where dieback occurred if the new ecosystem type was indeed forest. In their model, the long-run supply of timber expanded because the overall area of forest land was projected to increase and net primary productivity in forests increased. Although they linearized the pace of the impacts, their results suggested that some regions, such as North America, could experience negative market outcomes, even though long-run productivity in forests was projected to increase.

Gerardo Mery: Roundwood exports from Chile

Photo 4.1 It has been projected that globally climate change will increase the supply of timber in the long term.

Regional Impacts

Regional impacts on outputs and producer returns from various studies are summarized in Table 4.2. The United States remains the most widely studied country in terms of estimates of economic impacts of climate change in timber markets (see Joyce et al. 1995, Sohngen and Mendelsohn 1998, 1999, Irland et al. 2001, Joyce et al. 2001, Alig et al. 2002). There are few studies of the economic impact of climate change on timber markets in other regions, although the global models do provide insights into the potential effects in most regions. Regional studies in these other regions are largely a collection of ecological assessments of the impacts of climate change on net annual increment, holding timber harvests at baseline levels (e.g. Lelyakin et al. 1997, Nabuurs et al. 2002).

By and large, studies in the USA have found that climate change likely will reduce prices for wood products and increase output in the USA. These changes will in turn benefit consumers, but potentially harm producers. Effects in the USA, however, have been found to vary from region to region. Sohngen and Mendelsohn (1998, 1999) suggest that producers in the southern and Pacific north-western USA could experience the negative economic impacts of climate change, while producers in the north-eastern and north central USA gain. Because climate change reduces prices, regions with large inventories of merchantable trees have the biggest potential losses in asset value. Burket et al. (2000) found similar results for the southern USA using a regional economic model for just that region. Alig et al. (2002), however, suggest that output is likely to expand more in the southern USA than the northern US as climate changes.

Results for the USA and Canada derived from global models are largely consistent with the regional analyses. Sohngen and Sedjo (2005) illustrate that output in North America depends on whether there are large-scale disturbance events related to climate change. Specifically, if climate change increases disturbance-related forest dieback, output in North America is projected to decline. The largest impacts on output are projected to occur in northern and western mountain regions, suggesting relatively larger potential impacts in Canada. Because prices are lower due to the expansion in global output, producer returns decline if dieback occurs in North America. The results in Sohngen and Sedjo (2005) illustrate how sensitive output and producer returns in regions of the world are both to changes in disturbance regimes and climate impacts in other countries. Although they do not explicitly account for changes in disturbance regimes, Perez-Garcia et al. (2002) also find that producer returns decline in Canada and the USA.

Table 4.2 Economic estimates of climate change impacts on output and producer returns.

Region	Output		Producer returns
	2000–2050	2050–2100	
North America[1]	–4 to +10%	+12 to +16%	Decreases
Europe[2]	–4 to +5%	+2 to +13%	Decreases
Russia[3]	+2 to +6%	+7 to +18%	Decreases
South America[4]	+10 to +20%	+20 to +50%	Increases
Australia/New Zealand[4]	–3 to +12%	–10 to +30%	Decreases & Increases
Africa[5]	+5 to +14%	+17 to +31%	Increases
China[5]	+10 to +11%	+26 to +29%	Increases
South-east Asia[5]	+4 to +10%	+14 to +30%	Increases

[1] Alig et al. (2002), Irland et al. (2001), Joyce et al. (1995, 2001), Perez-Garcia et al. (1997, 2002), Sohngen et al. (2001), Sohngen and Mendelsohn (1998, 1999), Sohngen and Sedjo (2005)

[2] Karjalainen et al. (2003), Nabuurs et al. (2002), Perez-Garcia et al. (2002), Sohngen et al. (2001)

[3] Lelyakin et al. (1997), Sohngen et al. (2001)

[3] Lelyakin et al. (1997), Sohngen et al. (2001)

[4] Perez Garcia et al. (1997, 2002), Sohngen et al. (2001)

[5] Sohngen et al. (2001)

Nabuurs et al. (2002) and Karjalainen et al. (2003) utilize the EFISCEN model to assess the influence of climate change on forest stocks and markets in Europe until 2050. Their results indicate that climate change will increase net annual increment in forests up to the middle of the century. They do not estimate the effects of these changes on consumers and producers, but they instead assume that harvests follow the same path with and without climate-change impacts on forest growth (suggesting that there would not any economic impacts in markets). Given the strong increase in net annual increment with climate change projected by their model, however, economic theory tells us that timber production would increase in Europe, and timber prices would fall as a result of climate change.

Sohngen et al. (2001) find that output in Europe increases with climate change this century. The results in Perez-Garcia et al. (2002) show both increases and decreases in output depending on the specific scenario in their analysis. Lower global timber prices in both models cause producer returns to decline as a result of climate change.

Lelyakin et al. (1997) examine the effects of climate change on Russian forests over a relatively short time period (until 2020). They show increased net annual growth through all of Russia by 2020, with the largest increases in the northernmost areas, suggesting that forest output in Russia would expand as climate changes. Sohngen et al. (2001) do show output expanding in Russia modestly up to 2050 (2–6% relative to base), but then more rapidly to the end of the century (7–18% relative to base). Producer returns in Russia decline despite the increase in output due to the reduction in prices caused by climate change.

Over the past 30 years, timber production in regions such as Australia, New Zealand and South America has increased dramatically, due to the expansion of fast-growing plantation species. For the most part, these trends are expected to continue, and strengthen, in the absence of climate change. For example, Perez-Garcia et al. (2002) suggest that output will expand 10–13% over the next 50 years in Chile, and Sohngen et al. (2001) suggest similar gains (10–20%) in output over the next 50 years in South America, with stronger gains thereafter (20–50%). The results in Sohngen et al. (2001) do show potential losses in output in Australia and New Zealand as a result of the ecological predictions they used.

Only one of the studies with results reported in Table 4.2 has examined impacts in developing regions, such as Africa, South-east Asia and China. The results of that study (Sohngen et al. 2001) indicate that output and forestry revenues increase in the countries of those regions due to rising timber yields and adaptation by shifting to shorter rotation species. As in South America, foresters are projected to expand their output by continuing a shift towards short rotation species as climate changes.

Table 4.3 Global import values of selected NWFPs for 1992–2002 (FAO 2005a).

Commodity description	Global import value (1000 USD) 1992	2002
Mosses and lichens for bouquet, ornamental purposes	9 352	25 476
Truffles, fresh or chilled	4 201	23 656
Mushrooms other than agaricus, fresh or chilled	n.a	364 412
Mushrooms & truffles, dried	n.a	219 548
Plants & parts, pharmacy, perfume, insecticide use	689 926	777 980
Rattan used primarily for plaiting	118 987	51 327
Maple sugar and maple syrup	43 632	116 202
Ginseng roots	38 345	221 435
Palm hearts, otherwise prepared or preserved	16 082	67 514
Oak or chestnut extract	8 653	917
Gum Arabic	101 312	105 510
Natural cork, raw or simply prepared	7 874	110 702

4.2.2 Non-Wood Products

Importance of Non-Wood Forest Products to Forest-Dependent Communities

Forests and woodlands are increasingly recognized for their precious biological resources beyond timber which sustain the livelihoods of hundreds of millions of people in forest-dependent and adjacent agricultural communities, and contribute significantly to their domestic energy, food- and health-security needs. These non-timber forest resources include fuelwood and charcoal, and wood used for tools, carving and other household purposes; they also include non-wood forest products (NWFPs) such as livestock fodder, gums, resins, honey, fruits, nuts, tubers, mushrooms, spices, fish, wild meat and other wild foods, plants and oils for pharmaceuticals and cosmetic products, as well as rattans and bamboos (De Beer and McDermott 1989, FAO 1995, 1999, CIFOR 1999, Belcher 2003). For the rural poor living in and adjacent to forests, NWFPs provide essential food and nutrition, medicine, fodder, fuel, thatch and construction materials, mulch and non-farm income. Forests often serve an important 'safety net' function, providing some measure of relief during the 'hunger periods' in the agricultural cycle through their provision of wild foods (Arnold and Townson 1998, Falconer 1990, McSweeney 2004).

Despite their importance to forest-dependent people worldwide, accurate information on marketing and use of NWFPs is limited and often mixed with agricultural production statistics. The 2000 FAO Forest Resources Assessment (FRA) NWFP component found a significant lack of quantitative data at the national level on both NWFP resources and products (FAO 2001). Statistical data, if accessible at all, is limited to export data for a selected number of internationally traded NWFPs. For the industrialized temperate and boreal countries, data on quantities and monetary values (global import values) are available for Christmas trees, cork and a number of species of mushroom (such as truffles), berries, medicinal plants, decorative foliage, game meat, hides and pelts, honey and nuts (see Table 4.3).

Through their experience with forest-dependent communities, forestry experts have recently begun to appreciate the enormous significance of NWFPs for sustaining rural livelihoods. In recent years, a growing body of scientific research has shown that, given certain basic conditions, non-wood forest resources can help communities to meet their needs on a sustainable basis (FAO 1995). There is strong evidence that the poorest of the rural poor are the most dependent on forests and woodlands to meet their domestic energy needs for cooking and heating, and for a wide variety of NWFPs (Neumann and Hirsch 2000), and that the poor frequently depend on their collection as an 'employment of last resort' (Angelsen and Wunder 2003). Regardless of the real and potential importance of NWFPs, national institutions are not carrying out standard monitoring of these resources or assessments of their socio-economic contribution.

Collection and sale of NWFPs can provide employment during slack periods of the agricultural cycle and provide a buffer against climatic risk and household emergencies (Iqbal 1993, Cavendish 2000). In many rural sub-Saharan Africa communities, for example, NWFPs may supply over 50% of a farmer's cash income and provide the health needs for over 80% of the population (FAO 2004).

NWFPs that enter into global trade statistics,

Box 4.2 Gum arabic

Gum arabic is one of the most important NWFPs in Sudan. It is an exudate from *Acacia senegal* tree obtained by bark tapping. Gum arabic production is one of the main activities and source of economic stability in the arid rural areas of Kordofan and Darfur regions of Sudan, where all community members (men, women and children) take part in gum-arabic operations i.e. tapping, collection, sorting, cleaning and marketing. In all, more than five million people work in planting trees, gum production and marketing of gum Arabic in the Sudan.

Over the years traditional farmers in the Sudanese gumbelt have developed a close relationship with, and a comprehensive husbandry system for, this tree (known as *Hashab* in Arabic). In ideal settings a farmer will divide his landholding into four parts, each managed differently for production of Hashab and/or agricultural crops. These four systems include: mature Hashab trees; younger trees among which crops are interplanted; pure cropping where soil fertility is declining and will soon be planted or allowed to regenerate naturally with Hashab; and new cropping areas which had been under trees for 15–20 years (Abdel Nour 2003). This system is currently being modified (less area allocated for cropping with a greater emphasis on Hashab management) to adapt to land shortages and declining rainfall.

Assessment of current and long-term impacts of climate change (2030 and 2060) on gum arabic production has been conducted in Sudan (GoS, 2003). The study indicated that a rise in temperature associated with increased water stress would lower gum arabic production significantly. A southward shift in the natural distribution of this tree species is already being detected and is projected to continue with declining rainfall. It is estimated that this will result in a reduction in gum arabic production, region-wide, of between 25% and 30%.

such as bamboo, rattan, cork, gum arabic, aromatic oils and medicinal plants, can attain high prices in comparison with NWFPs traded on national markets, and contribute to national economic development. Rattan, for example, is one of the most important commercial non-wood forest products in Asia (FAO 2005a). More than 700 million people worldwide trade or use rattan for a variety of purposes. Domestic trade and subsistence use of rattan and rattan products is valued at an estimated USD 3 billion per annum, and another USD 4 billion is generated through international trade, according to assessment made by the International Rattan and Bamboo Network (INBAR 2007).

Different types of NWFPs are used for subsistence and in support of small-scale, household-based enterprises, so their contribution to improving adaptive capacity of local people through diversification of local economies and livelihoods is beginning to be recognized. Moreover, locally traded NWFPs contribute to the fulfilment of daily needs and provide employment and income, mainly for rural people and especially women. In eastern and northern Sudan, for example, Doum (*Hyphaene thebaica*) forests provide a diversity of non-timber forest products of great importance in the rural economy. These products include: sa'af, or fibre from the leaves of young trees used for the manufacture of ropes, baskets and mats; fuelwood and charcoal; and edible nuts, the kernels of which produce 'vegetable ivory'. In addition, the timber from mature trees provides a strong and durable building material for house construction and posts. The manufacture of handicrafts from Doum is predominantly the task of women, thus providing an important source of income at the household level (Abdel Magid 2001).

Potential impacts of climate change on the forest-dependent poor and their subsistence use of wood fuels and NWFPs

The impact of climate change on NWFP is an area that requires greater attention from the research community (Easterling et al. 2007). The site specific nature of both climate change and the provision of NWFP services complicate the understanding of climate change impacts on NWFPs (e.g. Irland et al. 2001). In general, the influences of climate change on these goods and services are more difficult to assess because of high uncertainty regarding ecological effects of climate change, and also because data on the current and projected future demand for these products is incomplete at the global as well as regional and national levels. As Easterling et al. (2007, p. 290) point out 'climate change will substantially impact other services, such as seeds, nuts, hunting, resins, plants used in pharmaceutical and botanical medicine, and in the cosmetics industry; these impacts will also be highly diverse and regionalized'.

Climate change is expected to result, in many regions, in increased frequency and severity of ex-

Matti Nummelin: Collecting fuelwood in Niger

Erkki Oksanen: Picking mushrooms in Finland

Photo 4.2 Climate change is expected to have negative effects on NWFP production in many regions. This can impose additional stresses on people who depend on fuelwood for domestic energy and NWFPs for livelihoods.

treme climate events such as heat stress, droughts and flooding in the coming decades. In particular, it will modify the risks of fires and pest and pathogen outbreaks, with negative consequences for food, fibre and forest production including NWFPs (Easterling et al. 2007). In regions with large forest-dependent populations, particularly in Africa, expected decreases in rainfall, and increased severity and frequency of drought, can be expected to exacerbate current exploitation pressures on forest and expansion of agriculture into forest lands. In these regions, this can be expected to impose additional stresses on people who depend on fuelwood for their domestic energy needs and NWFPs for their livelihoods.

FAO (2005b) points out that smallholder and subsistence farmers, pastoralists and fisherfolk in developing countries may not be able to cope with climate change effectively due to their reduced adaptive capacity and higher climate vulnerability. Eastaugh's (2008) multidisciplinary review of adaptation of forests to climate change found that climate change is expected to impact heavily forest-dwelling communities with no other source of sustenance. The lack of support infrastructure and effective governance system can further increase vulnerability (Adger 1999, Adger et al. 2003, Brockington 2007). This review also highlighted the current research gaps in this area such as: socio-economic effects of climate-change impacts on subsistence lifestyles of forest-dependent communities and the role of forest in adaptation responses within different sectors and regions. Other important research gaps, identified by the 4th IPCC assessment report, include the integrated assessment of climate-change impacts on ecosystem services including on food, fibre, forestry and fisheries, and the relationship between biodiversity and the resilience of ecosystem services at a scale relevant to human well-being (IPCC 2007).

Contribution of NWFPs to Climate Change Adaptation

The sustainable management of forests and trees outside forests for non-timber forest products and benefits presents a range of potential adaptation options, particularly for rural people in developing countries. In semi-arid regions trees not only improve natural rangelands but also provide browse, which is often the only fodder available at critical times of the dry season and during drought years.

Traditional forest-management practices for the production of different types of NWFPs such as fruits, medicine, gums and honey exist in many forest-dependent communities worldwide. The revival and further development of this local knowledge and management practices for sustainable production of NWFPs may represent an important element in the adaptation responses of forest-dependent people to climate change, although the rich indigenous knowledge and associated social institutions and governance structures that support these local practices are disappearing in many regions, as discussed below in sub-chapter 4.5 and in Chapter 5 (sub-chapter 5.1.2). Moreover, such knowledge may be critical for the development of effective strategies for coping with anticipated changes in forest productivity and frequency of disturbances. For example, traditional approaches, combined with insights from forest science, could be used to develop new planting schemes: afforestation, reforestation and degraded land rehabilitation and forest landscape restoration programmes using tree species and varieties that are both adapted to anticipated climatic conditions and are valued by local communities; agroforestry systems that include valued tree and plant species which may become increasingly rare in natural forests due to climate-induced changes in forest structure; and domestication of high-value medicinal plants or other NWFPs on farms and in home gardens (Sampson et al. 2000, Parrotta 2002). Moreover, Carmenza et al. (2005) highlighted that the promotion of agroforestry systems as Clean Development Mechanism (CDM) projects can result in additional positive impacts, including increased food security or diversification of farmer incomes through production and sale of NWFPs.

4.3 Regulating Services

4.3.1 Hydrological Regulation and Water Quality

Among the key forest ecosystem services which are expected to be affected by climate change are those related to hydrological regulation and water quality. These include, among others: the regulation of run-off and river discharge; the maintenance or improvement of water quality through forest filtering and retention of freshwater for consumptive use; buffering against coastal damage by tropical storms and tsunamis (see Box 4.3 on mangrove forests).

As discussed in Chapter 3, the projected future hydrological impacts of climate change on forests, as well as the opportunities and vulnerabilities which these changes present, are highly variable both between and among the world forest domains. Here we consider the socio-economic implications of these forest impacts, and climate change-induced land-use changes that will affect the capacity of forested landscapes to provide users with adequate supplies of fresh water.

Changes in water availability may be influenced by the changes in terrestrial freshwater systems likely to be affected by climate change (Box 4.4). These may in turn be exacerbated by changes in land-use patterns (Brouwer and Falkernmark 1989). Both extremes of very wet and dry conditions predicted for water availability (IPCC 2007, see also Chapter 3) have major socio-economic implications on human well-being and land-use change patterns (e.g. agriculture, urban activities, waste water disposal), which may place further pressure on forests (through their conversion and/or degradation) and negatively affect their capacity to provide key regulating services.

Climate change impacts on water and soil resource are likely to increase existing socio-economic vulnerabilities and adversely affect livelihoods and national development plans, especially in developing countries. At present, soil erosion and extreme weather events (floods and droughts) that affect water availability and quality present major global environmental challenges (OMAFRA 2003, Pimentel et al. 1995, Sophocleous 2004); their socio-economic impacts are unevenly distributed across the world, with greater severity in poorer and more vulnerable regions. Rapid demographic changes in most regions are already increasing demand for water resources and new lands for agricultural production which climate change will, in many regions, only exacerbate (Rogers 1994, Vörösmarty et al. 2000). It is estimated that developing countries will require an additional 120 million ha of land for crops and an expansion of irrigated areas by 40 million ha in the next 30 years requiring 14% increase in extracted water from surface and groundwater resources (Williams et al. 2004).

Under rain-fed agricultural systems that predominate in developing countries, decreased water availability in drought-prone regions may further limit agricultural productivity and encourage changes in land use, including agricultural expansion and forest conversion. The current increasing demand for water in rain-fed agricultural production systems – which account for an estimated 60–70% of global crop production (International Rivers Network 2006) – has in many regions resulted in significant losses of forest hydrological services as a consequence of deforestation of riparian and upland watershed

Box 4.3 Coastal mangroves

Coastal mangroves are an example of a widely utilized forest resource that also provides critical regulating services. They provide multiple provisioning and regulating ecosystem services, including providing nurseries for important fish species and in regulating and protecting coastal areas from floods and coastal storm surges. These ecosystem services are highly valued in the tropical coastal regions, yet mangrove areas have been in decline in the past half century (Alongi 2008).

Coastal storms are projected to increase in most regions of the world under all scenarios of climate change, and impacts will be closely associated with sea level rises of 3–4 mm yr^{-1} (IPCC 2007). With increasing erosion rates and increased frequency or intensity of storms in the tropics, the coastal protection function of mangroves will become more critical over time. But mangrove forests are themselves vulnerable to these impacts: their ability to adapt successfully depends on accretion rates relative to sea level, and while there appears to have been adaptation to sea level rises observed to date, such adaptation will become increasingly difficult at higher rates of rise and with increasing other pressures on mangroves for conversion and lack of space for landward migration (Alongi 2008). Since the IPCC reports in 2007, there has been some evidence from global assessments suggesting that observed and projected sea level rises may in fact exceed those reported in IPCC (Hansen 2007, Rahmstorf 2007), which would exacerbate the vulnerability of mangroves.

The coastal protection function of mangroves is well documented (Walters et al. 2008, Sathirathai and Barbier 2001, Barbier 2006, Tri et al. 1998) and quantified in terms of its economic contribution to well-being. Walters et al (2008) review estimates of the economic value of this protection function ranging from USD120 per household to USD 3 700 and USD 4 700 per hectare of mangrove, depending on the method of estimation (Badola and Hussain 2005, Sathirathai and Barbier 2001, Costanza et al. 1989). While the physical principles have been quantified to show that mangrove forests can attenuate wave energy (Quartel et al. 2007), the efficiency of this energy absorption and the extent to which mangroves can reduce coastal erosion is strongly dependent on physical properties and vegetation dynamics. In areas such as Vietnam, where previous deforestation has occurred, there have been attempts at reforestation, particularly to provide regulating services of coastal protection (IFRC 2002). The Red Cross estimates that planting 12 000 hectares of mangroves reduced the cost of maintaining sea dikes that protect the coast by USD 7.3 million per year. Replanted mangroves provide multiple functions and hence can be justified in local livelihood terms even without the important benefits of coastal protection regulation (Tri et al. 1998, Bosire et al. 2008).

areas (Rockström et al. 2007). This in turn jeopardizes the quantity, flow rates, sedimentation and water quality, thereby affecting other development initiatives such as irrigation schemes for agriculture and hydropower supply. In drought-prone regions, anticipated reductions in water availability resulting from climate-change impacts may encourage prompt human (and animal) migration away from the most severely affected areas towards more favourable areas, and thereby increase potential for conflicts over land and water resources, including between humans and wildlife. Such migration of people would exacerbate land conversion for new settlements and livelihood resources mostly at the expense of forest land. Unfortunately, in spite of these close land-water interactions and the implications of climate change, conventional approaches to natural resources management generally address land and water separately (Falkenmark and Lundqvist 1997).

In addition to the expected impacts of climate change on forests' capacity to provide adequate water resources for agriculture, their effects on public health, particularly for the poor, may be severe. Water available during extreme climate events of drought or floods is often of poor quality and is linked to a range of health problems such as diarrhoea, intestinal worms and trachoma. The burden of obtaining safe drinking water and sufficient water for proper sanitation and hygiene is more profound for the poor who very often live in degraded environments and who are predominantly women and children. Today, 20% of the total occurrence of disease in the developing world, and 34% in sub-Saharan Africa, is associated with environmental degradation; lack of access to safe, affordable water and sanitation constitute the major threat to health in these countries. Forest loss can contribute directly to the severity of these health problems through disruption of the water cycle and increased soil erosion, as well as indirectly – though very significantly – through its effects on local and global climate change, which in turn can have a profound effect on the survival and spread of disease pathogens (World Bank (2001). In developing countries, drought has severe health

Box 4.4 Climate-change projections and water risks (IPCC 2007)

- The impacts of climate change on freshwater systems and their management are mainly due to observed and projected increases in temperature, sea level and precipitation variability (very high confidence).
- Increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas (high confidence).
- Semi-arid areas and arid areas are particularly exposed to the impacts of climate change on freshwater (high confidence).
- Efforts to offset the decline in surface water will be hampered by considerable decrease in groundwater recharge (high confidence).
- Vulnerability will be exacerbated by rapid increase in population and water demand (very high confidence).
- Higher water temperatures, increased precipitation intensity, and long periods of low flows exacerbate many form of pollution, with impacts on ecosystems, human health, water-system reliability and operating costs (high confidence).
- The negative effects of climate change on freshwater systems outweigh its benefits (high confidence).

For an explanation of the confidence levels see sub-chapter 1.3.5.

impacts, with widespread crop failure and food shortages resulting in famine. Further, drought conditions can increase the potential for forest fires, which, in turn, can cause loss of life or respiratory distress due to poor air quality, as well as emotional and psychological stresses related to mass evacuations which can accompany both large-scale forest fires and drought-induced famines.

4.3.2 Human Health and Well-Being

Changes in the climate are expected to lead to significant changes in forested landscape structure and forest biodiversity in all forest domains, as discussed in Chapters 2 and 3 of this report. These changes may have significant implications for human health in many forest regions, particularly in tropical and subtropical regions, which should be a cause for concern.

The projected increases in the frequency and intensity of forest fires in many parts of the world will have clear impacts on human health if not prevented or mitigated. Colfer (2001) describes the dismaying results of the 1997–98 forest fires in East Kalimantan following a serious El Niño event. Climate change specialists predict that such events will be more frequent and more intense in the future. More generally WHO (2002) reported that 200 million people in Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore and Thailand were affected by these same fires. Pneumonia cases increased from 1.5 to 25 times in Southeast Kalimantan, Indonesia, and the number of respiratory diseases increased 2- to 3-fold in Malaysia. Vegetation fires seriously increase the risk of acute respiratory infections, which are already a major killer of young children. The adverse health implications of breathing smoke and other air pollutants have been clearly demonstrated by various researchers (e.g. Smith 2008, Warwick and Doig 2004).

Health professionals, such as Haines et al. (2006), note additional potential effects of climate change: extremes of temperature and rainfall (heat waves, floods and droughts) can lead to hunger and malnutrition, environmental refugees and resulting mental disorders from such catastrophes. Changes in temperature and rainfall may in turn change the distribution of disease vectors; particularly worrisome in forested areas are malaria, dengue and diarrhoea (discussed further below). Sea level rise can threaten low-lying coastal forest populations, particularly where economic conditions do not allow adequate control measures.

Gaining an understanding of the disease implications of climate change in forested areas is particularly difficult, because much of the literature on disease does not specify whether the area is forested or not. Of those diseases that are common in forests and projected to increase with climate change, the most thoroughly studied is malaria. While the number of studies has been increasing over time, there is no broad scientific consensus regarding the likely future impacts of climate change on malaria in forested regions (cf. Matola et al. 1987, Hay et al. 2002, Sheil, in Colfer et al. 2006, Zhou et al. 2004). Haggett (1994) anticipates the health implications of climate change linked to expansion of tropical organisms – many from forested regions – into temperate zones, as do Patz and Wolfe (2002), COHAB2 (2008) and others. Mayer (2000) discusses various possible health implications of warmer temperatures, including an estimate that the population at risk of developing malaria could rise to 2.5 billion people under some temperature scenarios. In explaining the re-emergence of epidemic *Plasmodium falciparum* malaria in East African highlands, these authors focus on human population increase and movement (including the presence of people without functional immunity to local strains – a very common problem in forested regions), land-use change and temperature variability as the important factors. They note that human mortality is increased by drug resistance, inadequate access to drugs, failure to seek treatment in a timely manner and HIV infection.

Russell (1998), although concerned about the implications of global warming for certain arbo-viruses, also does not consider the panic in some quarters about the increasing incidence of malaria to be warranted. Specific ailments he anticipates increasing under conditions of global warming, and which he discusses in some detail for northern (tropical) Australia, include Murray Valley encephalitis and Kunjin viruses, with the arthritides Ross River and Barmah Forest viruses causing more infections. He concludes by noting that risk of increased transmission will vary by locality, vector, host and human factors.

Graczyk (2002) emphasizes the likely climate-related changes in zoonotic diseases more generally, anticipating an increase in vector-borne diseases with global warming (see Gonzalez et al. 2008 for a recent, complex description of forest-disease-wildlife interactions). Several authors (WHO 2007, Shea and the Committee on Environmental Health 2007) emphasize the likely increase in diarrhoea, which is already a major killer of children in the forests of developing countries. They anticipate that increased temperatures will lead to greater incidence of the disease.

Climate-induced changes in the forest landscapes can have effects, particularly on the cultures of those people most dependent on the natural environment (e.g. indigenous and forest peoples). All peoples' mental health is related to the integrity of the cultural systems of which they are a part, and many cultural systems are intimately bound up with the forests (e.g. Lewis 2005, Dounias and Colfer 2008, Gómez 2008). Climate change may induce fundamental changes that can have debilitating effects on these cultural systems (cf. van Haaften's [2002] writings on the psychological effects of Sahelian crises on the victims). Some researchers also predict increases in violence as a result of uncertainties and scarcities that derive from climatic changes (cf. Richards 1996, who documents the impacts of Sierra Leone's wars on its youth).

The predicted alterations of forest landscape and forest biodiversity as a result of climate change may reduce access to forest products – forest foods, forest medicines, fibres, timber and other NWFPs. Such losses can also affect people's health directly, via lower medicinal plant availability, or indirectly, via loss of potential marketed goods and, over time, loss of indigenous knowledge and unique cultural uses of such products. Many of the foods that people obtain from wild sources (anticipated to be under increasing threats) have higher nutritional value than more familiar agricultural products (see e.g. Vinceti et al. 2008). An interdisciplinary group looking at the links between food/nutrition and biodiversity also noted the additional robustness of native species and wild foods, as well as their cultural importance (COHAB2 2008).


John Parrotta: Traditional medicines, India

Photo 4.3 Climate change may reduce access to traditional medicines derived from forest plants and animals. This can have direct health effects on people relying on such medicines or indirect effects through the loss of marketable goods, and over time, loss in indigenous knowledge on uses of such products.

Forest biodiversity losses are widely anticipated results of climate change, which will affect forest-dependent people's access to food, medicine and other forest products, although Jutro (1991) predicted that greater changes will occur in high latitudes than in the tropics. The implications for forest-derived foods, medicines and local people are likely to be complex and severe, but remain difficult to predict precisely.

To summarize, as with many climate-change issues, the uncertainties with respect to its impact on forests in relation to human health and well-being outweigh the certainties. However, there is clearly significant cause for concern and for increased global attention to developing ways to anticipate and adapt to the harmful health effects of the coming changes. Better monitoring of climate-change impact on human health and well-being and more effective involvement of forest communities supported by their local governments will be needed in anticipating, monitoring and solving these problems.

4.4 Cultural Services

4.4.1 Spiritual and Cultural Values

Forests provide a wide range of benefits beyond those related to production and regulating services. According to the definitions for FRA 2005 (FAO 2005b), social services provided by forests include recreation, tourism, education and conservation of sites with cultural or spiritual importance. The area of forests designated for social services is an indication of the extent to which countries and forest managers are actively considering these services as part of the benefits that forests provide. In Europe, for example, nearly three-quarters of the forest area is managed to provide social services, often in combination with other management objectives (FAO 2005b). The social functions of forests are often more difficult to measure and vary to a great extent among countries, depending on their level of development and traditions (FAO 2005a).

Mature forests and old trees have strong cultural and spiritual value in many parts of the world. Several writers have made the analogy between the individual, cultural and social characteristics of trees and people. Rolston (1988) refers to the forest as a religious resource and compares forests to places of worship (i.e. cathedrals). The spiritual-religious values of wilderness have long been noted. Societies most closely entwined with forests tend to regard them with a healthy respect, awe at their splendour and majesty, sometimes dread and fear of the powerful spirits that lurk within them (Laird 2004). In rural areas in Africa, old trees represent social clubs where community leaders meet with their people to discuss important livelihood issues; sometimes trees act as courtyards where villagers meet to solve their local conflicts and disputes. These cultural and spiritual values associated with forests – and trees outside forests – underlines the importance of taking the social dimension of climate change into consideration, particularly where changes in forest structure and species composition are projected as a result of climate change and its associated impacts (changes in natural disturbance regimes – i.e. fire, pests and diseases, wind damage). A more complete understanding of the relationship between people and forests is needed, so that the potential effects of climate change on the cultural services that forests provide can be recognized and taken into consideration in the development of adaptation responses to minimize the negative social and cultural impacts of these changes.

4.4.2 Recreation and Eco-Tourism

The Third and Fourth Assessment Reports of the Intergovernmental Panel on Climate Change both concluded that compared to research in market sectors like timber and agriculture, relatively little work had been done to examine the effects of climate change on recreation (Gitay et al. 2002, Easterling et al. 2007). Recent reports by the US Climate Change Science Program (Sussman et al. 2008), the Finnish Environment Institute (Sievänen et al. 2005) and Hamilton and Tol (2007) come to similar conclusions, although these studies do indicate that the research area is growing and more studies are emerging

It is quite clear, given the large number of days individuals spend in outdoor recreation (e.g. Cordell et al. 1999), that the impacts of climate change could be substantial. However, most studies examine impacts on specific activities (e.g. skiing or fishing), only some of which need to occur in forests. For example, Breiling and Charamza (1999) found that with a temperatures increase of 2ºC, high-altitude ski areas would not necessarily lose recreational visits, but low-altitude ski areas could have negative visitation effects. Irland et al. (2001) found that the specific impacts for the ski area depended on the specific impacts of climate change on that area. Unfortunately, climate models still have substantial variation with respect to their regional projections of climate change.

With respect to summer recreation, Richardson and Loomis (2004) examined visitation to a national park in the US, and found that under two climate scenarios, visitation would likely increase. The park they considered, Rocky Mountain National Park in Colorado, does include forests, but forests are not the only attraction and it is impossible to separate recreational impacts on forest attributes and other attributes. Their analysis also included an ad-hoc scenario to examine ‘extreme heat’, which suggested that above certain thresholds in temperature, visitation to natural amenities could start to decline.

One interesting study that explicitly considered forests is Layton and Brown (2000), who found that the residents of USA were willing to pay USD 10–100 per month for nature conservation to avoid changes in forest structure and function associated with climate change in the Rocky Mountains of Colorado and maintain its recreational function. As expected, higher payments were associated with more severe climate impacts in forests.

Forest ecosystems in Africa support biodiversity and habitat for plants and wildlife. Eco-tourism which is defined by the International Ecotourism Society (TIES 2008) as: 'responsible travel to natural areas that conserves the environment and improves the well-being of local people' is threatened by climate variability. According to the IPCC (2007) climate change may increase the frequency of flooding, drought and land degradation in Africa, and subsequently reduce biodiversity (one pillar of ecotourism) and the viability of recreation activities and wildlife safaris. More frequent droughts may also increase the pressure on the reserve by pastoralists, which may in turn change the human use of land adjacent to the reserve, on which wildlife in the reserve interacts. Ecotourism has been viewed by many as a viable option for improving rural livelihoods in Africa that could be one possible replacement for farm income. However, there is a great need for research and technology in Africa to assess the impact of climate change on ecotourism, particularly on sensitive ecosystems of high touristic value such as the rainforest of the Congo Basin and mountainous biodiversity (Viner and Agnew 1999).

4.5 Relationship between Governance and Socio-Economic Impacts

4.5.1 Governance

All adaptations to changing ecosystem service availability will involve either actions by individuals changing their forest use, or collective action in changing the rules by which individuals use and consume ecosystems services. Hence adaptation to climate change essentially involves altering and adjusting governance structures. Adaptations will take place in reaction to changes in forest productivity, ecosystem change and changes in the provision of ecosystem services from forests and in anticipation of such changes. This sub-chapter highlights two issues. First, it examines whether inappropriate or absent governance and forest policy environments could amplify or exacerbate climate-change impacts in terms of vulnerability of services and forest-dependent people. Second, this sub-chapter examines the potential for adaptations to policies and governance structures to ameliorate and reduce such risks and vulnerabilities. Specifically it examines how the globally observed trend towards decentralized responsibility for the management of forests directly affects the adaptive capacity of the forest sector to cope with shocks such as climate change. It concludes that the impacts of climate change on forest ecosystem provisioning, regulating and cultural services can be ameliorated by human actions to adapt and manage risks associated with these impacts, but that there are significant barriers to action.

4.5.2 Double Exposure of Socio-Economic Impacts to Climate Change and Inappropriate Governance

It is well established that lack of accountability, unclear property rights and rent-seeking directly affect outcomes such as forest integrity and rates of exploitation. In addition, there is some evidence that the breakdown of governance structures can cause or exacerbate conflict over scarce resources such as forests, and that failures in policy environments are likely to exacerbate the difficulty in adapting forest management to a changing set of climate-related risks. Hence it can be hypothesised that a lack of sustainable forest management and governance structures will exacerbate the socio-economic vulnerabilities identified in this chapter.

Analysis of the causes and consequences of lack of governance and the skewed ownership and control of natural resources often uses cross-national statistical analysis. Mikkelson et al. (2007), for example, show that countries with more unequal distributions of income have experienced greater loss of biodiversity as measured through loss of natural habitat such as forests. It should be noted, however, that some analysts have questioned the validity of the methodologies involved in conducing global regression analysis of deforestation (Kaimowitz and Angelsen 2004). Deacon (1994) and Smith et al. (2003) show similar results for forest cover related to levels of corruption. Mikkelson et al. (2007) argue that vulnerabilities are transmitted through the mechanisms of skewed land ownership and lack of accountability. Continuing trends of unaccountable decision-making are likely to make adaptation to climate change more difficult.

A further consequence of failure of governance structures to promote sustainable forest management is the potential for reductions in forest ecosystem services induced by climate-change impacts to exacerbate conflict and non-cooperation over remaining resources, creating downward spirals of unsustainable resource use and well-being of those dependent on them. The evidence base in this area is relatively weak, especially in the context of forest resources (Nordas and Gledditich, 2007). Yet it can be inferred from research on causes of displacement migration, violent conflict and resource management that climate change may aggravate already existing conflicts in the forest sector, or deepen the conflict between forests for conservation and forests for livelihoods (Fairhead and Leach 1995, Bannon and Collier 2003, McNeely 2003). Hence the vulnerabilities and socio-economic impacts on forests highlighted in this chapter are likely to be exacerbated in situations where forests are over-exploited.

4.5.3 Governance Mechanisms to Reduce Vulnerability

Changes in policy that promote sustainable forest management and the maintenance of forest ecosystem services will at the same time reduce the vulnerability of forest- dependent people. The question remains whether current trends in forest governance can potentially decrease resilience. Current trends, as identified by Agrawal et al. (2008), include 'decentralization of forest management, logging concessions in publicly owned commercially valuable forests, and timber certification, primarily in temperate forests'. These trends are confirmed by work from other authors for cases of forest management in West Africa and South-east Asia (Barr et al. 2001, Ribot 2002, Wollenberg and Kartodiharjo 2002).

According to Ribot et al. (2006), Colfer and Capistrano (2005), Agrawal and Ribot (1999), Tacconi (2007) and others, decentralization has the potential to increase local-level capacities to deal with climate change and related threats. But the empirical evidence on whether these benefits are realised is contested (Ribot et al. 2006, Tacconi et al. 2006, Tacconi 2007). A case study on forest ecosystem goods and services and adaptation from Burkina Faso shows that a decentralized governance system may offer maximum space for adaptation to climate-change impacts due to the potential of governance at the local level. But the use of such space for adaptation is dependent upon individual and organizational experiences – experiences with climate change as the context-related challenge and the experiences with the new roles and responsibilities in a changing institutional environment as a structural challenge (Brockhaus and Kambire 2009). Hence co-management and other decentralization of forest management, while having the potential to reduce vulnerabilities identified in this chapter, face significant barriers in realizing their potential.

4.6 Conclusions

- Despite uncertainties associated with current climate and ecosystem model projections, the associated changes in the provision of forest ecosystem services are expected to be significant in many parts of the world.
- The vulnerability of forest systems is related not just to the direct and indirect impacts of climate change, but also to anthropogenic impacts, particularly land-use change and deforestation, which are likely to be extremely important in many parts of the world. These will present significant social and economic challenges for affected communities and society as a whole, particularly among the forest-dependent poor, who are already highly vulnerable in many countries throughout the world, especially in the tropical and subtropical domains.
- Economic studies of climate change rely on climate and ecological modelling to determine how changes in climate variables influence important ecological drivers of annual timber output. Some of the most important factors that have been modelled to date are: changes in the growth of timber as a result of changing net primary productivity or biomass production; changes in disturbance patterns; changes in the geographic distribution of species. The results of most studies suggest that climate change will increase timber production globally, although output could decline in some regions and during some time periods. While reductions in output or reductions in timber prices will have negative effects on timber producers in some regions, timber consumers will benefit from lower prices.
- Regions that appear most susceptible to climate-change impacts on timber production over the next 50 years are North America, Europe, Australia and New Zealand. Output in North America and Europe could decline in the next 50 years due to climate-induced dieback of existing stocks of timber and lower investments in timber production due to lower prices. These changes, however, are expected to be modest, with output increasing over the second half of the century. In contrast, output in Russia is expected to expand modestly through the first half of the century, with stronger increases later in the century.
- In order to understand better the regional impacts of climate change on timber outputs, it is imperative to build a better understanding of the underlying change in climate. The existing studies show that the results over the first half of this century are most susceptible to the effects of climate-related forest dieback. Anything that has a large effect on accessible stocks in regions that currently produce

a large portion of the world's timber will have large impacts on markets. Thus stronger dieback effects in temperate and boreal regions would lead to larger negative impacts in those regions and globally.

- Non-timber forest products are important sources of income and livelihood security for forest-dependent people, and often provide a 'safety net' for agricultural communities during periods of economic stress due to crop failures that may become more common as a result of climate change. Efforts to promote sustainable management, local processing and marketing of non-timber forest products can help to enhance incomes and buffer agricultural livelihood impacts of climate change.
- Changing forest structure and plant and animal species composition may present opportunities for utilization of new forest species in some regions, but decrease availability of non-timber products for sustenance or commercial use derived from species that will become rarer. Taking advantage of opportunities and reducing vulnerabilities associated with changing availability of non-timber forest products may require new approaches to forest management to sustain their productivity and special measures, such as ex-situ conservation and development of domestication/ cultivation practices for key non-timber forest products, e.g. for high-value tree and other plant species in agricultural, agroforestry and silvo-pastoral systems.
- Potential impacts of climate change on non-wood forest products and other services provided by forests are not well researched. Consequently the contribution of forests to adaptive capacity of local communities are not well understood. More work is needed to generate the information on forest-related adaptation strategies.
- Both extremes of very wet and dry conditions predicted for water availability have major socio-economic implications on human well-being and land-use change patterns (e.g. agriculture, urban activities, waste-water disposal), which may place further pressure on forests (through their conversion and/or degradation) and negatively affect their capacity to provide key regulating services.
- The projected increases in the frequency and intensity of forest fires in many parts of the world will have clear impacts on human health if not prevented or mitigated. The predicted alterations of forest landscape and forest biodiversity as a result of climate change may reduce access to forest products. Such losses can also affect people's health directly, via lower medicinal plant availability, or indirectly, via loss of potential marketed goods and, over time, loss of indigenous knowledge and unique cultural uses of such products.
- Gaining an understanding of the disease implications of climate change in forested areas is particularly difficult, because much of the literature on disease does not specify whether the area is forested or not. However, it is expected that changes in temperature and rainfall will change the distribution of disease vectors; particularly worrisome in forested areas are malaria, dengue and diarrhoea. Sea level rise can threaten low-lying coastal forest populations, particularly where economic conditions do not allow adequate control measures.
- Climate-change impacts on forest can be exacerbated by lack of sustainable forest management and governance structures which in turn will exacerbate the socio-economic vulnerabilities. The highlighted vulnerabilities and socio-economic impacts on forests are likely to be exacerbated in situations where forests are over-exploited. It is argued that vulnerabilities are transmitted through the mechanisms of skewed land ownership and lack of accountability. Continuing trends of unaccountable decision-making is likely to make adaptation to climate change more difficult.
- Failure of governance structures to promote sustainable forest management has the potential for reducing forest ecosystem services induced by climate-change impacts, exacerbate conflict and non-cooperation over remaining resources, and eventually create downward spirals of unsustainable resource use and well-being of those dependent on them. It is likely that climate change can aggravate already existing conflicts in the forest sector, or deepen the conflict between forests for conservation and forests for livelihoods.

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