1 Forest Ecosystem Services: A Cornerstone for Human Well-Being

Coordinating lead author: Bastiaan Louman

Lead authors: Andreas Fischlin, Peter Glück, John Innes, Alan Lucier, John Parrotta, Heru Santoso, Ian Thompson and Anita Wreford

1.1 Justification

The Intergovernmental Panel on Climate Change (IPCC 2007a) presents evidence that the climate is changing. Emission of greenhouse gasses is the main anthropogenic cause of climate change (IPCC 2007a), and the degree to which societies are able to reduce these emissions (defined as mitigation, see glossary) will affect the size of future changes. Regardless of mitigation activities implemented, today or in the near future, the planet will still experience a certain degree of change due to historical emissions and inertia in the climate system. Sea level rise, melting of the polar ice caps and increased frequency of severe fires, pests and storms are some of the effects that have already been attributed to changes in climate and its variability (IPCC 2007a; see also Chapter 2 for a more extensive discussion of past impacts and vulnerabilities). Some of these phenomena have caused serious social stress and have shown the need to be better prepared for future changes. Because of this, it is essential that individuals, societies and institutions are aware of the likely changes and have strategies in place to adapt to a changing climate.

Forests and the goods and services they provide are essential for human well-being. The assessment of the likely impacts of climate change on forests and forest-dependent people and their vulnerabilities are thus important for enhancing climate change adaptation. It also forms the basis for developing adaptation options to avoid harmful effects of climate change and to take advantage of opportunities provided by it. This report provides an assessment of the current knowledge concerning the following questions:

- What are the interrelations between forest ecosystems and the services provided by them, and the climate?
- What are the past and future climate change impacts on and vulnerabilities of forest ecosystems and the people that depend on them?
- What are the management and policy options for adaptation?

The present report is based on information and knowledge published in the scientific literature as well as from reliable sources of traditional and technical knowledge. It consists of three parts: an *introduction*, which presents the conceptual framework used for the assessment (Chapter 1). The second part deals with *past and future impacts and vulnerabilities*. Past observations of impacts, vulnerabilities and adaptations are discussed in Chapter 2. The future environmental and socio-economic impacts and vulnerabilities are discussed in Chapters 3 and 4 respectively. In the third part, current *adaptation measures and policies* are summarized in Chapter 5 and a range of forest management and forest policy options for adaptation are presented in Chapters 6 and 7. Chapter 8 sums up the main conclusions, knowledge gaps and research needs.

The report aims to provide knowledge for enhancing the adaptive capacity of both forests and people to the impacts of climate change. At the same time, scientific input into policy processes cannot be limited to the production of a written report, but rather has to be seen as a socially interactive process (Guldin et al. 2005). Consequently, the authors of this report expect that through their involvement in this process they may contribute to the development of strategies with key actors, raise the visibility of adaptation of forests to climate-change impacts on the policy agenda of the UNFF (United Nations Forum on Forests) and other international policy fora.

1.2 Concept of Adaptation

In this report, IPCC's (Intergovernmental Panel on Climate Change) universally recognized definition of adaptation is followed (IPCC 2007b, p. 869, see also glossary): 'Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. Adaptation may be anticipatory or reactive, autonomous or planned. Biological adaptation is autonomous and reactive: organisms respond over time to changing conditions. People, on the other hand, may show autonomous adaptation in response to changes, or plan for adaptation either in response to changes (both reactive) or to reduce vulnerability or enhance resilience in anticipation of expected changes (anticipatory adaptation) (Adger et al. 2007). For example, planning to strengthen water works in anticipation of expected sea-level rise is anticipatory adaptation. Actual adaptations in forests and forestry practices are mainly reactive and autonomous (see Chapter 2) and depend on locally experienced changes and vulnerabilities. This report, however, stresses that the expected changes (Chapter 3 and 4) require planned anticipatory adaptation (Chapters 5, 6 and 7) partially based on learned lessons and slight adjustments of current practices, but in other cases requiring new, out of the box thinking.

Planned adaptation is based on expected changes. Projections of such changes on a local level may not be very accurate (see also Chapter 3) or may be poorly understood. This introduces the risk of maladaptation. Strategies to reduce the risk of maladaptation are discussed in chapters 5, 6 and 7.

Many adaptation strategies focus on reducing vulnerability, or strengthening the ability to capture the benefits from the effects of change. Vulnerability is therefore strongly related to adaptation. It has been defined (Metzger et al. 2006, IPCC 2007b, see also glossary for more detailed definition) as a function of exposure, sensitivity and adaptive capacity. Adaptation strategies oriented at reducing vulnerability can therefore include (Adger et al. 2007):

Altering the exposure of a system, through for example, investing in hazard preparedness and early warning systems, such as seasonal forecasts.

Reducing the sensitivity of the affected system (degree to which a system is affected, see glossary) through, for example, planting hardier crops, increasing reservoir storage capacity, or ensuring that infrastructure in flood-prone areas is constructed to allow flooding.

Increasing the resilience (ability to absorb disturbances, see glossary) of social and ecological systems, through specific measures which enable populations to recover from loss.

The potential vulnerability of a system to climate change will depend on that system's ability to adapt appropriately in anticipation of the hazard (Brooks et al. 2005), which will depend on the adaptive capacity of the system. Adaptive capacity is a function of different elements, including the ability to modify exposure to risks associated with climate change, to absorb and recover from losses stemming from climate impacts, and to exploit new opportunities that arise in the process of adaptation (Adger and Vincent 2005). Forest ecosystems with greater diversity usually show a greater adaptive capacity (SCBD 2003, Fontaine et al. 2005), being able to adapt in a variety of ways to different changes, although large disturbances may affect highly diverse systems as much as those of low diversity, preventing the system from recovering its original state (Walker et al. 2006).

It is often assumed that societies with a higher level of economic development have a higher adaptive capacity. However, evidence from traditional societies demonstrates that the capacity to adapt in many senses depends more on experience, knowledge and dependency on weather-sensitive resources: economically little developed forest-dependent indigenous people in the south-west Amazon, for example, may have a greater adaptive capacity than the economically more sophisticated people living in the Andes, who rely on rain-dependent agricultural practices. Adaptation can involve both building adaptive capacity and implementing adaptation decisions, i.e. transforming the capacity into action (Adger et al. 2005).

1.3 Conceptual Framework for the Report

1.3.1 Forest Ecosystem Services and Human Well-Being

Humans use forests for many purposes, and the products derived from forests, and their benefits, are referred to as 'forest goods and services' (MEA 2005). Generally the services fall into four groups: supporting, provisioning, regulating, and cultural services (Diaz et al. 2005, Fischlin et al. 2007) (Figure 1.1). Although forest goods are the result of provisioning services, they are usually mentioned separately, being more tangible than the other services. This value chain includes wood and wood products such as fuelwood, paper, charcoal and wood structural products, and non-wood products (foods and plant products) such as rattan, mushrooms, nuts and fruits, honey, bushmeat, rubber and biochemicals. Forest services refer to benefits provided to humans, many of which have so far no readily assigned economic value. The

Erkki Oksanen: Boreal forest, Finland

Photo1.1 Forests provide multiple tangible and intangible benefits. The same forest area can for example provide wood, non-wood forest products such as wild berries, clean water and an environment for recreation.

main services from forest ecosystems include: habitat provision, clean water, flood protection, carbon sequestration and storage, climate regulation, oxygen production, nutrient cycling, genetic resources for crops, and spiritual, cultural, recreational and tourism values.

While some of these goods and services may also be provided for by other ecosystems (Campos et al. 2005, Fischlin et al. 2007), the contribution of forest ecosystems to these goods and services has a significant economic value, with global trade in primary wood products valued at around USD189 billion in 2005 (FAO 2006). Nevertheless, many of the ecosystem services and a large part of the non-timber forest products are not accounted for in national product calculations (section 4.5 in Fischlin et al. 2007) but yet have value. For example, carbon sequestration is a service provided by plants and algae – a part of biodiversity – occurring in forests. While this service had no assigned value until the 1990s, in 2008 the carbon market grew to a worth of over USD 60 billion (Bull 2008). Another example of a forest good that often has no monetary value and is rarely included in calculations of national product is clean water. Regardless of whether or not forest goods and services are assigned economic values, they provide many people with a source of livelihood and generally directly affect human well-being and are especially important for the large number of forest-dependent communities (Kaimowitz 2002, CBD 2008).

Biodiversity is a cornerstone for the provision of many of the ecosystem services (Figure 1.1) (Campos et al. 2005, CBD 2008), although many of the supporting and some of the regulating services are necessary for maintaining biodiversity. The relationship between production and species diversity is, however, not as well understood. For example, not all species contribute equally within systems – the loss of an individual tree species from a forest ecosystem does not necessarily result in a reduction in productivity, especially in diverse systems (Gitay et al. 2002, SCBD 2003). Nevertheless, the functional components of biodiversity are linked to ecosystem production (Diaz and Cabido 2001, Diaz et al. 2005) and the loss of key functional species from forest systems will generally reduce certain goods and services produced by that system (Hooper and Vitousek 1997, Tilman et al. 1997, Diaz et al. 2005). Differences in composition, structure and diversity of forests may therefore mean that forests show differences in the provision of goods and services.

Global forests are highly diverse with many distinct forest types recognized under various classification schemes. The abundance of forest types is related to latitude and altitude, with greater diversity

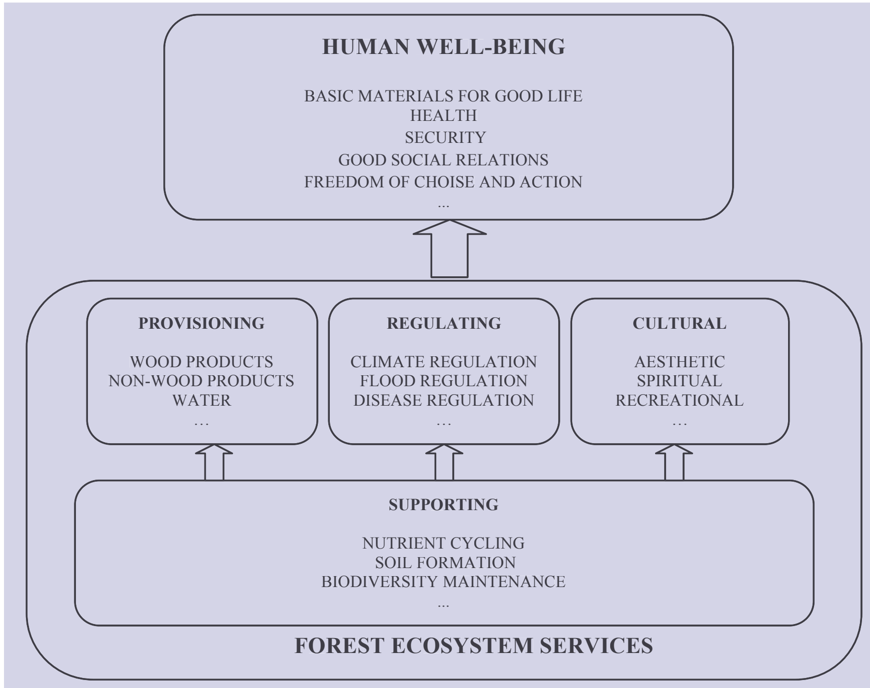

Figure 1.1 Ecosystem goods and services and their relation to well-being (modified from MEA 2005).

Table 1.1 Forest types recognized and number of ecoregions identified in Olsen et al. (2001).

Forest type	Ecoregions
Tropical and subtropical moist broadleaf forest	231
Tropical and subtropical dry broadleaf forests	54
Tropical and subtropical coniferous forests	17
Temperate broadleaf and mixed forests	84
Temperate coniferous forest	53
Mediterranean forests, woodlands and shrub	39
Boreal forests/Taiga	28
Mangroves	19

at low latitudes and at lower elevations. United Nations Environment Programme – World Conservation and Monitoring Centre produced a map based on 26 forest types divided between tropical forests (13 plus 2 plantation types) and non-tropical forests (9 plus 2 plantation types) (UNEP-WCMC 2000). For Forest Resources Assessments, the FAO (Food and Agriculture Organization of the United Nations) uses 13 forest types: 4 tropical, 3 subtropical, 3 temperate and 3 boreal (FAO 2001). Within each forest type, regardless of the classification hierarchy used, there are multiple ecoregions (Olsen et al. 2001) (Table 1.1.). Tropical regions maintain about 2.5 times the number of recognizable ecoregions than temperate regions and 10 times the number found in boreal forests, indicating their high level of species richness and diversity.

Ecosystem services and their relation to the constituents of well-being (Figure 1.1) may vary between different ecoregions, just as exposure, sensitivity and adaptive capacity may also differ, in turn affecting the optimum recommendations for forest management and policies. In some ecoregions flood regulation may be the main service. In other ecoregions, it might be providing personal safety and allowing local people to obtain basic material for a good life from their immediate surroundings. Or primary production and the subsequent provision of fuelwood and timber may be the most important services for local human well-being. However, for the purposes

John Parrotta: Western Ghats, Kerala, India

Photo 1.2 Biodiversity is the foundation for the provision of many ecosystem services such as water regulation. At the same time many of the supporting services and some of the regulating services are needed for maintaining biodiversity.

of this report it is impossible to describe vulnerability, management and policy options for each different ecoregion. The Expert Panel has therefore opted for a very rough global approach, recognizing only four global forest types, following the FAO classification: tropical, sub-tropical, temperate and boreal (see Chapter 3 for a more detailed description of each forest type and their main goods and services). Further specifications will be made only in those cases where evidence of different approaches within these global forest types exists.

While a relatively large amount of information is available on the effects of climate change on these four different global forest types (Chapter 3) and conclusions can be drawn on general strategies per forest type (Chapter 5), no correspondingly wide information is available by forest type on the impacts on and vulnerabilities of social systems, nor on specific adaptation options. As a result, Chapters 4 and 6 concentrate on services, rather than forest types, referring to forest types only where sufficient information is available. Chapter 7 analyses the effectiveness of policy instruments at the national and international level for forest adaptation and describes what steps can be taken to strengthen forest governance for the provision of forest ecosystem services.

1.3.2 Climate Change and Forest Ecosystem Services

Forests play an important role in the emission of greenhouse gases: about 20% of the total carbon emissions come from forest cover loss and forest degradation (Houghton 2003, Houghton 2005, Denman et al. 2007, IPCC 2007c). In countries experiencing high rates of forest loss, such as Brazil, land-use change was estimated to contribute up to 75% of all CO_2 emissions in 1994 (GCGCC-MST 2004). Carbon sequestration and carbon storage are important forest ecosystem services oriented at reducing or compensating for these emissions (mitigation), and the loss of this service may influence the level of climate change. Avoiding deforestation (avoids emission) and increasing the forest biomass (carbon sequestration) have therefore great mitigation potential (Kanninen et al. 2007, Nepstad et al. 2007), but their success in doing so will also depend on the sensitivity and adaptive capacity of the resulting natural systems (Guariguata et al. 2007).

Forests and their conservation or loss influences climate, and climate in its turn is a key driver of the changes in forest ecosystems. Changing CO_2 levels in the atmosphere, changing temperatures and precipitation, or changes in the frequency of extreme events, may affect forests in a number of different ways (e.g. temperature and moisture affect growth rates, changes in natural disturbance regimes may affect species composition). Together with existing socioeconomic processes (e.g. deforestation, forest fragmentation, other forms of habitat loss, population growth, income growth, urbanization), these changes may result in changes in the ecosystem services provided by forests (see Chapter 3).

Climate change has the capacity to cause ecosystems to move to new states – for example, from spruce forest to pine forest, or from forest to savannah (Nobre and Oyama 2003, Fischlin et al. 2007, Mendes 2007, Nepstad 2007). Maintaining a dynamic equilibrium and resilience over time and space is important in the continued delivery of ecosystem goods and services, independent of the level of emissions expected. In forests, this dynamic equilibrium often exists over time and across the forest landscape, as a forest undergoes both slow and fast changes but continues to supply goods and services (Walker et al. 2006, Drever et al. 2006). Resistance to change is an emergent property of forest ecosystems (Drever et al. 2006).

Ecological theory about functional redundancy predicts that a relationship exists between the capacity for resistance to environmental change and the diversity within a system (Chapin et al. 1996, Diaz et al. 2003, Walker et al. 2006). For example, a monoculture plantation may be highly susceptible to a root rot, whereas a diverse forest ecosystem with many tree species is less prone to decline from the same pathogen. Hence, highly diverse systems tend to be more resistant to change than simpler systems (SCBD 2003, Fontaine et al. 2005), including resistance to invasion by alien species (Mack et al. 2000). In part, this stability is due to the level of connectedness within the system and the lack of available niches in diverse systems (Hooper et al. 2005, Diaz et al. 2005), and also to the level of genetic variability that can allow systems to adapt to change (Joshi et al. 2001, Davis and Shaw 2001, Davis et al. 2005).

The relationship between biodiversity and resilience is unclear (Schmid et al. 2002), however; systems that have moved to new states as a result of some perturbation find it difficult to recover because of changes in biodiversity and in associated ecosystem processes (Walker et al. 2006, Gunderson and Holling 2002). Such highly altered systems are unlikely to continue to provide the same levels or types of goods and services as they did prior to disturbance, e.g. as when forest changes to grassland (SCBD 2003, Diaz et al. 2005). Hence, protection of the biodiversity in the system is an important means to assist communities to adapt to climate change (Diaz et al. 2005, Drever et al. 2006).

The scale and intensity of ecosystem change will depend on the level of exposure as well as on the adaptive capacity of the forests (e.g. high diversity, adaptation to fire, nature of ecological processes). It is therefore important to consider the different emission scenarios of the IPCC (2007a), each of which may imply different levels of exposure. In Chapter 3 four scenario clusters are presented to simplify this vast range of options for the discussions in this report: unavoidable, stable, growth and fast growth.

Adaptation involves changes in how services are being affected by climate change, as well as in the way that services relate to human well-being. Generally, when climate conditions change, as they have often in the past, depending on the severity of the change, species must adapt (genetically or behaviourally) or migrate to follow and find suitable conditions (Jansen et al. 2007, Fischlin et al. 2007). Forest ecosystems can tolerate some change (Fischlin et al. 2007) but if resistance is overcome this may have severe consequences for the nature of, in particular, the supporting services as well as for the availability of the other services locally and in some cases also at the regional and global level (Diaz et al. 2005, 2006).

These changes may have a negative or positive impact on the constituents of well-being, depending also on the nature of the relation between service and constituent as well as on the vulnerability of the social system studied (Figure 1.1 and Chapter 4). Some of the relations between services and constituents of well-being are stronger than others (for example, the relation between provisioning services and basic material for good life and health, or those of the regulating services with security, basic material and health), and changes in these services may have a greater impact on human well-being.

Current socioeconomic processes are biased towards modifying the relation between provisioning goods and basic materials for a good life (Figure 1.1), but future adaptation practices will need to address all services as well as their relations to the different constituents and the balance between those constituents. Chapters 5, 6 and 7 summarize existing experiences on anticipatory and reactive adaptation strategies to reduce exposure (e.g. mitigation, windbreaks), reduce sensitivity (e.g. less change with same exposure, or less dependency on one or few forest ecosystem services) or increase adaptive capacity (e.g. increased technology, diversity of genetic resources, governance that balances individual freedoms of choice and action).

1.3.3 Forest Users, Vulnerabilities and Adaptations

The variety of forest users in the world is enormous. Broad groups of users are society, governments and companies as well as private forest owners and lo-

Matti Nummelin: Belayara, Niger

Photo 1.3 The vulnerability and priorities of different forest users in relation to changes in the environment vary. For the poorest the immediate priority may be to secure livelihoods and protect assets from climate and other risks.

cal communities. The last category can be roughly subdivided into those who live in the forests, those who live in an area with an active agricultural frontier, and those in areas where the agricultural frontier has passed many years ago. Each of these groups show different vulnerabilities to changes in their environment, which may also differ according to their geographical location and cultural background. The factors that affect vulnerabilities (as a function of exposure, sensitivity and adaptive capacity) may also vary widely between the user groups. For example, poorer people with low geographic mobility will be more vulnerable to the impacts of climate change and need tailor-made strategies of forest management and policies to reduce their vulnerability (Reid and Huq 2007).

Which adaptation options, or combinations of adaptation options, are chosen, will depend largely on vulnerabilities, which are among other things determined by the social and economic situation of households and communities, their physical location, their networks of relationships (social and economic) and their access to resources and power. This provides us with an enormous array of adaptation options that cannot all be dealt with in this report. Chapters 6 and 7, therefore, should be read keeping in mind the main target groups at which adaptation strategies and specific options are directed.

Sustainable forest management (SFM) has been described by the UN (United Nations) (UN 2007, see also glossary) as 'a dynamic and evolving concept, aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations'. Forest management is one of several factors that, together with land-use change, may influence the effects of climate change in forests (Fischlin et al. 2007). SFM aims to contribute to sustainable development. The IPCC Fourth Assessment Report concluded that sustainable development can reduce vulnerability to climate change by increasing resilience and enhancing adaptive capacity (Yohe et al. 2007, Adger et al. 2007). SFM can thus play an important role in adaptation to climate change, in particular where SFM is embedded in an array of sustainable land uses within a landscape and where it considers the different expectations, vulnerabilities and capacities of the different actors within that landscape (Table 1.2).

While the influence of climate change on forest ecosystems poses new questions about how SFM can be achieved, the principles and practice of SFM embodies many of the activities that will be required to respond to the effects of climate change on forests (Ogden and Innes 2007, Spittlehouse and Stewart

Table 1.2 Illustration of differences in forest dependence, vulnerability to the impacts of climate change and factors affecting the vulnerability of different forest user groups using the example of the State of Pará, Brazil (own elaboration based on information from Galloway et al. 2005, Lentini et al. 2005, Chomitz 2007, Mendes 2007, Nepstad 2007, Sabogal et al. 2008).

User group	Main goods and services	Level of vulnerability	Factors affecting		
			Exposure	Sensitivity	Adaptive capacity
Federation	Biological diversity; timber and non-timber products; emission reductions; hydro-electric energy	Low for some goods and services, high for others	Geographic location; GHG emissions	Deforestation and un-controlled logging increases sensitivity	Mobility of resources; accessibility to technology, human and financial resources; diversity of land uses; biological diversity
State government (e.g. Pará)	Biological diversity; timber and non-timber products; emission reductions	Medium to high	Geographic location; GHG emissions	Deforestation and un-controlled logging increases sensitivity	Limited mobility; limited access to technology and resources; limited diversity of land uses
Logging companies	Timber	High	Geographic location; GHG emissions	Demand for timber; unauthorized forest conversion; forest degradation	Limited mobility and access resources; SFM and diversification of species harvested may increase adaptive capacity and reduce sensitivity
Forest communities in Pará	Timber and non-timber forest products; drinking water; soil restoration	High to very high	Geographic location; GHG emissions	High dependence on forest products and services in an area of high potential exposure	Diversity of uses; maintenance of biodiversity; very limited mobility and access to resources
Communities outside forests in Pará	Some timber and non-timber forest products; energy from wood	High to very high	Geographic location; GHG emissions	Market demand for agriculture products; poor soil management	Very limited mobility and access to resources; limited diversity

2003). For example, social, environmental and economic objectives are intricately linked and therefore adaptation and SFM decision-making must consider these multiple objectives (Burton et al. 2002, Sayer and Campbell 2004).

If SFM is to play an important role in adaptation to climate change, it will be necessary to develop, disseminate and apply a greater variety of management options, adaptable to different site conditions, considering the different thematic elements of SFM and backed-up by sound and coherent natural resource policy frameworks. These are the main focus of Chapters 6 and 7. The Expert Panel, however, recognizes that many production forests of the world, in particular in the tropics, are not managed on a sustainable basis and that there is still a long way to go to ensure good management in such forests. For this to happen, some basic conditions will need to be met, among them security of land tenure and property rights in general, availability of human and technological resources, a healthy and productive forest, and institutional frameworks (including markets) that facilitate forest management (Poore 1989, Smith et al. 2006). In addition, a broader intersectoral and participatory multistakeholder approach to forests and their management is needed to facilitate adaptation of the forest sector to changing conditions (Sabogal 2008), including those driven by climate change. New forms of governance (see Section 1.3.4 and Chapter 7) are among the main requirements to improve these enabling conditions for SFM.

Because an increasing number of forests are now being managed as elements of a landscape, SFM is becoming one of the elements of landscape or ecosystem management, taking into consideration its interactions with other land uses and users within the same geographically delimited area. Indeed, the recent trends in SFM lend themselves well to the application of the principles of the CBD's ecosystem approach (CBD 2000, Wilkie et al. 2003), although the latter usually lacks tangible objectives, concerns a geographical broader area, is cross-sectoral and puts a greater emphasis on integrating conservation and use of biodiversity (Sayer and Maginnis 2005).

1.3.4 Governance, Adaptation and Adaptive Capacity

The diverse and sometimes incompatible values held by the actors involved in decision-making around adaptation can mean that, despite the recognized IPCC definition of adaptation, the specific goals of adaptation in individual circumstances may not be consistent between actors. The values that underpin adaptation decisions become more diverse and contradictory as one moves from smaller scales and single actors to larger scales and multiple actors, as in the case of landscape or ecosystem management. This is more apparent in planned adaptation, where different actors have experienced or expect different effects of climate change on their livelihoods and therefore may have different goals. However, it also holds for autonomous adaptation, where actors may get into conflict based on the different ways they adapt to the effects of climate change.

For some actors adaptation means conservation of the status quo, while for others the current situation is undesirable and so adaptation is about progress. For example, well-developed institutions and wealthier societies or individuals may seek to maintain their current situation or standard of living through adaptation, while developing countries may aim to continue development and enhance the standard of living of their citizens. For those on the margins of society, the immediate priority may be to secure livelihoods or protect assets from climate and other risks (Rappaport 1977).

For adaptation to contribute to sustainable development, social groups of different vulnerabilities (Table 1.2) will have to agree on the appropriate decisions, their implementation and their monitoring at different levels – international, national and local. This requires a change from traditional top-down decision- and policy-making, towards multi-level information sharing, transparent decision-making, accountability, well-defined access and property rights and collaboration between the different actors or actor groups. This new type of environmental governance is discussed in more detail in Chapter 7.

1.3.5 Uncertainty and Scenarios

Providing an assessment on the current knowledge concerning forests, climate change impacts, and adaptation practices and options requires a synthesis of available information from laboratory and field experiment results, meta-analysis reviews of the scientific literature and integrated modelling analyses,. It also requires the drawing of conclusions or findings from that available information, including the authors' experience and judgment. Assessment reports such as this Expert Panel Assessment Report integrate a wide variety of information, from analytical studies to surveys to working reports. In developing a finding or determining the likelihood of an outcome, several lines of supporting evidence may exist. For quantitative analyses, expert judgment is used to assess the correctness of the underlying data, models and analyses in order to assess the chances of a finding being correct; e.g. temperature will warm. For some areas, such as adaptation practices, the literature may not yet be available to support definitive conclusions about their effectiveness. Here, authors will be drawing from associated literature and developing a conclusion based on it.

It is important to note that in an ideal world, managers would have perfect information about future climate at a particular location. This does not exist. Instead, analyses based on numerous climate and economic models suggest the changes in climate that might occur if a particular trajectory of global economic development and global mitigation strategies is adopted. With any given global climate model, each trajectory involves different future climates at particular locations based on different economic futures. Uncertainty is also introduced by the differences in the outputs of different global climate models for specific economic trajectories. As a result, while certain changes can be suggested from the unavoidable scenario group (see Chapter 3), it is impossible to project future climate changes precisely, either globally or locally. As climate change considerations are set out, uncertainties can arise on the understanding of the forest response to climate change, the completeness to which the management response of the forest is known, the extent of interactions with current stressors such as air pollution, the potential for interactions with the market and on the time span for which projections are made.

As such, there is a limit to the scientific understanding of how well adaptation options will succeed under the different groups of scenarios of climate change discussed in Chapter 3. For that reason, the Expert Panel has decided to follow the IPCC approaches in the following manner:

- When assessing literature about past observations and future potential impact and vulnerabilities associated with climate change, the following scale of confidence levels is used to express the assessed confidence of a finding being correct: very high confidence at least 9 out of 10; high confidence about 8 out of 10; medium confidence about 5 out of 10; low confidence about 2 out of 10; and very low confidence less than 1 out of 10 (IPCC 2007d).
- When assessing literature about adaptation options, uncertainty is characterized by providing a relative sense of the amount and quality of evidence (that is, information from theory, observations or models indicating whether a belief or proposition is true or valid) and the extent of agreement (that is, the level of concurrence in the literature on a particular finding). This approach is used by WG III of the IPCC fourth assessment through a series of self-explanatory terms such as: high agreement, much evidence; high agreement, medium evidence; medium agreement, medium evidence, etc. (IPCC 2007d).

Time is of critical importance for adaptation: it influences the level of exposure to climate change (over time effects increase) as well as our and the forests' capacity to adapt. In addition, the further in time our projections, the greater the uncertainty involved in the projections. For the purpose of this report, the Expert Panel identified the following general categories: immediate, short-term, medium-term and long-term. The perceptions regarding these timescales, however, may vary according to the main thematic areas of the report, between the different scientific disciplines involved and according to the needs of different forest user groups. The Expert Panel decided, therefore, to use absolute figures (number of years) as well, whenever possible.

1.4 Limitations of the Study

1.4.1 Other Factors Affecting Ecosystem Services

Climate change results in changes in ecosystem functions and the ecosystems' capacity to provide society with goods and services, affecting society's options for socioeconomic development. On the other hand, stakeholders' priorities define the type and quantity of goods and services used, indicating directly or indirectly which functions and biophysical attributes are most relevant for society, and therefore which ones may be under pressure and need to be managed and conserved. To serve society better in the long term, policies need to consider adaptation needs and redirect stakeholders' priorities in such a way that their use of goods and services does not affect the functions and attributes of the ecosystems to the extent that their capacity to provide the relevant goods and services is diminished.

Within this context, it is important to recognize that many factors, other than climate change, may also affect forest ecosystems' capacity to provide goods and services, including natural disturbance regimes (fires, insect and disease outbreaks, wind storms, etc.), which may also be affected by climate change and current climatic variability. In addition, stakeholders' priorities that affect the capacity of forest ecosystems to provide goods and services on a sustainable basis are and will continue to be driven by other factors than climate change and forest policies (such as markets for agricultural products, land-tenure policies, infrastructure) (Spittlehouse 2005). While the Expert Panel recognizes the need to consider these other factors in conjunction with climate change, their importance and interaction with climate change differs greatly between different natural and social systems. The Expert Panel decided, therefore, not to discuss these interactions, unless it was necessary to have a better understanding of impacts, vulnerabilities or adaptation options discussed.

1.4.2 Large-Scale Predictions Must Lead to Local Solutions

Adaptation must be local, while the reliability of projections of climate change effects decrease with scale, in particular in areas with limited data and more so for projections of rainfall rather than temperature. On the other hand, reliability for regional and local projections increases for models that allow for inclusion of more locally significant climate system processes, such as vegetation-atmosphere relations or cloud feedback (Randall et al. 2007). One of the big challenges remains, therefore, to select the right scenario and right adaptation option for a particular site.

Due to the limited time for this study and the enormous amount of information available on climate change and adaptation, it is impossible to include analyses of all possible scenarios in all forest types and under different social-economic and political settings. This report is therefore general in nature, highlighting some of the common adaptation strategies and providing examples through the use of boxed case studies. Some of these have shown that the main factor allowing for successful adaptation is local adaptive capacity through strong social and human capacities. This report will be particularly useful for those countries and project areas where these capacities exist and where the appropriate adaptation strategies can be locally selected out of the multiple options presented here.

1.4.3 Need for Action despite Lack of Information

Adaptation studies are relatively recent and while many promising experiences exist, only a few have documented evidence of their success as an adaptation strategy. This is especially true for adaptation strategies in the tropics. This assessment can provide only a picture of the experiences to date, and it is expected that similar studies five to ten years from now will give much greater insight into the effectiveness of different adaptation strategies. Climate change is progressing too fast, however, to allow for the luxury to wait and see for the results of future studies. In an assessment of climate prediction and adaptation to climate change, Dessai et al. (in press) argue that society can (and indeed must) make adaptation decisions in the absence of accurate and precise climate predictions.

References

Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B. & Takahashi, K. 2007. Assessment of adaptation practices, options, constraints and capacity. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (eds.). Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK. p. 717–743.

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

Adger, W.N. & Vincent, K. 2005. Uncertainty in adaptive capacity. Comptes Rendus Geosciences, 337(4): 399–410.

Brooks, N., Adger, W.N. & Kelly, P.M. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change 15(2): 151–163.

Bull, G.Q. 2008. The global carbon market. Canadian Silviculture, May: 7–10.

Burton, I., Huq, S., Lim, B., Pilifosova, O. & Schipper, E.L. 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. Climate Policy 2: 145–159.

Campos, J.J., Alpizar, F., Louman, B., Parrotta, J. & Porras, I.T. 2005. Chapter 6: An integrated approach to forest ecosystem services. In: Mery, G., Alfaro, R., Kanninen, M., Lobovikov, M. (eds.). 2005. Forests in the Global Balance – Changing Paradigms, IUFRO World Series vol. 17. Helsinki. p. 97–116.

CBD 2000. Ecosystem Approach. Decision V/6 of the 5th Conference of the Parties Nairobi, 15–26 May, 2000. Available at: http://www.cbd.int/decisions/cop5/?m=COP-05&id=7148&lg=0. [Cited 9 Dec 2008].

CBD 2008. Forest biodiversity. [Internet site]. Available at: http://www.cbd.int/forest/about.shtml. [Cited 21 Jul 2008].

Chapin, F.S., Reynolds, H.L., Antonio, C.M.D. & Eckhardt, V.M. 1996. The functional role of species in terrestrial ecosystems. In: Walker, B. & Steffen W. (eds.). Global change and terrestrial ecosystems. Cambridge University Press, Cambridge, UK. p. 403–428.

Chomitz, K.M. 2007. At loggerheads? Agricultural expansion, poverty reduction, and environment in the tropical forests. A World Bank Policy Research Report. The International Bank for Reconstruction and Development/The World Bank, Washington DC, USA. 284 p.

Davis, M.B. & Shaw, R.G. 2001. Range shifts and adaptive responses to Quarternary climate change. Science 292: 673–679.

Davis, M.B., Shaw, R.G. & Etterson, J.R. 2005. Evolutionary responses to changing climate. Ecology 86: 1704–1714.

Denman, K.L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P.M., Dickinson, R.E., Hauglustaine, D., Heinze, C., Holland, E., Jacob, D., Lohmann, U., Ramachandran, S., da Silva Dias, P.L., Wofsy, S.C. & Zhang, X. 2007. Couplings between changes in the climate system and biogeochemistry. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller, H.L. (eds.). Climate change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, NY, USA. p. 499–587.

Dessai, S., Hulme, M., Lempert, R.J. & Pielke, Jr. R. In press. Climate prediction: a limit to adaptation? In: Adger, W.N., Lorenzoni, I. & O'Brien, K. (eds.). Adapting to Climate Change: Thresholds, Values, Governance. Cambridge University Press, Cambridge.

Diaz, S. & Cabido, M. 2001. Vive la difference: plant functional diversity matters to ecosystem functioning. Trends in Ecology and Evolution 16: 646–655.

Diaz, S., Fargione, J., Chapin, F.S. & Tilman, D. 2006. Biodiversity Loss Threatens Human Well-Being. PLoS Biol 4(8): e277. DOI:10.1371/journal.pbio.0040277.

Diaz, S., Synstad, A.J., Chapin, F.S., Wardle, D.A. & Huenneke, L.F. 2003. Functional diversity revealed in removal experimentation. Trends in Ecology and Evolution 18: 140–146.

Diaz, S., Tilman, D., Fargione, J., Chaopin, F.S., Dirzo, R., Kitzberger, T., Gemmill, B., Zobel, M., Vila, M., Mitchell, C., Wilby, A., Daily, G.C., Galetti, M., Laurance, W.F., Pretty, J., Naylor, R., Power, A. & Harvell, D. 2005. Biodiversity regulation of ecosystem services. In: Hassan, R., Scoles, R. & Ash, N. (eds.). Ecosystems and Human Well-Being: Current State and Trends. Millennium Ecosystem Assessment Volume 1. Island Press, Washington, DC. p. 297–329.

Drever, C.R., Peterson, G., Messier, C., Bergeron, Y. & Flannigan, M. 2006. Can forest management based on natural disturbances maintain ecological resilience? Canadian Journal of Forest Research 36: 2285–2299.

FAO 2001. Global Forest Resources Assessment 2000. Main report. FAO Forestry Paper 140. FAO, Rome. Available at: http://www.fao.org/forestry/11747/en/ Rome, Italy. [Cited 8 Dec 2008].

FAO 2006. Global Forest Resources Assessment 2005. Progress towards sustainable forest management. FAO Forestry Paper 147. FAO, Rome, Italy. 320 p.

Fischlin, A., Midgley, G.F., Price, J.T., Leemans, R., Gopal, B., Turley, C., Rounsevell, M.D.A., Dube, O.P., Tarazona, J. & Velichko, A.A. 2007. Ecosystems, their properties, goods and services. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (eds.). Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK. p. 211–272.

Fontaine, C., Dajoz, I., Meriguet, J. & Loreau, M. 2005. Functional diversity of plant pollinator interaction webs enhances the persistence of plant communities. PLoS Biology 4: 129–135.

Galloway, G., Kengen, S., Louman, B., Stoian, D., Carrera, F., Gonzalez, L. & Trevin, J. 2005. Chapter 15: Changing paradigms in the Forestry Sector of Latin America. In: Mery. G., Alfaro, R., Kanninen, M. & Lobovikov, M. (eds.). 2005. Forests in the Global Balance – Changing Paradigms, IUFRO World Series vol. 17. Helsinki. p. 243–264.

GCGCC-MST (General Coordination on Global Climate Change – Ministry of Science and Technology) 2004. Brazil's initial communication to the United Nations Framework Convention on Climate Change. Ministry of Science and Technology, Brasilia, Brazil. 275 p.

Gitay, H., Suárez, A., Dokken, D.J. & Watson R.T. 2002. Climate Change and Biodiversity. IPCC Technical Paper V. IPCC, Geneva, Switzerland. 77 p.

Guariguata, M R., Cornelius, J.P., Locatelli, B., Forner, C. & Sánchez-Azofeifa, G.A. 2007. Mitigation needs adaptation: Tropical forestry and climate change. Mitig Adapt Strateg Glob Change 13: 793–808. DOI: 10.1007/s11027-007-9141-2.

Guldin, R.W., Parrotta, J.A. & Hellström, E. 2005. Working effectively at the interface of forest science and forest policy. IUFRO Occasional Paper no. 17. Vienna, Austria. 29 p.

Gunderson, L.H. & Holling, C.S. 2002. Panarchy: understanding transformations in systems of humans and nature. Island Press, Washington, DC.

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A.J., Vandermeer, J. & Wardle, D.A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monograph 75: 3–35.

Hooper, D.U. & Vitousek, P.M. 1997. The effects of plant composition and diversity on ecosystem processes. Science 277: 1302–1303.

Houghton, R.A. 2003. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850–2000. Tellus B 55(2): 378–390.

Houghton, R.A. 2005. Tropical deforestation as a source of greenhouse gas emissions. In: Moutinho, P. & Schwartzman, S. (eds.). Tropical Deforestation and Climate Change, Instituto de Pesquisa Ambiental da Amazonia, Belém, Brazil and Environmental Defence, Washington DC. p. 13–21.

IPCC 2007a. Climate change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller, H.L. (eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA. 996 p.

IPCC 2007b. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (eds.). Cambridge University Press, Cambridge, UK. 973 p.

IPCC 2007c. Summary for policymakers. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (eds.). Cambridge University Press, Cambridge, UK. p. 7–22.

IPCC 2007d. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri, R.K. & Reisinger, A. (eds.). IPCC, Geneva, Switzerland. 104 p.

Jansen, E., Overpeck, J., Briffa, K.R., Duplessy, J.-C., Joos, F., Masson-Delmotte, V., Olago, D., Otto-Bliesner, B., Pelteir, W.R., Rahmstorf, S., Ramesh, D., Raynaud, D., Rind,O., Solomina, R., Villalba R. & Zhang, D. 2007. Paleoclimate. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor M. & Miller, H.L. (eds.). Cambridge University Press, Cambridge, UK. p. 434–496.

Joshi, J., Schmid, B., Caldeira, M.C., Dimitrakopoulos, P.G., Good, J., Harris, R., Hector, A., Huss-Danell, K., Jumpponen, A., Minns, A., Mulder, C.P.H., Pereira, J.S., Prinz, A., Scherer-Lorenzen, M., Siamantziouras, A.S.D, Terry, A.C., Troumbis, A.Y. & Lawton, J.H. 2001. Local adaptation enhances performance of common plant species. Ecological Letters 4: 536–544.

Kaimowitz, D. 2002. Pobreza y Bosques en America Latina: Una Agenda de Acción. Revista Forestal Centroamericana No. 39–40: 13–15.

Kanninen, M., Murdiyarso, D., Seymour, F., Angelsen, A., Wunder, S. & German, L. 2007. Do trees grow on money? The implications of deforestation research for policies to promote REDD. CIFOR, Bogor, Indonesia. 61 p.

Lentini, M., Pereira, D., Celentano, D. & Pereira, R. 2005. Fatos Florestais da Amazônia 2005. Imazon, Belém, Brazil. 138 p.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. & Bazzaz, F.A. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Ecol. Applications 10: 689–710.

MEA (Millenium Ecosystem Assessment) 2005. Ecosystem and human well-being. Synthesis. Island Press, Washington D.C. 137 p.

Mendes, H. 2007. Brazil faces forecast of heat and dust. Science and Development Network. [Internet site]. Available at: http://www.SciDev.Net. [Cited 8 Dec 2008].

Metzger, M.J., Rounsevell, M.D.A., Acosta-Michlik, L., Leemans, R. & Schröter, D. 2006. The vulnerability of ecosystem services to land use change. Agriculture Ecosystems and Environment 114: 69–85.

Nepstad, D.C. 2007. The Amazon's Vicious Cycles, drought and fire in the greenhouse. A report prepared for the World Wide Fund for Nature, Gland, Switzerland. 23 p.

Nepstad, D.C., Merry, F., Moutinho, P., Rodriques, H.O., Bowman, M., Schwartzman, S., Almeida, O. & Rivero, S. 2007. The costs and benefits of reducing carbon emissions from deforestation and forest degradation in the Brazilian Amazon. Paper prepared for the UN Framework Convention on Climate

Change Conference of the Parties, Thirteenth session. The Woods Hole Research Center, Falmouth, USA. 26 p.

Nobre, C. & Oyama, M. 2003. A new climate-vegetation equilibrium state for Tropical South America. Geophysical Research Letters 30(23): 2199–2203.

Ogden, A.E. & Innes, J.L. 2007. Perspectives of forest practitioners on climate change adaptation in the northern forest sector, Canada. Forestry Chronicle 83(4): 557–569.

Olsen, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P. & Kassem, K.R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51: 933–938.

Poore, D. 1989. Chapter 7. Conclusions. In: Poore, D., Burgess, P., Palmer, J., Rietbergen, S., Synnott (eds.). 1989. No timber without trees. Earthscan Publications, London, UK. p. 191–209.

Randall, D.A., Wood, R.A., Bony, S., Colman, R., Fichefet, T., Fyfe, J., Kattsov, V., Pitman, A., Shukla, J., Srinivasan, J., Stouffer, R.J., Sumi, A. & Taylor, K.E. 2007. Climate Models and Their Evaluation. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller H.L. (eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA. p. 589–662.

Rappaport, R.A. 1977. Maladaptation in social systems. In: Friedman, J. (ed.). Evolution of Social Systems. Duckworth, London. p. 49–71.

Reid, H. & Huq, S. 2007. Community-based adaptation. A vital approach to the threat climate change poses to the poor. IIED Briefing paper. Available at: http://www.iied.org/pubs/. [Cited 8 Dec 2008]. 2 p.

Sabogal, C., de Jong, W., Pokorny, B. & Louman, B. (eds). 2008. Manejo forestal comunitario en América Latina. Experiencias, lecciones aprendidas y retos para el futuro. CIFOR – CATIE. Bogor, Indonesia/Turrialba, Costa Rica. 294 p.

Sayer, J. & Campbell, B. 2004. The science of sustainable development. Local livelihoods and the global environment. Cambridge University Press, Cambridge, UK.

Sayer, J.A. & Maginnis, S. 2005. New challenges for forest management. In: Sayer, J.A. & Maginnis, S. (eds.). Forests in landscapes. Ecosystem approaches to sustainability. IUCN/Earthscan, London, UK. p. 1–16.

SCBD (Secretariat of the Convention on Biological Diversity) 2003. Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. CBD Technical Series no. 10. SCBD, Montreal. 154 p.

Schmid, B., Roshi, J. & Schlapfer, F. 2002. Empirical evidence for biodiversity-ecosystem functioning relationships. In: Kinzig, A.P., Pacala, S.W. & Tilman, D. (eds.). The functional component of biodiversity. Princeton University Press, Princeton, USA. p. 120–245.

Smith, J., Colán, V., Sabogal, C. & Snook, L. 2006. Why policy reforms fail to improve logging practices: The role of governance and norms in Peru. Forest policy and economics 8(4): 458–469.

Spittlehouse, D.L. 2005. Climate change: impacts and adaptation in forestry. In: O'Neill, G.A. & Simpson, J.D. (eds). Climate Change and Forest Genetics, Proc. 29th Meeting, Canadian Tree Improvement Assoc., part 2, Symposium. p. 43–48.

Spittlehouse, D.L. & Stewart, R.B. 2003. Adaptation to climate change in forest management. Perspectives. BC Journal of Ecosystem Management. 4(1), 11 p. Available at: http://www.forrex.org/jem/ISS21/vol4_no1_art1.pdf. [Cited 8 Dec 2008].

Tilman, D., Knops, J., Wedin, D., Reich P., Ritchie, M. & Siemann, E. 1997. The influence of functional diversity and composition on ecosystem processes. Science 277: 1300–1302.

UN 2007. Non-legally binding instrument on all types of forests. Note by the Secretariat 17 October 2007. 10 p.

UNEP-WCMC (United Nations Environmental Program – World Conservation Monitoring Center) 2000. Global Distribution of Current Forests. [Internet site]. Available at: http://www.unep-wcmc.org/forest/global_map.htm. [Cited 8 Dec 2008].

Walker, M.D., Wahren, C.H., Hollister, R.D., Henry, G.H.R., Ahlquist, L.E., Alatalo, J.M., Bret-Harte, M.S., Calef, M.P., Callaghan, T.V., Carroll, A.B., Epstein, H.E., Jonsdottir, I.S., Klein, J.A., Magnusson, B., Molau, U., Oberbauer, S.F., Rewa, S.P., Robinson, C.H., Shaver, G.R., Suding, K.N., Thompson, C.C., Tolvanen, A., Totland, O., Turner, P.L., Tweedie, C.E. & Webber, P.J. 2006. Plant community responses to experimental warming across the tundra biome. Proceedings National Academy of Sciences 103: 1342–1346.

Wilkie, M.L., Holmgren, P. & Castaneda, F. 2003. Sustainable forest management and the ecosystem approach: two concepts one goal. FAO working paper FM 25. Rome, Italy.

Yohe, G.W., Lasco, R.D, Ahmad, Q.K., Arnell, N.W., Cohen, S.J., Hope, C., Janetos, A.C. & Perez, R.T. 2007. Perspectives on climate change and sustainability. In: Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (eds.). Cambridge University Press, Cambridge, UK. p. 811–841.