The Kyoto Protocol: what does it mean for forests and forestry?

D. Schoene and M. Netto

International climate change treaties seek to protect forests against the effects of global climate change while harnessing their unique powers for mitigating it.

Dieter Schoene is Senior Forestry Officer (Forest and Climate Change) in the Forest Conservation Service, FAO Forestry Department, Rome. **Maria Netto** is Programme Officer in the Support to Implementation Programme of the United Nations Framework Convention on Climate Change (UNFCCC), Bonn, Germany.

The views expressed in this article are those of the authors and do not necessarily represent the views of the United Nations or the UNFCCC Secretariat.

When FAO published its first assessment of the world's forest resources in this journal (FAO, 1948), it defined forests as "vegetative associations dominated by trees of any size, capable of producing timber or other forest products or of exerting an influence on the climate or the water regime". Although the greenhouse effect had already been discovered and global warming had been predicted, the originators of this historic definition were probably not intending to refer to a role of forests in mitigating climate change. However, that climate change was eventually to affect forestry had become obvious by 1989, when environment ministers from 68 nations proposed afforestation of 12 million hectares annually in the Noordwijk Ministerial Declaration on Climate Change (IUCC, 1993). Today it is acknowledged that forests can help mitigate climate change, need to be adapted to it and may help humankind in coping with its effects.

This article reviews the links between forests and climate change and their incorporation in international climate change agreements, pinpointing some of the challenges for enhancing the role of forests in mitigating climate change worldwide.

FORESTS CAN HELP MITIGATE CLIMATE CHANGE

Enhancing carbon storage in forests and their products

Planting new forests to absorb excess CO_2 in the atmosphere is the option that usually comes to mind first in the context of harnessing forests for curbing climate change. The idea of carbon offset plantings, originally proposed by Dyson (1977), is now being implemented worldwide under the Kyoto Protocol (see articles by Oyhantçabal and Masripatin in this issue) or even without regard to this agreement (see article by Tuttle and Andrasko in this issue). However, beyond planting trees in productive or protective plantations, agroforestry systems or urban forests, an entire palette of silvicultural and management options exists for enhancing carbon uptake and storage in forest ecosystems, such as restoring degraded forests, enrichment plantings, extending rotations in even-aged forests, thinning lightly, favouring species with high sequestration rates, underplanting open forests, and fertilizing or irrigating stands. Immature forests, widespread in Europe, North America and East Asia, act as carbon "sinks" without deliberate human intervention; half of the biomass that they accumulate is carbon.

Outside the forest, wood products can store carbon for decades and even centuries. In industrialized countries, the carbon pool in wood products amounts to 20 to 40 tonnes of carbon per hectare of forest area (Dewar, 1990). Under certain circumstances, managed forests and their products may store more carbon than unmanaged, natural forests (Dewar and Cannell, 1992).

Conserving stored carbon in forests

If one likens global warming to a fever of the planet, then forests do not only function as a potential remedy; their destruction also contributes to the illness. Deforestation and forest degradation contribute 24 percent of all anthropo-

USDA-FS/J. WITCOSKY/WWW.FORESTRYIMAGES.ORG/1441133

Management options such as light thinning (see stand on the right) can help enhance carbon uptake in forest ecosystems

genic carbon emissions and 18 percent of all greenhouse gas emissions combined (IPCC, 2000; Baumert, Herzog and Pershing, 2005); by eliminating the forests' capacity for future carbon absorption, they make the loss all the more serious. In developing countries, most emissions do not originate from smokestacks and tailpipes, but from land-use change. Therefore provision of financial incentives for managing forests more sustainably and reducing their conversion has been proposed by some as an option for lowering emissions.

In addition to reducing deforestation, there are other options for conserving forest carbon, such as reduced-impact-logging (Marsh *et al.*, 1996), managing forest fires (Goldammer, Seibert and Schindele, 1996), replacing even-aged by uneven-aged stands where possible, minimizing carbon loss during timber conversion to forest products (Muladi, 1996), developing alternatives to slash-and-burn activities and reducing rot in trees.

Substituting wood for fossil fuels and high-energy products

Where countries obtain energy from fossil fuels, substituting them with sustainably produced fuelwood to the extent possible should leave a roughly equivalent amount of fossil carbon underground and eliminate corresponding emissions. The use of sustainably produced fuelwood essentially does not produce emissions because carbon released through combustion will be compensated by an equivalent amount absorbed by forest growth. Logging residues may supplement wood harvested from fuelwood plantations. For each cubic metre of growing stock removed as industrial wood from the world's forests, approximately 1 tonne of above-ground biomass remains in the forest as a possible source of bioenergy (FAO, 2006). Each tonne of fuelwood or logging slash biomass could in turn replace about 400 litres of oil and prevent 0.3 tonnes of carbon emissions (Grammel, 1989).

Producing wood products requires less energy (usually from fossil fuel) than producing competing products made from steel or aluminium. On average, every cubic metre of construction timber substituting for steel or aluminium avoids 0.3 tonnes of carbon emissions (Burschel, Kürsten and Larsen, 1993).

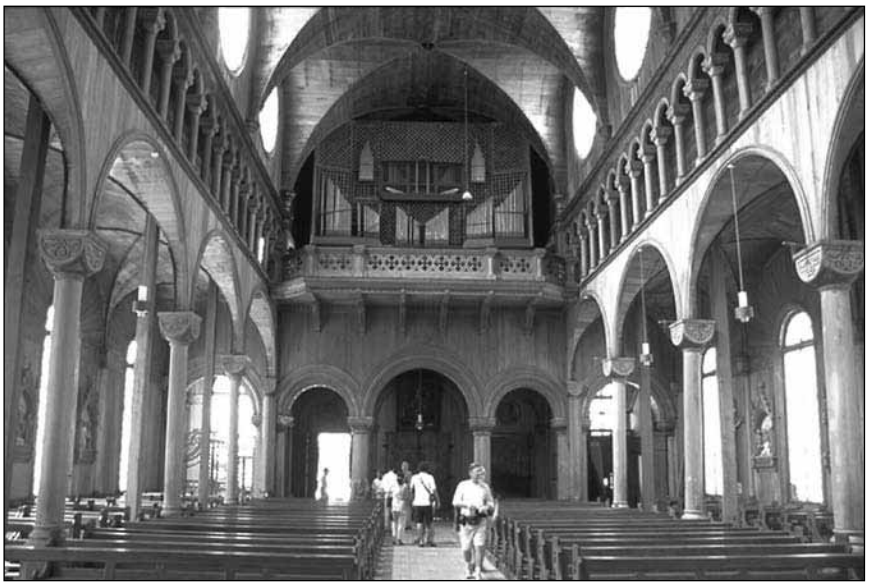
FORESTS MUST BE ADAPTED TO CLIMATE CHANGE

Forests are also possible victims of the planet's figurative fever, and without adaptation they may not fulfil expectations in climate change mitigation. Site and vegetation mapping has shown that forests respond with great sensitivity to even minute differences in temperature and moisture regimes (Schoene, 1983). The warming trend in the global average surface temperature of 0.6ºC since 1900 is already resulting in the death of trees in boreal forests (FAO, 2003), and major shifts in the geographic distribution of forest vegetation and some dieback and decline are expected. In most instances, decline will not be caused directly by climate change but by climate-influenced stresses such as fire, pests, diseases and deficiencies of nutrients and water.

On the other hand, some forests may

Immature forests, widespread in Europe, North America and East Asia, act as carbon sinks without deliberate human intervention; half of the biomass that they accumulate is carbon (shown, young white pine and larch in the United States)

C. SCHNEPF/WWW.FORESTRYIMAGES.ORG/1171054



FAO/FO-0777/M. NOEBAUER

Outside the forest, wood products can store carbon for decades and even centuries – the cathedral in Paramaribo, Suriname, constructed entirely from wood both inside and out

actually benefit from longer growing seasons, warmer temperatures and enhanced growth. Increased CO_2 in the ambient air may also improve water use efficiency, as water stress impairs photosynthesis less in carbon-enriched air (Schulin and Bucher-Wallin, 2001).

Proposed adaptive strategies focus on gene management, forest protection, forest regeneration, silvicultural management, operations, management of non-wood resources and park and wilderness management (FAO, 2003).

FORESTS MAY HELP HUMAN SOCIETIES ADAPT TO CLIMATE CHANGE

Forests and trees outside forests may help local communities cope with effects of climate change in numerous ways (Robledo and Forner, 2005). Plantations or naturally regenerated trees can protect watersheds against climate-change induced drought, flash floods or landslides, and they can halt or stem desertification. Agroforests and trees in the landscape integrate food and wood production and supply a range of environmental and social services, thus heightening resilience against adverse climatic events. Trees in urban environments sequester relatively small amounts of carbon, but they transpire large quantities of water and reflect more radiation than asphalt surfaces, thus keeping cities cooler (Jo and McPherson, 2001). Plantations of mangroves may protect coastlines against the effects of storm surges and rising sea level.

The fate of forests as a cause, cure and victim of climate change will ultimately affect people: 60 million indigenous forest dwellers depend fully on forests and their products; 1.2 billion people in developing countries obtain food from trees and at least 70 percent depend on forests as their sole source of medicine; and over 2 billion people use mainly wood for cooking and heating (German Federal Ministry for Economic Cooperation and Development, 2004). How forests fare in climate change will therefore strongly influence human well-being and progress towards the Millennium Development Goals.

HOW DO THE INTERNATIONAL CLIMATE CHANGE AGREEMENTS ADDRESS FORESTS?

Both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol list general obligations regarding forests that apply to all member countries. They should promote sustainable forest management and promote and cooperate in the conservation and enhancement of forests as sinks and reservoirs of greenhouse gases. They should promote afforestation and reforestation as well as renewable energy. They should also consider forests as part of national inventories of greenhouse gas emissions and removals, in technology transfer and in national programmes of adaptation to climate change.

The Kyoto Protocol then assigns different specific requirements relating to

S. MIDGLEY

In developing countries, most emissions do not originate from smokestacks and tailpipes, but from land-use change; preventing deforestation could be an option for lowering emissions

D. MAGUIRE/WWW.FORESTRYIMAGES.ORG/2714052

The use of sustainably produced fuelwood – e.g. from coppice forests which store carbon while meeting bioenergy needs – leaves fossil fuel underground and eliminates corresponding emissions

forests in developed and developing countries.

Developed countries

Developed countries shall promote sustainable forest management practices, renewable forms of energy, afforestation and reforestation, and they must adopt national policies and take corresponding measures on the mitigation of climate change by enhancing greenhouse gas sinks and reservoirs. They must assess net greenhouse gas emissions and removals from afforestation, reforestation and deforestation since 1990 that occur during the first commitment period of the Kyoto Protocol (2008 to 2012) and incorporate them into their accounting of net greenhouse gas emissions. They must decide by the end of 2006 if they wish to include forest management related greenhouse gas removals or emissions, up to country-specific limits, in their national accounts (FAO, 2003).

Using the mechanism known as Joint Implementation (see article by Lakyda, Buksha and Pasternak in this issue), industrialized countries and countries with economies in transition may jointly carry out greenhouse gas offset projects involving afforestation, reforestation or forest management. Some or all of the greenhouse gas offsets achieved in the host country's forests are transferred to the investor country on the basis of contractual arrangements between the partners.

Allowing developed countries to offset emissions by increasing the amount of carbon stored in wood products could potentially provide an incentive for the use of wood in durable goods; however, this will not be allowed in the first commitment period of the Kyoto Protocol because of lack of agreement on greenhouse gas accounting methodologies for wood products.

Developing countries

UNFCCC and the Kyoto Protocol refer in several articles specifically to developing country forests. Article 4(1e) of UNFCCC contains a mandate to all members to cooperate in protecting and rehabilitating areas affected by drought and desertification, particularly in Africa. According to Article 4(8), developed countries must give full consideration to meeting the climate-change related needs of developing countries with forested areas and areas liable to forest decay. Forests may be included in vulnerability assessments, and adaptive measures may be funded by the Global Environment Facility (GEF) or other funds established under UNFCCC and the Kyoto Protocol (Robledo and Forner, 2005; Verheyen, 2003).

Clean Development Mechanism. The most important mechanism for forests in developing countries is the Clean Development Mechanism (CDM) of the Kyoto Protocol, which allows developed countries to meet a part of their greenhouse gas reduction obligations through offset projects in developing countries. CDM projects that reduce emissions from sources can be carried out in many sectors, particularly energy, including wood energy. However, afforestation and reforestation are the only carbon sequestration activities allowed. Projects to reduce deforestation or forest degradation are not eligible. Carbon sequestration in agricultural crops and soils is also ineligible in the first commitment period of the Kyoto Protocol. CDM projects must promote sustainable development in host countries through investment, as well as through knowledge and technology transfer. Unilateral CDM projects in the host country and subsequent sale of credits are also feasible.

The CDM is a market-based mechanism, driven by demand for credits – certified emission reductions – from private or public entities in developed countries, and by supply from offset projects in developing countries.

Before national forestry administrations embark on promoting afforestation and reforestation based on climate-change related concerns, a number of conditions need to be examined (see Box) and many prerequisites need to be met (FAO, 2005).

To avert criticism of large-scale forest plantations under the CDM and to help meet the goals of food security and rural development, the CDM contains

Climate change causes forest decline indirectly through climate-influenced stresses such as fire, pests, diseases and deficiencies of nutrients and water

FAO/FO-0005/R. HOFF

a small-scale category with simplified conditions and reduced fixed costs. Projects cannot obtain credit for more than 2 200 tonnes of carbon sequestered annually on average and must be undertaken by low-income communities and individuals. Projects may include agroforests or urban forests and, depending on productivity and envisaged stocking levels, may encompass areas between 200 and 4 000 ha. Within these constraints, bundling of smallholder plots is allowed. The UNFCCC Conference of the Parties at its tenth session (COP-10) gave international organizations a special mandate to help facilitate such small-scale afforestation and reforestation projects (UNFCCC, 2004).

By the end of 2005, more than 70 CDM projects in all sectors had been registered and another 500 were being processed by UNFCCC. Of these, less than 20 afforestation and reforestation projects have been presented, and none of them has yet been submitted for registration because the first methodologies for setting a baseline and for monitoring afforestation and reforestation activities have only recently been approved. Many of the forestry projects have been rejected because of flaws involving either the rules on methodologies or forestry issues. Also, companies that should certify such projects are still in the process of being accredited. As a consequence the first afforestation and reforestation projects are expected to be registered by the end of the second quarter of 2006.

While credit prices have reached more than US$100 per tonne of carbon in European Union emission trading (the only existing international market for trading greenhouse gas emissions), the price of credits from afforestation projects is currently as low as US$10 to $15 per tonne of carbon because of perceived risks to buyers (FAO, 2005). Clearly, unless hurdles to widespread implementation and some misconceptions about carbon credits from forestry projects can be overcome and a market developed, a potentially huge stream of investments in the CDM will bypass forestry.

Other challenges and opportunities for the forest sector in developing countries. UNFCCC requires developing countries to submit periodic national inventories of greenhouse gas emissions by sources and removals by sinks as part of their National Communications. Industrialized countries finance the full costs of these communications through funds established under UNFCCC and the Kyoto Protocol and managed by

Should my country participate in the CDM? A checklist for decision-makers

- **Will afforestation and reforestation fit into national concepts and priorities for forests and sustainable development, articulated for example in national forest programmes?**
- **Are suitable areas available at adequate scales, comprising suitable soils and sites?**
- **What experiences have been gained or can be gained through ex-post evaluation of existing, business-as-usual afforestation? Are there potential species and forest types and sufficient data on costs and revenues, growth, yield and carbon sequestration?**
- **Are there established markets or uses for products of afforestation and reforestation other than carbon?**
- **How high are fixed and transaction costs for afforestation and reforestation, and do they justify costs of national institutions and capacity building?**
- **Who should be the driver for afforestation and reforestation projects?**
- **Can standard projects be designed that can be transposed easily in the country or the region?**
- **Is there an extension service to facilitate such projects?**

Agroforests integrate food and wood production and supply a range of environmental and social services, thus heightening resilience against adverse climatic events

J.LI

GEF. Forests merit greater attention in National Communications by developing countries than they have received to date, since they are of high importance for food security and rural livelihood in some countries and can constitute a major source of emissions, particularly in some African countries. Unfortunately, national forest assessments in many developing countries are obsolete or of poor quality, or both (Saket, 2002), making their greenhouse gas inventories unreliable. GEF supports greenhouse gas inventories and National Communications as enabling activities through funds administered by the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP).

All least-developed countries set out priorities for adaptation in their National Action Plans for Adaptation (NAPAs), which are also financed through GEF. The GEF Trust Fund and other funds established under UNFCCC (Special Climate Change Fund) and the Kyoto Protocol (Adaptation Fund) provide support to developing countries for vulnerability and adaptation assessments, capacity building and technology needs assessments.

Negotiations for the second commitment period

Negotiations for the second commitment period of the Kyoto Protocol started in 2005 as required by the Kyoto Protocol. Countries could negotiate to include other forestry activities under the flexible mechanisms of the Kyoto Protocol. Reducing greenhouse gas emissions from deforestation and forest degradation is a prime contender; other possible inclusions are rehabilitation of degraded forests, reduced-impact logging, reduction of losses in converting timber to forest products and enhanced wood energy use. These discussions would benefit from more forestry expertise, which was lacking in previous negotiations, particularly from developing countries.

KYOTO ENCOURAGES NEW THINKING ABOUT FORESTS AND FORESTRY

In industrialized countries, the rediscovery of the link between forests and carbon could be bringing forestry to a turning point. In Western Europe, for example, forestry was mainly focused on charcoal for centuries, until the discovery of coal shifted the interest to timber. The demand for high-quality large timber shifted forestry practices away from high-density hardwoods to conifers and longer rotations. Interest in carbon sequestration could generate a new shift; some native, high-density hardwoods may sequester as much carbon as some introduced, fast-growing but low-density softwoods, and for a longer time (Schoene and Schulte, 1999). A premium on carbon sequestration lengthens rotations and raises average growing stock (Hoen and Solberg, 1994). In industrialized countries that opt to include forest management as an elective activity in accounting under the Kyoto Protocol, growing stock values will increase on 1 January 2008 by the monetary equivalent of carbon stocks. After that date, converting forest to a highway, housing development or golf course will become more expensive, as the country will have to offset the carbon lost.

Many developing countries, too, have taken a new look at their forests from the perspective of the Kyoto Protocol. Developing countries currently cause approximately 60 percent of all anthropogenic greenhouse gas emissions, including those from land-use change and forestry. One-third of developing country greenhouse gas emissions originate in land-use change and forestry, primarily from deforestation; in the least-developed countries this sector contributes 62 percent (Baumert, Herzog and Pershing, 2005). The emissions from deforestation are not less harmful than those from fossil fuels; on the contrary, they not only affect the earth's atmosphere immediately after their release, but also signify reduced capacity to sequester excess carbon in the future. New proposals from developing countries, led by Papua New Guinea and Costa Rica, for industrialized countries to compensate forest conservation in developing countries appear understandable from this perspective (see article by Moutinho *et al.* in this issue). Opponents point to technical difficulties in assessing carbon savings and doubt that monetary rewards for carbon

Planted mangroves (shown in Fiji) can protect coastlines against the effects of storm surges and rising sea level

conservation will succeed in markedly reducing deforestation, which after all has many well-known causes.

IMPROVING FORESTRY EXPERTISE, RESEARCH AND PRACTICE

Forestry education

Many proposed afforestation and reforestation projects under the CDM have failed because they were prepared with insufficient forestry expertise. As mentioned above, expertise in both forestry and climate change will be vital to define the future role of forests in the Kyoto Protocol. Professional foresters might need to hone their skills. So far, few forestry faculties appear to have integrated climate change into their programmes, yet a review of five years of CLIM-FO-L, FAO's electronic newsletter on climate change and forestry (see www.fao.org/forestry/site/17828/en), suggests that new professional opportunities in this field are arising with mounting frequency.

Forest inventories

Remote sensing, carbon flux measurements and inverse atmospheric modelling augment understanding of the globe's carbon cycle and the role of forests in it. However, terrestrial forest inventories are indispensable to complement or substantiate estimates and models for quantifying the vast carbon stocks and flows in forest ecosystems. Better and more frequent national forest assessments have become more urgent with the advent of obligatory reporting on carbon stock changes by countries (FAO, 2003). In addition, accounting for greenhouse gas emissions avoided through reduced deforestation and degradation would not be feasible without quality forest and greenhouse gas inventories.

Forest policy and public relations

Public awareness of global warming is growing rapidly. Forests contain by half more carbon than the entire atmosphere of the earth (FAO, 2006), and they will remain for the foreseeable future the only viable, large-scale tool to remove excess CO_2 from the atmosphere. Moreover, they transform excess CO_2 into wood, foliage, products and green landscapes which appeal to the senses and emotions of most people. Awareness of climate change may help to raise esteem for forests and forestry in the public perception. It may also promote appreciation for and competitiveness of forest products. Forest policy and public communication should be used to raise awareness.

Forest management

Today, reactions of forests to climatic shifts may exceed those to forest management (Pretzsch, 2005). Historic silvicultural prescriptions based on a century's growth and yield observations no longer apply; predictions of growth and reactions to interventions have become highly uncertain. Today, the methods of flexible management under conditions of uncertainty formulated by Biolley (1920) are re-emerging in the form of modern adaptive management of natural resources (Walters, 1986) and are proposed for managing forest in the face of climate change (MacIver and Wheaton, 2005).

Research

Forestry research, too, must integrate considerations of climate change; ad hoc responses to new questions raised by the advent of climate change will not do. To consider the inclusion of wood products as accountable carbon stores in future commitment periods of the Kyoto Protocol, for example, better and more specific data are needed on carbon in wood products and its fate in the life cycle of products. The potential of coppice forests to simultaneously fulfil goals of bioenergy production and carbon storage should be explored. Can the fledgling art of carbon inventories and assessing sequestration rates in forests be refined to become as simple as using a yield table today?

Since forests established today will grow for decades or centuries and will definitely experience climate change, an important area for research is vulnerability assessment and management methods for adaptation of forests to climate change (Spittlehouse and Stewart, 2003), which has only recently begun

FAO/M. SAKET

Improved national forest assessments are indispensable for quantifying forest carbon stocks and flows and have become more urgent with the advent of obligatory reporting on carbon stock changes (shown, inventory work in Guatemala)

to receive some of the attention already devoted to the vulnerability and adaptation of human societies (Smith, Klein and Huq, 2003).

CONCLUSIONS

Forests and forestry are intricately entwined with climate change. UNFCCC and the Kyoto Protocol explicitly acknowledge this link. The international treaties seek to protect forests against the effects of global climate change and to harness their unique powers for mitigating it and safeguarding human societies. The CDM singles out afforestation and reforestation projects for greenhouse gas removal in developing countries. This flexible instrument is a striking model for reaching the UN Millennium Development Goals through global partnerships.

Climate change and the international treaties dealing with it have created a plethora of new challenges, opportunities and tasks for the forest sector. Meeting them successfully requires fresh perspectives, modified priorities, new knowledge, skills and creativity. ◆

Bibliography

Baumert, K.A., Herzog, T. & Pershing, J. 2005. *Navigating the numbers*. Washington, DC, USA, World Resources Institute.

Biolley, H. 1920. *L'aménagement des forêts par la méthode expérimentale et spécialement la méthode du contrôle*. Paris, France, Attinger Frères.

Burschel, P., Kürsten, E. & Larsen, B.C. 1993. *Die Rolle des Waldes und der Forstwirtschaft im Kohlenstoffhaushalt*. Munich, Germany, Schriftenreihe der Forstwissenschaftlichen Fakultät München.

Dewar, R.C. 1990. A model for carbon storage in forests and forest products. *Tree Physiology*, 6: 417–428.

Dewar, R.C. & Cannell, M.G.R. 1992. Carbon sequestration in the trees, products and soils of forest plantations: an analysis using U.K. examples. *Tree Physiology*, 11: 49–71.

Dyson, F.J. 1977. Can we control the carbon dioxide in the air? *Energy*, 2: 287–291.

FAO. 1948. Forest resources of the world. *Unasylva*, 2(4): 1–22.

FAO. 2003. *State of the World's Forests 2003*. Rome.

FAO. 2005. *Afforestation and reforestation projects under the Clean Development Mechanism of the Kyoto Protocol*. Fact sheet. Rome. Available at: www.fao.org/forestry/site/30108/en

FAO. 2006. *Global Forest Resources Assessment 2005 – progress towards sustainable forest management*. FAO Forestry Paper No. 147. Rome. (In press).

German Federal Ministry for Economic Cooperation and Development (BMZ). 2004. *Fortschrittsbericht zur deutschen bilateralen Entwicklungszusammenarbeit im Waldsetor*. Bonn, Germany. Available at: www.bmz.de/de/service/infothek/fach/materialien/materialie142.pdf

Goldammer, J.G., Seibert, B. & Schindele, W. 1996. Fire in dipterocarp forests. *In* A. Schulte and D. Schoene, eds. *Dipterocarp forest ecosystems: towards sustainable management*, pp. 155–185. Singapore, World Scientific.

Grammel, R. 1989. *Forstbenutzung*. Berlin, Germany, Parey.

Hoen, H.F. & Solberg, B. 1994. Potential

and economic efficiency of carbon sequestration in forest biomass through silvicultural management. *Forest Science*, 40: 429–451.

Information Unit on Climate Change (IUCC). 1993. *Noordwijk Ministerial Declaration on Climate Change*. Châtelaine, Switzerland, UNEP. Available at: www.cs.ntu.edu.au/homepages/jmitroy/sid101/uncc/fs218.html

Intergovernmental Panel on Climate Change (IPCC). 2000. *Land use, land-use change and forestry.* Special report. Cambridge, UK, Cambridge University Press. Available at: www.grida.no/climate/ipcc/land_use/index.htm

Jo, H.K. & McPherson, E.G. 2001. Indirect carbon reduction by residential vegetation and planting strategies in Chicago, USA. *Journal of Environmental Management*, 61: 165–177.

MacIver, D.C. & Wheaton, E. 2005. Tomorrow's forests: adapting to a changing climate. *Climatic Change*, 70: 273–282.

Marsh, C.W., Thay, J., Pinardi, M.A., Plitz, F.E. & Sullivan, T.E. 1996. Reduced impact logging. *In* A. Schulte and D. Schoene, eds. *Dipterocarp forest ecosystems: towards sustainable management*, pp. 293–307. Singapore, World Scientific.

Muladi, S. 1996. Quantification and use of dipterocarp wood residue in East Kalimantan. *In* A. Schulte and D. Schoene, eds. *Dipterocarp forest ecosystems: towards sustainable management*, pp. 603–626. Singapore, World Scientific.

Pretzsch, H. 2005. Wachstum von Rein- und Mischbeständen bei veränderten Umweltbedingungen. *Allgemeine Forstzeitschrifteine Forstzeitschrift*, 9: 465–468.

Robledo, C. & Forner, C. 2005. *Adaptation of forest ecosystems and the forest sector to climate change*. Forest and Climate Change Working Paper No. 2. FAO, Rome.

Saket, M. 2002. Gaps in national-level information on forests and trees in developing countries. *Unasylva*, 210: 24–27.

Schoene, D. 1983. *The valuation and use of site information for Douglas-fir reforestation in Western Oregon.* Ph.D. thesis. Oregon State University, Corvallis, Oregon, USA.

Schoene, D. & Schulte, A. 1999. Forstwirtschaft nach Kyoto: Ansätze zur Quantifizierung und betrieblichen Nutzung von Kohlenstoffsenken. *Forstarchiv*, 70: 167–176.

Schulin, R. & Bucher-Wallin, I.K. 2001. Wasserhaushalt. *In* C. Brunold, P.W Balsiger, J.B. Bucher & C. Körner, eds. *Wald und CO_2: Ergebnisse eines ökologischen Modellversuchs*, pp. 176–185. Birmensdorf, Switzerland, Eidgenössische Forschungsanstalt/Bern, Switzerland, Haupt.

Smith, J.B., Klein, R.J.T. & Huq, S., eds. 2003. *Climate change, adaptive capacity and development.* London, UK, Imperial College Press.

Spittlehouse, D.L. & Stewart, R.B. 2003. Adaptation to climate change in forest management. *BC Journal of Ecosystems and Management*, 4: 1–11.

United Nations Framework Convention on Climate Change (UNFCCC). 2004. *Decision 14/CP.10. Simplified modalities and procedures for small-scale afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol and measures to facilitate their implementation*. Bonn, Germany. Available at: unfccc.int/resource/docs/cop10/10a02.pdf#page=26

Verheyen, R. 2003. Adaptation funding. Legal and institutional issues. *In* J.B. Smith, R.J.T. Klein & S. Huq, eds. *Climate change, adaptive capacity and development*, pp. 163–189. London, UK, Imperial College Press.

Walters, C. 1986. *Adaptive management of renewable resources*. New York, USA, MacMillan. ◆