



POLICY BRIEF

Making forests fit for climate change

A GLOBAL VIEW OF CLIMATE-CHANGE IMPACTS ON FORESTS AND PEOPLE AND OPTIONS FOR ADAPTATION



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PUBLISHED BY

MINISTRY FOR FOREIGN AFFAIRS OF FINLAND

INTERNATIONAL UNION

OF FOREST RESEARCH ORGANIZATIONS

ISBN 978-3-901347-82-5

PRINTED BY

ERWEKO 2009



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Foreword by Paavo Väyrynen, Minister for Foreign Trade and Development

The climate for forests and people is changing. There is increasing evidence that climate change affects forests and the people depending on them. Yet, the effects of climate change may be quite different in various parts of the world. They may be positive or negative, small or profound, and they may occur abruptly or in the long run.

Millions of people around the globe depend on the goods and services provided by forests for their livelihood, and in some cases even for their survival. Climate change will alter the ability of forests to provide essential goods and services and is likely to impose considerable additional stresses on forest dependent communities and in particular the rural poor. This is why climate change is an issue of high concern for international policy and decision makers, donors and stakeholders concerned with forests and trees.

The Development Policy of Finland emphasises the importance of ecologically, economically and socially sustainable development and the contribution that sustainable forest management is able to make for effective poverty reduction.

Projected changes in the climate indicate that the boreal region will be exposed to more warming than equatorial zones. Consequently, and because boreal forests are limited by temperature, climate change is of particular concern also to my country, Finland, which has initiated its own National Strategy for Adaptation to Climate Change already in the year 2005.

By means of suitable adaptation responses, it is possible to moderate the harmful effects of climate change on forests and trees and to exploit beneficial opportunities for people and na-

ture. However, understanding the impacts of climate change, the related vulnerabilities and the options for adaptation is a complex task which requires a solid scientific underpinning.

Very appropriately, adaptation of forest to climate change has therefore been identified as the theme of the first Global Forest Expert Panel of the Collaborative Partnership on Forests (CPF). Many times in the past the effectiveness of policies has suffered from insufficient information about a given problem. This IUFRO-led initiative is a promising new mechanism for providing policy and decision makers with the state-of-knowledge about issues of high concern on the international agenda.

The Ministry for Foreign Affairs of Finland, together with the Swedish International Development Cooperation Agency, the UK Department for International Development, the German Federal Ministry for Economic Cooperation and Development, the Swiss Agency for Development and Cooperation and the US Forest Service have therefore decided to support this new initiative of the CPF.

The work of this first Global Forest Expert Panel constitutes the most comprehensive assessment to date of scientific information about climate-change impacts and how forests and people can adapt to it. Based on the assessment, this policy brief aims to provide policy and decision makers with essential knowledge for enhancing the adaptive capacity of both forests and people to the impacts of climate change. It is my sincere hope that it will contribute to more informed deliberations about this issue and that it may serve as a starting point for additional scientific inputs by future Global Forest Expert Panels on other themes.

It should be emphasised, that even if adaptation measures are of high priority and they will be enhanced, climate change effects on forests are problematic. Therefore, mitigation must be our first priority. Adaptation and mitigation go hand in hand. Both can be promoted by coherent policies and measures regarding reforestation and afforestation, protection of the biological diversity of forests and sustainable forest management.

Paavo Väyrynen
Minister for Foreign Trade and Development
Finland

Foreword by Jan Heino, CPF Chair

As Chairman of the Collaborative Partnership on Forests (CPF), I commend IUFRO for taking the lead in launching our recent joint initiative, Global Forest Expert Panels, in the autumn of 2007. Its establishment responds to the need for objective and independent scientific assessments of key issues in order to support more informed decision-making at the global level.

The Expert Panel on Adaptation of Forests to Climate Change was the first group formed under this CPF initiative. Almost 100 internationally-renowned scientists collaborated on a voluntary basis to provide the most comprehensive assessment

to date on the impacts of climate change on forests and on the people who depend on these resources for their livelihood and well-being. Their report also includes management and policy options for effective adaptation.

The work of this particular Expert Panel underscores the far-reaching implications of climate change on forests and recognizes that the issues are as complex as their solutions – ranging from direct causes such as excessive greenhouse gas emissions to indirect causes such as weak governance and poverty. The report also duly notes that the impacts are most often felt at the local level so that measures to address them must be site-specific. The concept of sustainable forest management embodies these and other sound principles and provides a robust framework for forest-based climate change mitigation and adaptation. In this regard, the report is entirely consistent with the proposals and key messages contained in the CPF Strategic Framework for Forests and Climate Change.

This Policy Brief summarizes the findings of the full assessment report and suggests ways to enhance the adaptive capacity of both forests and people to the impacts of climate change. The Chair of this Expert Panel, Professor Risto Seppälä, and the many scientists who carried out the assessment deserve full credit for advancing our knowledge on the critical relationship between forests and climate change adaptation. I congratulate them for a job well done and am confident that readers will find the information useful.

Jan Heino
Chair, Collaborative Partnership of Forests
Assistant Director-General, Forestry Department, Food and Agriculture Organization of the United Nations



JOHN PARROTTA

FORESTS PROVIDE MULTIPLE TANGIBLE AND INTANGIBLE BENEFITS. A SINGLE FOREST CAN, FOR EXAMPLE, PROVIDE WOOD AND NON-WOOD PRODUCTS, CLEAN WATER, AND AN ENVIRONMENT FOR RECREATION.



ERKKI OKSANEN

Key messages

1. Climate change over the past half-century has already affected forest ecosystems and will have increasing effects on them in the future. The carbon-regulating services of forests are at risk of being lost entirely unless current carbon emissions are reduced substantially; this would result in the release of huge quantities of carbon to the atmosphere, exacerbating climate change.
2. Climate change can increase the supply of timber in some regions although there will be considerable temporal variations.
3. The impacts of climate change on forest goods and services will have far-reaching social and economic consequences for forest-dependent people, particularly the forest dependent poor. Adaptation measures must go beyond single technical solutions and address also the human-institutional dimensions of the problem.
4. Sustainable forest management is essential for reducing the vulnerability of forests to climate change. The current failure to implement it limits the capacity of forests and forest-dependent people to adapt to climate change. To meet the challenges of adaptation, commitment to achieving the goals of sustainable forest management must be strengthened at both the international and national levels.
5. There is no universally applicable measure for adapting forests to climate change. Forest managers should, therefore, have sufficient flexibility to deploy the adaptation measures most appropriate for their local situations.
6. Flexible approaches to policy design are needed that are sensitive to context and do not rely on a single, one-size-fits-all mechanism. New modes of governance are required that enable meaningful stakeholder participation and provide secure land tenure and forest user rights and sufficient financial incentives.
7. More research is required to reduce current uncertainties about the climate-change impacts on forests and people and to improve knowledge about management and policy measures for adaptation. Nevertheless, despite the limitations of current knowledge, climate change is progressing too quickly to postpone adaptation action pending the outcomes of future studies.
8. Even if adaptation measures are fully implemented, unmitigated climate change would, during the course of the current century, exceed the adaptive capacity of many forests. Large reductions in greenhouse gas emissions from fossil fuels and deforestation are needed to ensure that forests retain their mitigative and adaptive capacities.

Why adaptation is needed

The Intergovernmental Panel on Climate Change (IPCC) has presented clear evidence that the climate is changing (Figure 1) and that the emission of greenhouse gases is the main driver of that change. The extent to which societies reduce their greenhouse gas emissions ('mitigation') will affect the scale of future change. Regardless of climate change mitigation measures taken today or in the near future, however, historical emissions and inertia in the climate system mean that further climate change is inevitable.

Forests provide supporting, provisioning, regulating and cultural services ('ecosystem services') that support human well-being locally and globally. Climate change is affecting the provision of these essential ecosystem services, with potentially serious consequences for human well-being. Individuals, societies and institutions, therefore, should be aware of the likely impacts of climate change on forests and should have strategies in place to adapt to them ('adaptation', Box 1). For some stakeholders, the purpose of adaptation will be to maintain the status quo. For others, for whom the existing situation is undesirable, adaptation might offer opportunities for positive change. For adaptation to be successful, however, the values and expectations of different stakeholders need to be recognised.

Box 1: Defining adaptation, vulnerability and resilience

The IPCC defines adaptation to climate change as '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 can be autonomous, reactive, anticipatory or planned. Many adaptation strategies focus on strengthening the ability of a system to absorb the disturbances caused by climate change and to capture the benefits arising from it (strengthened resilience) or increasing the degree to which a system is able to cope with climate change (enhanced adaptive capacity, thereby reducing vulnerability). The concepts of resilience and vulnerability are therefore strongly related to adaptation.

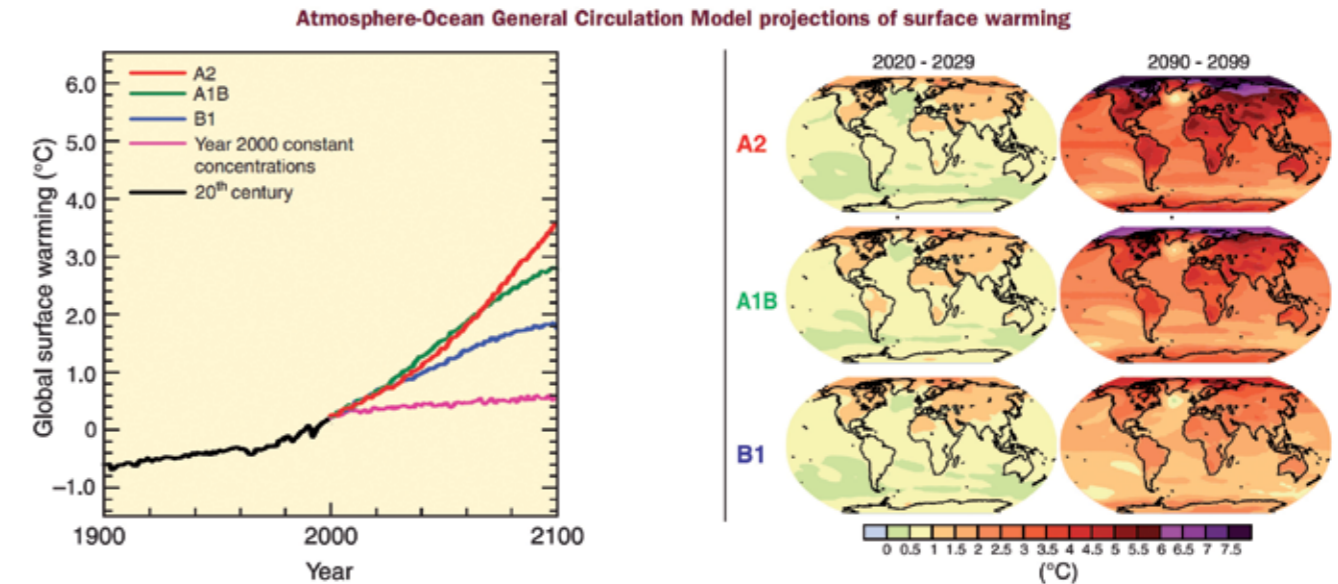


FIGURE 1: ATMOSPHERE-OCEAN GENERAL CIRCULATION MODEL PROJECTIONS OF SURFACE WARMING. CLIMATE CHANGE 2007: SYNTHESIS REPORT. CONTRIBUTION OF WORKING GROUPS I, II AND III TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. FIGURE 3.2, P. 46, IPCC, GENEVA, SWITZERLAND.



DEAD WHITE SPRUCE (*PICEA GLAUCA*), KLUANE, YUKON TERRITORY, CANADA. A SERIES OF WARMER-THAN-AVERAGE WINTERS HAVE ALLOWED POPULATIONS OF THE SPRUCE BEETLE (*DENDROCTONUS RUFIPENNIS*) TO DEVELOP, RESULTING IN THE MORTALITY OF ALMOST 400 000 HA OF THIS BOREAL FOREST.

How climate change affects forests and people

Climatic change over the past half-century has affected many aspects of forest ecosystems, including tree growth and dieback, the distributions of indigenous species, the proliferation of invasive species, seasonal patterns in ecosystem processes, and the population dynamics of forest species; in some cases it has been implicated in species extinctions. Climatic effects interact with non-climatic factors, such as land-use practices, through feedback systems that can be stabilising or destabilising. These interactions complicate the task of quantifying the impacts of climate change.

The observed effects of recent climate change are greater in boreal forests than in other forest domains (i.e. temperate, subtropical and tropical). In contrast, constraints to adaptive capacity that increase vulnerability to climate change, particularly those posed by socioeconomic and political conditions, are generally more severe in subtropical and tropical forests than in temperate and boreal forests.

Environmental impacts on forests globally

Future climate change and its impacts on forests and their goods and services cannot be predicted, but they can be projected using scenarios based on plausible assumptions about the possible evolution of demographic, socioeconomic, technological and environmental factors. The IPCC has developed global emission scenarios for greenhouse gases and aerosols and corresponding scenarios of climate change. These can be grouped into four clusters based on their emission patterns during the 21st century: *unavoidable*, *stable*, *growth*, and *fast growth* (Box 2).

Box 2: Scenario clusters

Unavoidable: Atmospheric CO₂ concentrations are frozen at current levels. This scenario is very unlikely to be attained because, in reality, emissions have been growing at an increasing rate since 2000. Such scenarios do, however, allow the assessment of minimum adaptation needs because they reveal the unavoidable warming that will take place due to past emissions and inertia in the climate system.

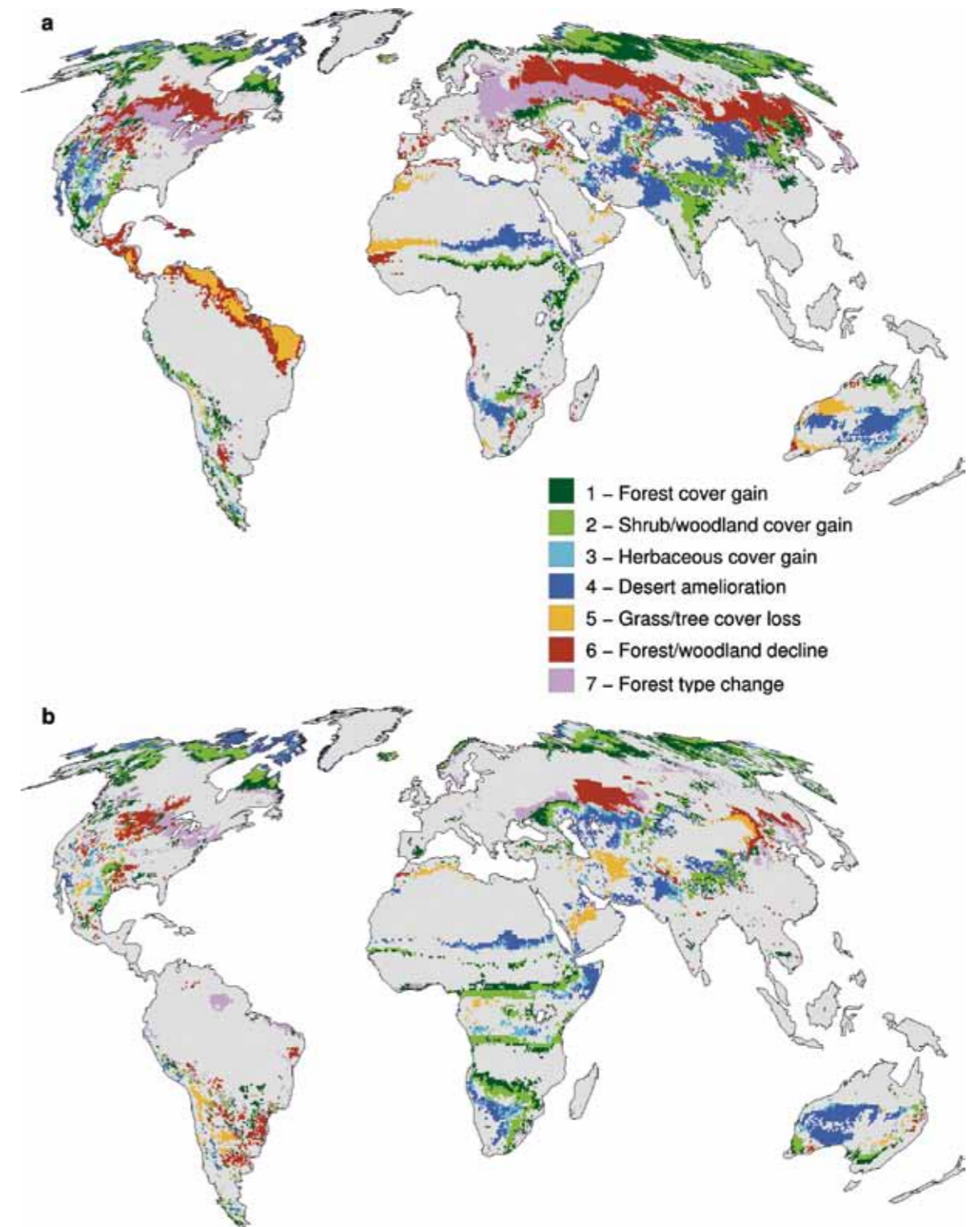
Stable: In scenarios in this cluster, greenhouse gas emissions decline during the course of the current century as a result of major socioeconomic changes permitting atmospheric CO₂ concentrations to approach a new equilibrium by the year 2100.

Growth: In scenarios in this cluster emissions continue to grow over the course of the current century at rates similar to those in the second half of the last century (i.e. 'business as usual'). Atmospheric CO₂ concentrations continue to rise for decades beyond 2100; the climate system is likely to be out of equilibrium for centuries thereafter.

Fast growth: Scenarios in this cluster are similar to those in the *growth* cluster but represent business-as-usual emissions since 2000. Those have reached unprecedented levels and exceed the high-end scenarios of the IPCC Special Report on Emission Scenarios.

Under all scenarios and in all four forest domains, climate change is expected to affect the distribution of forest types and tree species (Figure 2). Globally, forest ecosystems are expected to adapt effectively to the impacts of climate change associated with scenarios from the *unavoidable* and *stable* clusters, but will have major adaptation difficulties with the climate change associated with *growth* or *fast-growth* scenarios.

FIGURE 2: PROJECTED APPRECIABLE CHANGES IN TERRESTRIAL ECOSYSTEMS BY 2100 RELATIVE TO 2000 FOR TWO SCENARIOS FORCING TWO CLIMATE MODELS: (A) GROWTH SCENARIO CLUSTER, (B) STABLE SCENARIO CLUSTER. CHANGES ARE CONSIDERED APPRECIABLE AND ARE ONLY SHOWN IF THEY EXCEED 20% OF THE AREA OF A SIMULATED GRID CELL. CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY. WORKING GROUP II CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. FIGURE 4.3, P. 238. CAMBRIDGE UNIVERSITY PRESS.



Forest biomass and soils contain about half the total carbon in land ecosystems. Forests currently sequester slightly more than a quarter of total anthropogenic emissions, an important ecosystem service in the context of climate change. Several models project, however, that the current carbon-regulating services of forests could be lost entirely under a global warming of 2.5°C or more relative to pre-industrial levels (as occurs under climate-change scenarios at the upper end of the *stable* cluster and in the *growth* and *fast-growth* clusters), when all land ecosystems would begin to turn into net sources of carbon. Such carbon emissions would add significantly to those from fossil fuels and deforestation and forest degradation, exacerbating climate change. Adaptation alone, therefore, will be insufficient to preserve the ecosystem services currently provided by forests and to lessen the risks of significant biodiversity losses. In addition to adaptation, mitigation that effectively curbs climate change is necessary, notably through a large reduction in fossil-fuel emissions and a cessation of deforestation.

Key message: Climate change over the past half century has already affected forest ecosystems and will have increasing effects on them in the future. The carbon-regulating services of forests are at risk of being lost entirely unless current carbon emissions are substantially reduced; this would result in the release of huge quantities of carbon to the atmosphere, exacerbating climate change.

Regional impacts and vulnerabilities

The impacts of climate change on forests need to be analysed in a local context. Nevertheless, it is possible to indicate potential climate-change impacts and vulnerabilities for each of the four major forest domains as defined by FAO.

Boreal forests

The boreal region will experience more warming than equatorial zones. Since boreal forests are generally temperature-limited, they are likely to be particularly affected by climate change. They are expected to shift north, although there are major uncertainties regarding the time required for this shift. In the absence of disturbance, tree growth is likely to increase, even under *growth* scenarios. In many boreal forests, however, the positive effects of such increases will likely be outweighed by the increased prevalence of fire and pests. For example, recent modelling using *growth* and *stable* scenarios projected an increase in the area burnt in Alaska and northern and western Canada that is 5.5 times larger than the recent baseline. An increase in forest fires and insect epidemics is expected to result in the release of substantial amounts of carbon, exacerbating climate change.



▲ A REDUCTION IN FOSSIL-FUEL EMISSIONS AND DEFORESTATION LARGE ENOUGH TO EFFECTIVELY CURB CLIMATE CHANGE IS NECESSARY FOR FORESTS TO RETAIN THEIR ADAPTIVE CAPACITIES.

▼ BOREAL FORESTS ARE PARTICULARLY AFFECTED BY CLIMATE CHANGE.

► MORE INTENSE AND FREQUENT DROUGHTS WILL LIKELY LEAD TO MORE FIRES, ESPECIALLY IN SOUTHERN TEMPERATE FORESTS.



JOHN INNES



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GEOFF ROBERTS

◀◀ SUB-TROPICAL TAXODIUM DISTICHUM SWAMP IN THE EVERGLADES, FLORIDA, UNITED STATES. FORESTS THAT ARE DEPENDENT ON SPECIFIC WATER LEVELS WILL BE PARTICULARLY SENSITIVE TO CLIMATE CHANGE.

◀◀ THE USE OF SHORT-ROTATION SPECIES IN PLANTATIONS CAN OFFER POSSIBILITIES TO ADAPT TO CHANGING CONDITIONS.

◀ TROPICAL FORESTS ARE PROJECTED TO HAVE BETTER TREE GROWTH UNDER UNAVOIDABLE AND STABLE SCENARIOS WHEREVER TREES CAN FIND SUFFICIENT WATER. HOWEVER, UNDER GROWTH SCENARIOS TROPICAL FORESTS COULD BE SEVERELY AFFECTED BY CLIMATE CHANGE.

Temperate forests

Under most scenarios, the consequences of climate change are in the long run likely to be less severe in temperate forests than in forests in other domains. Large regional risks remain, however. Tree growth will increase in poleward temperate forests but decrease in forests bordering the subtropics. Storms are likely to become more frequent in the temperate zone and could cause major disturbances in its forests. Overall, the impact of climate change on temperate forests is likely to be positive under scenarios in the *stable* cluster due to the projected increases in productivity. The negative effects are more pronounced under scenarios in the *growth* and *fast-growth* clusters.

Subtropical forests

Under *growth* scenarios, subtropical forests are projected to experience rising temperatures, higher evaporation and lower rainfall. Fire will become more prevalent at first but will wane later as rainfall and, consequently, the volume of grass fuels decrease. The subtropics contain many biodiversity hotspots that are highly sensitive to climate change. Projections suggest that 40% of biodiversity of subtropical forests could be lost even under *stable* scenarios. Many subtropical forest species exist in highly fragmented environments and are therefore at particular risk of extinction. Many subtropical countries are increasing their share of global timber markets based on timber obtained from plantations. The short-rotation tree species used in these plantations can provide an effective strategy for adapting to climate change because they offers the possibility of tailoring species mixes to suit changing conditions.

Tropical forests

Under scenarios in the unavoidable and stable clusters, tree growth in tropical forests is projected to increase where water is sufficiently available and to decline in dry and seasonally dry environments. Under growth scenarios, tropical forests could be severely affected by climate change, with consequent impacts not only on the local climate but also on the global carbon cycle because of the release of substantial amounts of carbon. Tropical forests, particularly tropical rain forests, harbour the highest biodiversity of all land ecosystems. The IPCC has projected that global increases in temperature of 2–3°C above pre-industrial levels would put 20–30% of vascular plants and higher animals at an increased risk of extinction. Yet, estimates of temperature increases in tropical forests exceed the global averages. It is very likely that even modest losses of biodiversity would cause consequential changes in the delivery of some tropical-forest ecosystem services. Mangrove forests in the tropics provide an example of these endangered services (Box 3).

Box 3: Coastal mangroves

Coastal mangrove forests are a widely utilized resource, providing nurseries for important fish species, for example, and helping to protect coastal areas from floods and coastal storm surges. Although such ecosystem services are highly valued, the area of mangrove forests declined significantly in the last half-century.

Under all scenarios of climate change, coastal storms are projected to increase in most regions. As erosion rates and the frequency or intensity of storms increase in the tropics, the coastal protection function of mangroves will become increasingly critical. Mangrove forests, however, are themselves vulnerable to climate change, their persistence depending on accretion rates relative to sea level. While mangroves appear to have adapted to sea level rises that have already occurred, it will be harder for them to do so as the sea level rises more rapidly and as conversion pressures increase.



GEOFF ROBERTS

COASTAL MANGROVES ARE IMPORTANT FOR PROTECTING COASTAL AREAS FROM FLOODS AND STORMS.

Socioeconomic impacts and vulnerabilities

The expected environmental impacts of climate change on forests and their capacity to provide critical ecosystem services will have far-reaching social and economic consequences. In addition to climate change, factors such as human population growth, changes in the extent of croplands and pasturelands, invasive species, diseases, fires and industrial pollution already impose significant pressures on forest-dependent people.

Progress has been made in assessing the environmental impacts that projected climate change could have, but much more research is needed about its socioeconomic impacts, especially the potential vulnerabilities that might be exposed among forest-dependent people and how such vulnerabilities might be reduced. More precise regional or local-scale projections of climate change are needed to enable the tailoring of adaptation measures to local conditions.

Wood and wood products

A number of studies have projected that climate change will, in the long term, increase the supply of timber globally, although there will be considerable regional and temporal variation (Table 1). The projected reductions in timber prices due to this expansion in global output will have negative effects on timber producers in some regions, but will benefit timber consumers. The increases in economic productivity of forests that will occur in some regions will present new opportunities for forest industries and forest-dependent communities in these regions. Other regions, where pro-

ductivity is projected to decline, will face significant socioeconomic challenges.

Regions that, over the next 50 years, appear to be most vulnerable to the impacts of climate change on timber production are North America, Europe, Australia and New Zealand (see table). Output in North America and Europe as a whole could decline due to the climate-induced dieback of existing stocks of trees combined with lower investments in timber production due to lower prices. These changes, however, are expected to be modest, with output increasing again beyond 2050. In contrast, output in Russia is expected to expand modestly through the first half of the century, with stronger increases beyond 2050.

Key message: Climate change can increase the supply of timber in some regions, although there will be considerable temporal variations.

Table 1 Economic estimates of climate change impacts on output and producer returns

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

UNDER CURRENT PROJECTIONS, FOREST PRODUCTIVITY WILL RISE IN SOME REGIONS AND DECLINE IN OTHERS. THE PROJECTED SOCIOECONOMIC IMPACTS WILL PRESENT NEW OPPORTUNITIES AND CHALLENGES FOR AFFECTED COMMUNITIES AND SOCIETIES.



ERKKI OKSANEN



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MARKO KATILA



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Non-wood forest goods and services

It is more difficult to assess the influences of climate change on non-wood forest products and services. Insufficient data are available to reliably estimate the supply of these non-wood products and the extent to which they will be sought in the future. Non-wood forest products and services are rarely included in estimates of national product calculations. The carbon sequestration services performed by forest plants and algae, for example, had no assigned value until the 1990s, when forests planted after 1990 became eligible to earn carbon credits under the Kyoto Protocol. The role of forests and wood-based products in carbon markets is likely to become increasingly important.

Vulnerabilities of forest-dependent poor

The expected increases in extreme weather events such as heat stress, drought and flooding and the increased risk of fire and pest and disease outbreaks will cause additional stress in regions with large forest-dependent populations. The forest-dependent poor, who often depend directly on forests for their livelihoods and for

THE CULTURAL, AESTHETIC AND RECREATIONAL BENEFITS ASSOCIATED WITH FORESTS ARE DIFFICULT TO QUANTIFY, AND IT IS VERY UNCERTAIN HOW CLIMATE CHANGE WILL AFFECT THEM.

meeting domestic energy, food and health needs, will be most vulnerable to such stresses (e.g. Box 4). Non-wood forest products often provide a safety net for rural and urban communities during food shortages. Crop failures could increase under climate change, increasing the safety-net role of forests and placing greater pressure on them especially during extreme weather events. The increasing difficulty that people will have in meeting their basic needs for food, clean water and other necessities will lead to deepening poverty, deteriorating public health and increased social conflict (as, for example, people seek to migrate to more hospitable areas or to already-overcrowded urban centres).

Many indigenous peoples and local communities hold traditional knowledge about the sustainable production of non-wood forest products and services, such as traditional forest and water management practices, that can help them respond to climate change and that are important elements of effective adaptation strategies. Local knowledge can complement formal science in monitoring the effects of climate change and the formulation of strategies to adapt to such change.

CLIMATE CHANGE IS EXPECTED TO HAVE NEGATIVE EFFECTS ON THE PRODUCTION OF WOOD AND NON-WOOD FOREST PRODUCTS IN MANY REGIONS. THIS CAN IMPOSE ADDITIONAL STRESSES ON PEOPLE WHO DEPEND ON FUELWOOD FOR DOMESTIC ENERGY AND ON NON-WOOD FOREST PRODUCTS FOR THEIR LIVELIHOODS.



MATTI NUMMELIN



ERKKI OKSANEN



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Box 4: Gum arabic

Gum arabic, an exudate obtained from the tree species *Acacia senegal*, is one of the most important non-wood forest products in Sudan. Gum arabic production is a major source of economic stability in the Kordofan and Darfur regions, where all community members (men, women and children) take part in gum arabic production, including bark-tapping, collection, sorting, cleaning and marketing. In total, more than five million people are involved in the gum arabic industry in Sudan. Over the years, traditional farmers in the Sudanese gum-belt have developed a close relationship with, and a comprehensive husbandry system for, the gum arabic tree.

A recent assessment of the current and long-term (to 2030 and 2060) impacts of climate change on gum arabic production in Sudan indicated that increased water stress associated with a rise in temperature would significantly lower gum arabic production. A southward shift in the natural distribution of *Acacia senegal* is already being detected and is projected to continue as rainfall declines. It is estimated that, overall, the consequent reduction in gum arabic production will be accompanied by a decline in vital household income, region-wide, of 25–30%.

Influences on water quality and quantity

Climate-change models predict marked changes in seasonal snowfall, rainfall and evaporation in many parts of the world. Based on these changes, water quality and quantity could be negatively or positively influenced by forests. In many places, conventional water-management strategies will be unable to cope with the uncertainty associated with climate change and will struggle to meet growing future supply needs. Large-scale forest-planting to mitigate climate change could accentuate water shortages because fast-growing tree crops have the potential for high water demand and can lead to reduced water yields. The local trade-offs between energy generation opportunities and water impacts have to be assessed in particular in regions where climate change threatens water resources. For effective adaptation to climate change, explicit attention will need to be paid to managing water conflicts and assisting water users and managers to find mutually agreed solutions for the sharing of resources.



ERKKI OKSANEN

CLIMATE CHANGE MODELS PREDICT MARKED CHANGES IN SEASONAL SNOWFALL IN MANY PARTS OF THE WORLD.



JOHN PARROTTA

CLIMATE CHANGE COULD REDUCE ACCESS TO TRADITIONAL MEDICINES DERIVED FROM FOREST PLANTS AND ANIMALS. THIS COULD HAVE DIRECT HEALTH EFFECTS ON PEOPLE RELYING ON SUCH MEDICINES.



MARKO KATILA

UNCLEAR PROPERTY RIGHTS TO LAND AND UNCLEAR ACCESS AND USE RIGHTS TO FORESTS AND FOREST PRODUCTS ARE LIKELY TO INCREASE THE SOCIOECONOMIC VULNERABILITIES OF COMMUNITIES IN MANY TROPICAL AND SUBTROPICAL REGIONS.

Direct and indirect impacts on human health

Under many climate-change scenarios, forest fires are expected to occur more frequently in many parts of the world over longer fire seasons and at greater intensity, with significant negative effects on human health if not prevented. Changes in forest cover and biodiversity could reduce access to forest products, including forest foods, medicines and other non-wood forest products. Such losses would affect human health directly (e.g. by lowering the availability of medicinal plants), or indirectly (e.g. via the loss of marketable goods), and in the long term (e.g. because of the loss of indigenous knowledge about medicinal plants).

Lack of adaptive governance structures

Adapting to climate change will require many individuals to change their use and management of forests, which, in turn, is likely to require changes in the rules by which forest use and management take place. Unclear property rights to land, unclear access and user rights to forests and forest products, the lack of enforcement of such rights, and the lack of participatory and accountable decision-making mechanisms are likely to increase socioeconomic vulnerabilities and limit the adaptive capacity of communities and societies. Moreover, the failure of governance structures to promote sustainable forest management and investment in forest rehabilitation and reforestation could exacerbate conflict and reduce cooperation over remaining resources.

Key message: The impacts of climate change on forest goods and services will have far-reaching social and economic consequences for forest-dependent people, particularly the forest-dependent poor. Adaptation measures must go beyond single technical solutions and address also the human-institutional dimension of the problem.

Adaptation options

In the face of climate change, forest managers will be challenged to choose the most appropriate management options for maintaining and increasing the supporting, provisioning, regulating and cultural services of forests.

Sustainable forest management

The vulnerability of forest ecosystems can be reduced by reducing their exposure to climate change (e.g. through hazard preparation and early-warning systems, controlled burning, and other measures to reduce forest fuel loads), decreasing their sensitivity to climate change (e.g. by planting hardier species and increasing reservoir storage capacity to help avoid water stress in drought conditions), and maintaining or increasing resilience (e.g. by applying reduced impact logging, or by thinning overstocked stands).

Such measures can be implemented as part of sustainable forest management, which is an evolving system of forest practices that aims to ensure that the goods and services derived from forests meet present-day needs while at the same time securing their continued availability and contribution to long-term development. This concept of sustainable forest management reflects a shared understanding among the international forest policy community of the broad goals of contemporary forestry, to which the explicit goal of adaptation to climate change should be added.

The deployment of sustainable forest management is likely to help reduce environmental, social and economic vulnerabilities under a wide range of potential future climatic conditions. To date, however, limited progress has been made in adopting sustainable forest management, particularly in developing countries. This is likely to limit the ability to adapt to climate change; there is an urgent need, therefore, to increase capacity for sustainable forest management.

Key message: Sustainable forest management is essential for reducing the vulnerability of forests to climate change. The current failure to implement it limits the adaptive capacity of forests and forest-dependent people. To meet the challenges of adaptation, commitment to achieving the goals of sustainable forest management must be strengthened at both the international and national levels.



ERKKI OKSANEN

SUSTAINABLE FOREST MANAGEMENT CAN HELP TO REDUCE ENVIRONMENTAL, SOCIAL AND ECONOMIC VULNERABILITIES UNDER A WIDE RANGE OF POTENTIAL FUTURE CLIMATIC CONDITIONS.



FOREST MANAGERS NEED TO HAVE SUFFICIENT FLEXIBILITY TO CHOOSE LOCALLY APPROPRIATE MANAGEMENT PRACTICES AND TO WORK WITH OTHER STAKEHOLDERS, ESPECIALLY LOCAL PEOPLE, TO IMPROVE THESE PRACTICES.

Adaptive co-management

Climate change could result in the development of new forest ecosystems by changing site/species relationships, altering species' growth rates, and causing other ecological changes. In the absence of anticipatory adjustments it is very likely that climate change will increase the detrimental impacts from fires, pestilence and storms. Human activities may mitigate or exacerbate these effects of climate change.

Given the diversity of forests throughout the world, the diverse needs of various stakeholders for forest goods and services, and uncertainty about how climate change will affect different forests, no single approach to adaptation will suit all situations. Forest managers, therefore, need to have sufficient flexibility to choose locally appropriate management practices. They also need to work with other stakeholders, especially local people, to systematically improve these practices by means of observation, analysis, planning, action, monitoring, reflection and new action, a process known as adaptive co-management (Box 5). This will require extensive communication networks and monitoring schemes at all levels; it will also involve considerable investment in training, equipment and infrastructure (e.g. in communications, watch towers and road networks).

Key message: There is no universally applicable measure for adapting forests to climate change. Forest managers should, therefore, have sufficient flexibility to deploy the adaptation measures most appropriate for their local situations.

Box 5: Adaptive co-management

Adaptive co-management uses collaborative approaches to continually improve management policies and practices by learning from the outcomes of operational programmes. It involves a process of observation, analysis, planning, action, monitoring, reflection and new action.

CLEARANCE OF MONTANE TROPICAL RAINFOREST FOR AGRICULTURAL GARDENS AT PORING, SABAH, MALAYSIA. EFFORTS TO MANAGE TROPICAL FORESTS MORE SUSTAINABLY MUST TAKE INTO ACCOUNT THE COMPLEX RELATIONSHIPS BETWEEN THE WELFARE OF LOCAL PEOPLE AND GLOBAL CONCERNS SUCH AS CLIMATE CHANGE.



The need for new governance systems

Sustainable forest management must be supported by appropriate policies. Existing governance systems and policy designs are not coping well. A hierarchical, top-down style of policy formulation and implementation by the nation state and the use of regulatory policy instruments, such as forest laws, is likely to be insufficiently flexible in the face of climate change. Moreover, such traditional regulatory approaches have had uneven success in ensuring the sustainability of forest resources due to disparities in power and resources. For example, there has been a greater loss of biodiversity (as measured by the loss of natural habitat such as forests) in countries with highly unequal income distribution than in countries with less inequality. Given the uncertainties surrounding the impacts of climate change, a more flexible and collaborative approach to forest governance is needed that can respond more quickly to policy learning. Policies will need to place greater emphasis on financial incentives and information, supported, where necessary, by appropriate regulations.

Inter-sectoral coordination and policy integration

Although adaptive forest policy should be focused on forests, it cannot ignore the many drivers of change that originate in other sectors. Agricultural, energy, transportation and resource development policies can have significant negative impacts on forests, notably by encouraging deforestation. Through better coordination, policymakers can recognise the cumulative

effects on forests of other sectors and develop a more integrated approach to land management. Such policy integration, however, is often hampered by profound policy legacies, such as the institutionalisation of separate planning, permitting and monitoring regimes for each land use. Policymakers should aim to demonstrate the benefits of adapting forests to climate change through integrated land use at the project level rather than by attempting large-scale transformative changes that almost always fail.

New modes of governance

Implementing sustainable forest management including adaptation on the ground requires the formulation of policy goals that are sensitive to national and sub-national contexts. National forest programmes (NFPs) provide a basic governance framework for collaboration and policy learning that enables stakeholders to strike a mutually acceptable balance between the ecological, economic and social goals of sustainable forest management. They can be a core instrument of new forest governance arrangements at the national level and should include adaptation to climate change as an explicit objective. Nevertheless, the effectiveness of NFPs in formulating successful policies for forest adaptation depends on a number of factors, notably secure land tenure and forest user rights, the availability of sufficient financial incentives, and a conducive political culture in the nation or region. Evidence suggests that most NFP processes continue to restrict participation; this must change if they are to be an effective framework for achieving adaptation goals.



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Key message: Flexible approaches to policy design are needed that are sensitive to context and do not rely on a single, one-size-fits-all mechanism. New modes of governance are required that enable meaningful stakeholder participation and provide secure land tenure and forest user rights and sufficient financial incentives.

IN RECENT YEARS THE ESTABLISHMENT OF OIL PALM PLANTATIONS HAS INCREASED DUE TO GROWING DEMAND FOR BIOFUELS. THIS HAS INCREASED DEFORESTATION IN SOME REGIONS.

Implications for other policy instruments

The rapidly changing conditions under which sustainable forest management must operate require flexible policy instruments that encourage experimentation and reward innovation and technical progress. Market-based instruments such as forest certification, and approaches such as criteria and indicators for the monitoring and reporting of sustainable forest management, are more likely than regulatory approaches to serve this purpose. Both should incorporate climate-change adaptation as part of their approaches to sustainable forest management.



THE RAPIDLY CHANGING CONDITIONS FOR FOREST MANAGEMENT REQUIRE FLEXIBLE POLICY INSTRUMENTS THAT ENCOURAGE EXPERIMENTATION AND REWARD INNOVATION AND TECHNICAL PROGRESS. MARKET-BASED INSTRUMENTS SUCH AS FOREST CERTIFICATION ARE MORE LIKELY TO SERVE THIS PURPOSE THAN REGULATORY APPROACHES.



MORE SYNERGIES BETWEEN THE INTERNATIONAL POLICY REGIMES ARE NEEDED TO EFFECTIVELY ENHANCE FOREST ADAPTATION TO CLIMATE CHANGE.

Strengthening the adaptation of forests to climate change in international regimes

Forest-based climate-change adaptation measures are insufficiently financed. At the international level, policy development on the adaptation of forests to climate change takes place at the intersection of several existing policy regimes, especially those concerning forests, climate change and the conservation of biological diversity. Better integration of these regimes is needed to encourage experimentation and limit contradictory, ambiguous or duplicate initiatives. This need is clearest with respect to finance, where there is both a substantial shortfall in funds and a potential failure to use available funds to address the indirect effects of climate change (such as the conversion of forests to biofuel crops) that are already leading to deforestation. For this reason it is important that funding for reducing deforestation and forest degradation promotes adaptation as well as mitigation goals. In the longer term, efforts should be made under the Non-Legally Binding Instruments on All Types of Forests (NLBI) to restore official development assistance for sustainable forest management.

Continued support for research

Studies on adaptation of forests to climate change are relatively recent and only few have documented evidence on success in implementing various adaptation strategies. Given the diversity of forests, more precise regional and local climate-change projections are urgently required. Much more research is especially needed on the forest-related social and economic impacts of climate change.

Evaluations have shown that financial incentives can be very effective in promoting sustainable forest management when used in combination with regulation and sufficient information. Thus, also for financial incentives to work, research is needed to reduce the uncertainties associated with the impacts of climate change on forests and to improve knowledge about the management options that promote successful adaptation.

The problem with implementing research results is that especially experimental research on climate change impacts has to run for a long time before the results are available. At the same time, climate continues to change.

Key message: More research is required to reduce current uncertainties about the climate-change impacts on forests and people and to improve knowledge about management and policy measures for adaptation. Nevertheless, despite the limitations of current knowledge, climate change is progressing too quickly to postpone adaptation action pending the outcomes of future studies.

Limits to adaptation

Climate change adaptation and mitigation are complementary and closely linked. Indeed, given the importance of forests to climate, successful mitigation requires that forests are able to adapt to climate change. Many management actions taken in the context of adaptation, such as the prevention of large-scale fires, will also assist in the mitigation of climate change.

On their own, adaptation measures will be insufficient for forests to adapt to climate change; mitigation is essential. In line with the findings of the IPCC it can be stated with high confidence that the resilience of many forest ecosystems (i.e. their ability to adapt naturally) would be exceeded by 2100 by a combination of unmitigated climate change, associated disturbances such as fire, pestilence, drought and floods, and other factors such as land-use change, pollution and the over-exploitation of resources. Strong mitigation efforts outside the forest sector are therefore needed to preserve the adaptive capacity of forests and to enable them to make their essential contribution to the mitigation of climate change.

Key message: Even if adaptation measures are fully implemented, unmitigated climate change would, during the course of the current century, exceed the adaptive capacity of many forests. Large reductions in greenhouse gas emissions from fossil fuels and deforestation are needed to ensure that forests retain their mitigative and adaptive capacities.



Afterword and credits

This policy brief is the first document of its kind prepared within the framework of the Collaborative Partnership on Forests (CPF)'s Global Forest Expert Panels (GFEP) initiative. It is based on the peer-reviewed scientific global assessment report *Adaptation of Forests and People to Climate Change*, which was prepared on a collaborative basis by members of the CPF Expert Panel on Adaptation of Forests to Climate Change in the period February 2008 to February 2009 and published as IUFRO World Series Volume 22. The authors of the full report also greatly facilitated our work on the policy brief by providing written inputs, corrections and suggestions for improvement. However, we editors are fully responsible for the contents and possible faults of this policy brief.

We express our sincere gratitude to all the authors of the full assessment report: Andreas Fischlin, Peter Glück, John Innes, Bastiaan Louman, Alan Lucier, Balgis Osman-Elasha and John Parrotta (coordinating lead authors); Neil Adger, Matthew Ayres, Maria Brockhaus, Carol J. Pierce Colfer, Linda A. Joyce, David Karnosky, Seppo Kellomäki, Aynslie Ogden, Chin Ong, Gian-Kasper Plattner, Jeremy Rayner, Geoff Roberts, Heru Santoso, Brent Sohngen, Ian Thompson and Anita Wreford (lead authors); and Outi Bergäll, Trevor H. Booth, Susan Braatz, Talaat Dafalla, Craig Loehle, Nico Marcar, Johnson Nkem, Kevin Percy, Carmenza Robledo, Bob Scholes, Chris Swanston and Dmitry Zamolodchikov (contributing authors). In addition, we thank David Kaimowitz for providing expert advice and detailed comments on the policy brief, and Alastair Sarre for language editing.

Our thanks also go to the GFEP Steering Committee: the International Union of Forest Research Organizations (IUFRO) and its Secretariat gave outstanding support to the work of the Expert Panel, and the Center for International Forestry Research (CIFOR), the Food and Agriculture Organization of the United Nations, the World Agroforestry Centre

(ICRAF), the Secretariat of the Convention on Biological Diversity (CBD), and the Secretariat of the United Nations Forum on Forests (UNFF) provided overall guidance and generous in-kind support. We thank the UNFF Secretariat for organizing the translation of the Policy Brief into all official languages of the United Nations.

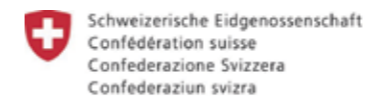
We gratefully acknowledge the generous financial support provided by the Ministry for Foreign Affairs of Finland, including for the layout and printing of this policy brief, the Swedish International Development Cooperation Agency, the United Kingdom's Department for International Development, the German Federal Ministry for Economic Cooperation and Development, the Swiss Agency for Development and Cooperation, and the United States Forest Service.

A short publication such as this cannot cover every issue related to the adaptation of forests and people to climate change. Moreover, scientific input into policy processes must not be limited to the production of written reports, but should rather be seen as a socially interactive process. The assessment reveals that there are still major gaps in knowledge about the impacts of climate change on forests and people and about how adaptation actions can best be tailored to local conditions. Nevertheless, it is our hope that this policy brief will contribute to the development of effective adaptation strategies and help to raise the visibility of adaptation of forests to climate change on the international policy agenda.

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March 2009

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