Adapting forests and their management to climate change: an overview

P. Bernier and D. Schoene

A synthesis of observations from the international conference on Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health, held in Umeå, Sweden in August 2008.

Pierre Bernier is a Research Scientist at the Laurentian Forestry Centre, Canadian Forest Service, Natural Resources Canada, Quebec. Seconded to FAO, Rome as a visiting expert for six months in 2008, he helped organize the conference in Umeå, Sweden on which this issue of *Unasylva* is based.
Dieter Schoene, forest and climate change specialist, retired from the FAO Forestry Department in 2007. He was a keynote speaker at the Umeå conference.

Forest adaptation to future environmental or social conditions resulting from climate change may significantly alter how and why forestry is practised in many parts of the globe. With the climate, and as a result the environment, undergoing perceptible changes within the life span of trees, achieving sustainable forest management will increasingly resemble aiming at a moving target.

The Intergovernmental Panel on Climate Change (IPCC, 2007) has concluded that warming of the climate system is unequivocal and most likely due to the observed increase in anthropogenic greenhouse gas concentrations in the atmosphere. In addition to the rise in average global temperatures, discernable changes have been observed in day, night and seasonal temperatures, in the frequency, duration and intensities of heat waves, droughts and floods, wind and storm patterns, frost, snow and ice cover, and in global sea levels.

Anthropogenic warming has already caused many changes in forests. As large, extensively managed, long-lived ecosystems, often on marginal sites, forests respond sensitively to climatic changes, together with the people, societies and economic activities that depend on them. IPCC rated boreal, mountain (see article by Maroschek *et al.*, this issue), Mediterranean, mangrove and tropical moist forests as the forest ecosystems most likely affected by climate change.

Forests also influence climate change, as sources of greenhouse gases when they are destroyed and as sinks for carbon when they grow or expand. The Bali Action Plan adopted by the thirteenth Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2007 proposes that forests in developing countries be considered a prime tool for climate change mitigation. Activities currently addressed include reducing emissions from deforestation and forest degradation in developing countries (REDD) and conservation and enhancement of carbon stocks through sustainable forest management.

Millions of indigenous forest dwellers depend directly on forests and their products. More broadly, forests contribute to human well-being through a well-known range of services. Hence, adaptation of forests to climate change is of critical importance. Locally, forest management and silviculture are likely to influence carbon sequestration by trees, the reaction of forests to climate change and the forest services provided to local populations. Here, mitigation and adaptation must meet.

Current observations and projections provide a first estimate of the adaptation measures that will be needed to cope in forestry and eventually in other sectors. Although the outlook is blurred by uncertainty, actions in today's forests link the present generation to those of the future, underscoring the need to incorporate adaptation to climate change in current forest management practices.

In August 2008, the international conference on Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health: A Review of Science, Policies and Practices brought together about 330 researchers, managers and decision-makers from

50 countries to discuss these issues (see www.forestadaptation2008.net). The conference was held in Umeå, Sweden and organized by the Swedish University of Agricultural Sciences, the International Union of Forest Research Organizations (IUFRO) and FAO. The following text captures some of the observations and ideas that emerged from the presentations and discussions.

CLIMATE CHANGE IMPACTS – PAST AND FUTURE

Forest ecosystems and their goods and services

At the local level, attributing a single extreme event to climate change is difficult. Climate is inherently variable and extreme events are not uncommon. An occasional insect outbreak or drought-induced mortality in one location may result from or be enhanced by natural climate variability. In many cases the absence of long-term, reliable records makes it difficult to determine if the frequency of extreme climatic events is increasing or not. At the global level, however, the current number and scale of such events provides strong circumstantial evidence of widespread and unusual changes in forest ecosystems (see article by Régnière).

Temperate and boreal forests experience reduced snow cover and earlier snowmelt, shorter frost periods and more extreme weather, which increases the likelihood, frequency, extent or severity of drought, heat waves, floods and intense storms. Forest fire seasons in many parts of the world are now longer or more severe. Warmer temperatures, coupled at times with poor forest management, have also predisposed some of the large, homogeneous forest ecosystems to outbreaks of insects, diseases and other pests. A vivid example is the current outbreak of mountain pine beetle (*Dendroctonus ponderosae*) that has ravaged more than 13 million hectares of forests in western Canada. Tropical forest ecosystems have experienced increased temperatures and more frequent and extreme El Niño–Southern Oscillation (ENSO) events resulting in a greater incidence of intense cyclones, extreme drought, fires, flooding and landslides. Lower river flow and higher storm surges are raising water salinity in mangroves and other coastal forested wetlands, leading to degradation of these vital ecosystems.

In arid and semi-arid lands, drought has increased tree mortality and resulted in degradation and reduced distribution of entire forest ecosystems, such as the Atlas cedar (*Cedrus atlantica*) forests of Algeria and Morocco. As drought reduces the productivity of adjoining agricultural land, many African communities with limited economic alternatives are likely to turn to the forests for crop cultivation, grazing and illicit harvesting of wood and other forest products, aggravating the local loss of forest cover.

The impacts of future climate change on health, growth, distribution and composition of specific forests cannot be predicted with certainty (see articles by van Zonneveld *et al*. and Silveira Wrege *et al.*). Local climate projections are still rare. In addition, biotic and abiotic factors can interact unpredictably. Growth may be stimulated by warmer seasons, longer growing seasons and the fertilizing effect of increased atmospheric CO_2 concentrations, as long as moisture or nutrient availability is not limiting. However, more frequent stand-replacing disturbances with abrupt, large and localized losses are foreseen (see article by Allen). Some climate change models predict a catastrophic dieback of parts of the Amazon and other moist tropical forests which would exacerbate global warming.

Changes to forests due to climate change may be aggravated by other human-induced changes in the natural environment. Ground-level ozone, a strong phytotoxic agent prevalent in developed countries, reduces tree growth. Nitrogenous pollutant deposition may enhance growth but may also cause nutrient imbalances. The accidental introduction of insect pests and pathogens via intercontinental trade, which has already profoundly altered many forest ecosystems worldwide, increases risks of large-scale infestations as climatic barriers to pest estab-

*Warmer temperatures have predisposed coniferous forest in western Canada to a severe outbreak of mountain pine beetle (*Dendroctonus ponderosae*) extending over more than 13 million hectares*

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lishment or proliferation are gradually lowered in high-latitude forests. Better management of these factors will help in the adaptation of forests to climate change.

The emerging pattern of current and future climate change impacts on forests is one of abrupt negative impacts from a wide spectrum of climate-related causes, and of more subtle negative and positive impacts that arise in some regions or at particular sites, often only for certain tree species. Overall, the risk for forests and for forest management over typically long rotation periods will increase steeply in most areas of the globe, and productivity gains of some forests are likely to be eradicated by disturbance. The environment for forestry is likely to become much more difficult during the course of this century.

People and livelihoods

Richer societies in industrialized countries have the means for dealing with the more immediate effects of climate change and are less prone to suffer in the short term. In contrast, the economic and human welfare impact of climate change can be severe for the many poor communities in developing and least-developed countries that depend on forests for food, fodder, fuelwood, medicines and ecosystem services. Water shortages and unpredictable rainfall, in combination with continued population growth and land degradation, increase pressure on forest ecosystems and their capacity to meet immediate livelihood needs. The promotion of community forestry in many developing countries may increase local adaptive capacity by putting decisions in the hands of the people who feel the effects of climate change first, and by enhancing the role of traditional knowledge in forest management (see article by Gyampoh *et al*.).

Even in developed countries, some communities depending on forest-based industries or located in forested landscapes are already affected by climate-related forest disturbance. In Canada, for example, the increased incidence of forest fires in boreal forests endangers population health and safety, and the vast mountain pine beetle outbreak will inevitably result in a major restructuring of the forest-based industrial sector, with consequences for the welfare of local populations (see article by Konkin and Hopkins).

Climate change also affects local revenues from tourism and recreational services when vast areas of dead or dying forests reduce scenic appeal or when sparse snow cover shortens skiing seasons.

ADAPTING FOREST MANAGEMENT PRACTICES

There are three possible approaches for adapting forests to climate change: no intervention, reactive adaptation and planned adaptation. Unfortunately, most current management belongs to the first or at best the second category.

No intervention means business as usual, with management targets and practices based on the premise that the forest will adapt more or less as it has in the past. Reactive adaptation is action taken after the fact, "crossing the bridge when we come to it"; examples include salvage cutting, post-disturbance changes in industrial processes to convert salvaged timber, updated harvest scheduling, recalculated allowable cuts and development of socio-economic support programmes for affected localities.

Planned adaptation, on the other hand, involves redefining forestry goals and practices in advance in view of climate change-related risks and uncertainties. It involves deliberate, anticipatory interventions at different levels and across sectors. At the community level, planned adaptation may include diversification of forest-based and non-forest based income sources, better local governance of forest resources and capacity building for monitoring and coping with possible calamities of unprecedented extent. Within the industrial forest sector, planned adaptation may involve the inclusion of bioenergy as a product or the promotion of wood products for their low carbon footprint. At the national and global levels, planned adaptation may include a timely monitoring and reporting system and the development of tools for vulnerability assessments and adaptation planning. Forest managers might also be increasingly required to weigh global implications of local interventions, as forests are part of global biogeophysical and biogeochemical cycles and are increasingly subject to international agreements or to certification schemes.

It may be argued that good forest management always involves planned adaptation. However, planning for climate change involves much greater uncertainty, novel risks and systematic risk reduction in response to anticipated events. Planned adaptation also includes exploring new opportunities that arise as a result of climate change, for example planting provenances or species that will grow faster under projected climatic conditions, or reaping the benefits of new products and services such as carbon sequestration and new forms of bioenergy. Planned adaptation may reduce vulnerability and increase resilience, or it may entail diversification at the expense of productivity.

At the stand level, planned adaptation may mean planting a larger diversity of species or provenances, or trees bred for resistance to expected stressors. Modification of thinning schedules may help stabilize stands against drought, storms and disease and may also help capture added growth from CO_2 fertilization.

At the scale of landscapes, planned adaptation may include measures to minimize the potential impacts of fire, insects and diseases, increased afforestation and reforestation, creation of biodiversity corridors (see article by Mansourian, Belokurov and Stephenson) and rehabilitation of degraded forests. At the scale of a forest management unit, adaptation options may include vulnerability assessments and increased preparedness for disaster. Finally, forest management planning can no longer be based solely on growth and yield trajectories over time. Management plans must incorporate uncertainty and the increased probability of extreme events, as well as the periodic comparison of projections against the evolving reality so as to update targets and methods.

Intensive forest monitoring is a key component of planned adaptation and will probably require additional technical and human resources. Monitoring can provide early warning of forest dieback and of pest and disease outbreaks, help reduce uncertainty in planning, and minimize losses. After an extreme event, rapid damage assessments are useful for planning timber salvage and conservation and predicting impacts on timber supplies, markets and socio-economic conditions. Most developed countries with significant forest cover already track tree growth and forest status; these efforts have sometimes been broadened to include aspects related to climate change such as monitoring of carbon and forest health. In developing countries, lack of funding and expertise for monitoring and assessment may hinder early detection of climate change impacts and timely responses. Here planned adaptation must start with capacity building for periodic forest assessments.

Combining forest monitoring and current knowledge of possible climate change impacts into vulnerability or risk assessments is the first vital step in developing an adaptation strategy. Such assessments can be used to identify where risk management is worthwhile and where the repertoire of response options in the forest sector is currently insufficient. Developing, testing and improving risk assessment methods can also provide new focus for monitoring.

SCIENCE TO SUPPORT PLANNED ADAPTATION

Climate change has permeated into many fields of environmental research, including forest ecology and forest management. Researchers increasingly need to interact with policy-makers and managers to ensure the relevance and effective application of research. In this respect, IPCC has been crucial and successful, transmitting authoritative technical information to policy-makers in readily accessible form. It has also heightened the awareness of the research community to the type of information needed by decision-makers and has reached out effectively to the public. Science–policy dialogue has flourished in national administrations as countries around the world have had to take a stance on climate change related issues in national policies and international negotiations.

Monitoring of forests is vital to planned adaptation to forest management. Multiscale monitoring can detect changes in forest status and health early. Remote sensing may facilitate early detection and mapping of forest health calamities and may prove particularly useful in areas lacking systematic ground surveys or as a stratification tool for subsequent ground surveys; improved frequency of coverage and resolution make it possible to capture even ephemeral, small-scale phenomena.

Risk assessments of changes in forests, and of changes outside the forest sector that could have impact on forests, are another key to effective adaptation; they will need to be designed to incorporate the complexities of forest responses to stress.

Although the most striking forest changes attributed to climate change are occurring at high latitudes, smaller changes in tropical climates may have large effects on vegetation because of the complex interdependence of forest organisms and their narrow climatic niches. Vulnerability and risk assessments for the tropics are thus particularly challenging.

The development of planting stock with desirable genetic traits may be a promising avenue to counter changes in the local climate. Achieved gains in

Agroforestry has potential for providing benefits from adaptation–mitigation synergies in developing countries because it enhances diversification, reduces risk and helps stabilize livelihoods (windbreak using Alnus acuminata*, Ecuador)*

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productivity and drought resistance suggest further potential for improvement of many commercially important species, although the need for stock that can thrive under current as well as future conditions presents a particular challenge.

Prospects for developing resistance to new pests or diseases through traditional breeding programmes, however, appear limited. After some 50 years of tree breeding, few gains have been made in this regard, except for major diseases in a few commercially important species, e.g. leaf rust in poplars (see article by Yanchuk and Allard). Emerging forest health risks in tropical plantations of exotic species also suggest a need for improved approaches in forest genetics.

Climate change accentuates uncertainty, but dealing efficiently with uncertainty and risk is not a well-developed concept in traditional forestry sciences. Climate scientists and IPCC have learned to communicate climate uncertainties quantitatively. Now forest managers and policy-makers must learn to integrate these probabilities systematically into planning and decisions on the ground. Expertise in managing uncertainty and risk might also be brought in from fields in which it is common, such as management science, operations research, financial management, insurance and engineering.

Finally, impetus for change in the forest sector and in society comes chiefly from socio-economic, not ecological, crises. It is therefore only by linking the physical events to their socio-economic impacts that scientists can fully inform policy-makers. This will involve elevating the importance of the social and behavioural sciences in forest management.

ADAPTING POLICIES AND INSTITUTIONS

Lessons may be learned from current forest crises linked to climate. The mountain pine beetle outbreak in Canada, for example, has underlined some key messages (see article by Konkin and Hopkins). Catastrophic events happen abruptly and overtax conventional knowledge and normal forest management structures. Data are important, but are often insufficient to change people's attitudes. Appropriate responses often require a dramatic departure from conventional views and practices. The challenge of planned adaptation, therefore, is to make organizational culture, established structures and forest management policies more flexible before crises arise.

Adaptation to climate change and mitigation of climate change are often considered separately but may be linked to provide greater benefits (see article by Blate *et al.*). In all countries, mitigation actions such as afforestation or curbing of deforestation need to be properly planned and linked to local adaptation policies in related sectors to help local people better their livelihoods and withstand negative effects of climate change.

It is particularly urgent to channel benefits from adaptation–mitigation synergies to local populations in developing countries (see article by Osman-Elasha). Agroforestry holds great potential in this regard because it enhances diversification, reduces risk and helps stabilize livelihoods. Agroforestry practices sequester only modest amounts of carbon per hectare, but trees, bamboos and palms can be combined in almost unlimited ways with agricultural crops, garden products, grazing or fishponds on a huge area worldwide.

Adaptation and mitigation can also meet within the concept of REDD. Conceived as a mitigation option to reduce global emissions of CO_2 to the atmosphere, REDD can best succeed by encouraging sustainable forest management in developing countries. Sustainably managed forests can better adapt to climate change, and sustainable management can reduce or reverse forest loss and degradation and enhance forest resilience to climate change. For developing countries, REDD also represents adaptation in the sense of exploiting novel opportunities created by climate change in the form

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Climate change mitigation efforts need to support local adaptation of people and communities (India)

of incentive payments, carbon sales and investments in forests.

One of the problems regarding the linkage between adaptation and mitigation is that adaptation is often a response to local circumstances and is therefore a local concern benefiting local populations, while mitigation is a response to a global concern and is usually dealt with at the country scale. The challenge of mitigation policies such as REDD, particularly in developing countries, is therefore to ensure that significant benefits from mitigation actions flow to communities or forest owners. The best manner of doing this may be to ensure that mitigation actions promote local adaptation to climate change and that they fit within an overall effort of decreasing the vulnerability and poverty of local communities.

Adaptation is also essential for industries, as climate change is a new variable in their operating environment. The production and use of products from sustainably managed forests also contributes to mitigation, as wood is one of the few truly renewable raw materials available, and products made from it store carbon. In many countries investment in wood production through improved silviculture or planted forests represents a joint mitigation and adaptation measure. Wood-based products are low-emission alternatives to steel and concrete, can be recycled and could be used for bioenergy at the end of their life cycle, enhancing their appeal as environmentally sound products. Where a net energy saving can be demonstrated, policies for diverting discarded solid wood materials from the traditional waste stream towards bioenergy facilities would have the double advantage of reducing methane emissions from landfills (in landfills not equipped to capture such emissions) and substituting fossil fuels. Development of the bioenergy market can also be used as an adaptation measure in areas that have suffered mass forest mortality. Coherent energy polices concerning the entire forest products value chain, in combination with awareness raising and incentives to encourage appropriate consumer response, could play an increasingly important part in mitigating climate change.

CONCLUSIONS

The health of many forest ecosystems is already affected by climate change, and the impact is likely to accelerate, with local and global negative consequences that will likely outweigh growth increases linked to climate change. Adaptation is possible, but it is essential to plan and act soon to avert the most detrimental impacts and capture the opportunities. Awareness of actual and potential impacts from climate change, assessment of uncertainties and inclusion of risks should form the backbone of adaptation policies in forest management planning. The main challenge may be to promote planned adaptation in the absence of immediate crisis, especially when planned adaptation means reducing the potential long-term gains that would be realized in the absence of climate change. Reactive adaptation may be the most natural option but will hurt forests and society in the long term.

Reducing deforestation in developing countries (REDD) is now high on the global climate change agenda, but it is not clear how internationally negotiated modalities and eventual national implementation will affect the people whose livelihoods depend totally or partially on forests. This potentially powerful option for climate change mitigation and adaptation can only succeed through sustainable forest management and ensuring that mitigation efforts support local adaptation of people and communities.

A message that stands out clearly from the Umeå conference is the large gap between developed and developing countries in terms of scientific, planning and operational capacity for adaptation. While many developed countries invest in large multidisciplinary efforts aimed at refining risk assessments and at implementing adaptation and mitigation, many developing countries face enormous deficits in information, leadership and funding essential to implementing adaptation, and are also constrained to focus on more immediate needs. Poverty and instability make planned adaptation difficult, and in vulnerable environments large negative impacts of climate change on livelihoods may be unavoidable. In these countries, all policies related to forest-based mitigation and adaptation of forest management to climate change need to be linked with rural development and agricultural policies that focus on people, poverty alleviation, food security and livelihoods. Planned adaptation is for the common good. Equity issues and technical capacity building are necessary components of the forest sector's adaptation to climate change in developing countries and thus call for attention from the global community.

Climate change highlights more clearly than ever the need to tackle global issues in a multisectoral manner and necessitates collaboration among countries. Regional and national institutions responsible for forest stewardship and management are stepping up collaboration on this issue. Specialized institutions and governance mechanisms are slowly taking shape as the scale of the challenge and the consequences of not tackling it globally become clear. ◆

Bibliography

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate change 2007: synthesis report*. IPCC Fourth Assessment Report. Geneva, Switzerland.◆