Forest Health

Context for the Canadian Forest Service's Science Program

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Cover, pages 1, 3, and 5: Old growth forest, Victoria, B.C. (detail); photo courtesy Eric Allen, CFS Pacific Forestry Centre, Victoria, B.C.

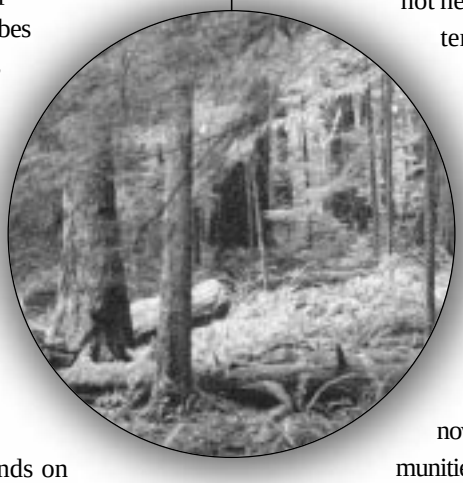
Page 7: Asian long-horned beetle (*Anoplophora glabripennis*); photo courtesy John Yanyshyn, Visions West Photography, Victoria, B.C.

Page 8: Ice storm, Gatineau Park, Que., January 1998; photo courtesy Ken Farr, Ottawa.

Introduction

Forest health has long been associated with protecting forests against insects and diseases and salvaging stands of damaged or infested timber. Protection of forests mainly involves preventing losses in forest crops, taking timber inventories, and dealing with products and services for which the forest is valued. Forest protection and surveys of forest insects and diseases, along with reforestation, formed the foundation of what is now the Canadian Forest Service (CFS), Natural Resources Canada. However, the concept of forest health has greatly expanded both in scope and in application since the founding of the CFS a century ago.

This paper is the first in a series of context papers intended as guides to the current and future directions of the CFS's science program. The present paper defines "forest health" and describes why the CFS, in cooperation with its wide range of partners, addresses forest health issues through research, monitoring, and assessment activities in its science and technology research networks.



What Is Forest Health?

How forest health is viewed depends on how forests are valued, whether for timber, watershed services, carbon sinks, recreation, aesthetics, wildlife habitat, or spiritual renewal.[1] Forest health affects both active and passive forest users. Healthy forests are essential to environmental health, wealth generation, and job creation in our country.

Forest ecosystems are healthy when their underlying ecological processes operate within a natural range of variability, so that on any temporal or spatial scale, they are dynamic and resilient to disturbance (see Kimmins 1997; AFMSC 1997; Lackey 1998). Natural range of variability refers to ecosystem composition, structure, processes, and patterns for a specified time and a specific area. Forest ecosystems are degraded when they are not expected to be as productive, in terms of all components of the ecosystem, and resilient after disturbance as they were before. Such a decline in forest health can occur when a forest is subjected to severe disturbances, such as flooding, drought, acidic deposition, toxic substances, or severe fires.

In the past, forest health was seen mainly as a problem in preventing standing timber from decaying or burning before it could be harvested. The focus was primarily on identifying forests that no longer provided resources and services of the quality or in the amounts expected. Accordingly, forest health was assessed more by the amount of timber damage and lost tree growth than by factors contributing to deterioration of forests or by those characterizing a healthy forest ecosystem. It is easier to measure the health of single trees than that of whole forest ecosystems; the presence of dead and dying trees does not necessarily mean that the forest ecosystem is unhealthy.

However, today's forest policymakers and managers are responsible for more than debating the definition of "forest health". They must ensure that Canada's forests will continue to provide competitive timber supplies and will satisfy a wide range of environmental, social, and cultural values. In addition, they now must work with public and local communities in forest management planning and, in some cases, operations. In their pursuit of sustainable forest management, forest policymakers and managers need to account for the following aspects of forest health: symptoms of forest decline; ecological determinants of forest condition; and socioeconomic and other consequences of changes in forest health and what can be done to prevent or alleviate their impacts.

Long before European settlement, Canada's vast forests evolved in response to recurrent and often profound, but inherent, influences including wildfire, wind, ice storms, floods, drought, insects, diseases, and climate change. Human activities have disrupted the natural range of variation in structure, composition, and landscape patterns of Canadian forests. These activities include introductions of insects, disease, and other foreign organisms;

land use and resulting land cover change; fires, both accidental and deliberate; atmospheric pollutants, including acidic deposition; changes in tropospheric ozone and ultraviolet-B radiation; and carbon dioxide and other greenhouse gases linked to climate change.

It is not always clear how much change in forest condition is due to natural processes and how much results from human activities. Some silvicultural systems can alter species composition and age classes, leaving residual stands more vulnerable to insect and disease attacks. For example, harvesting a white spruce–balsam fir stand favors the establishment and perpetuation of fir forests that are more vulnerable to eastern spruce budworm than the original forests. Successful exclusion of fire in lodgepole pine stands has resulted in forests that are more flammable and more susceptible to infestations of mountain pine beetle. However, it is difficult to attribute causes for the recent increase in forest fires to drier weather and more lightning storms or to past forest fire suppression policies. The change in frequency and severity of extreme weather may be the result, in part, of global environmental change.

Changes in forest condition may have negligible or even beneficial effects on ecosystem productivity and resilience, but may cause hardship to communities dependent on the forest or reduce a forest's attractiveness to tourists. Effects of some catastrophes may be essentially permanent if the ecosystem, for example, is reduced to bare rock. We need to understand the underlying ecosystem processes for different types and ages of forests and the contribution of these processes to the resilience of the ecosystem. However, the stresses and degree of perturbation an ecosystem can adapt to and still maintain a desired ecological condition are limited.

The degree of change in forest conditions (from insects, diseases, fires, etc.) that is unacceptable and seen as loss and damage depends on how people value forest tracts—whether for timber, wildlife habitat, parks, or watersheds. Forests that are healthy in terms of wildlife habitat may not be in terms of growing timber.

In general terms, a healthy forest is one that maintains biodiversity, resiliency, wildlife habitat, aesthetic appeal and resource sustainability.

Forest Health in Canada (CFS 1998)

Why Is Forest Health Information Needed?

The Canadian Forest Service addresses forest health by providing provincial and territorial forest agencies, private sector forest managers, other federal departments and agencies, Aboriginal forest organizations, non-governmental organizations, and the interested public with

- compilations and syntheses of information on forest health conditions and reports in the context of national and international criteria and indicators of sustainable forest management;
- knowledge about the underlying causes of changes in forest health;
- assessments of the socioeconomic impacts of forest health conditions;
- predictions of global change trends, their expected impacts on forest health, and resulting socioeconomic consequences; and
- an ecological basis for devising adaptive management strategies and forest practices to promote healthy forests.

Information about the status of forest insects, diseases, and fire, and their effect on Canada's timber supply remains important. Increasingly, information is needed to support Canada's participation in international agreements and to monitor and to assess forest-pest-related trade issues. Domestic forest health is closely related to international issues. Customers of Canadian forest products are demanding that our forest management practices be sustainable; that is, harvests do not exceed annual growth, cut-over areas are promptly regenerated, and site quality and biodiversity are conserved. The obligation to maintain carbon stocks under the Kyoto Protocol to the United Nations Framework Convention on Climate Change provides another example of a connection between international and regional issues.

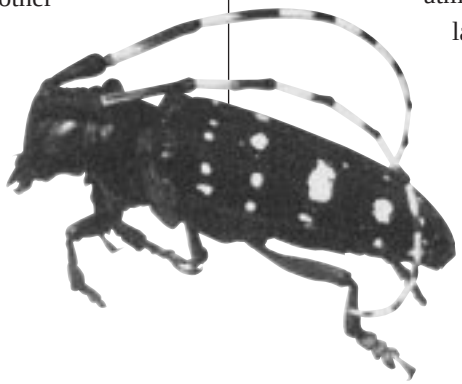
In addition, forest-management and other interested agencies, industries, communities, and the public need

to know the condition of the forest and how it is changing, as a basis for devising strategies to adapt to or if necessary to avoid these changes.

Exotic Insects and Diseases

The global spread of organisms beyond their native ranges poses a threat to indigenous species and to market access for Canada's forest products. Harmful exotic, or alien, insects and other organisms often arrive without their native predators, diseases, and various population checks (see Niemelä and Mattson 1996; Dawson et al. 1997; Allen et al. 1998a,b; Haack et al. 1997). These exotic forest pests are the subject of international agreements, notably the International Plant Protection Convention under the auspices of the United Nations Food and Agriculture Organization (FAO), and the North America Plant Protection Organization (NAPPO). Under this agreement signatories agree, among other things, to provide

- reports on the existence, outbreak, and spread of economically important non-native pests of plants and plant products that may be of immediate or potential danger, and
- information on means found to be effective in dealing with the pests of exotic plants and plant products.



NAPPO is recognized as the authority on phytosanitary issues under the North America Free Trade Agreement. In addition, Canada is participating with the North American Forestry Commission, which is also a regional FAO body, to produce a list exotic forest pests introduced to North America.

Phytosanitary regulations can present non-tariff barriers to trade. For example, allegations by the European Union that the pinewood nematode will be introduced into Europe in shipments of Canadian lumber and harm its forests threatens trade in wood products in that market. Countries have recourse to the phytosanitary agreement of the General Agreement on Trade and Tariffs, led by the World Trade Organization, to resolve disputes involving the movement of forest pests in wood products.

The Canadian Forest Service participates with the Canadian Food Inspection Agency in the detection, identification, and assessment of other known and potential foreign forest pests. Developing detection methods and creating risk scenarios to determine the likelihood of certain non-indigenous species establishing themselves in Canada is crucial for effective regulatory and pest management strategies (see Harrison and Smith 1997; Humble and Allen 1997).

The Health of Forests and Global Environmental Change

Global environmental change, as the consequence of natural processes and human activities, affect the global environment directly and cumulatively. Climate change is the most well-known of three interrelated components of global environmental change. The others are atmospheric environmental change and land cover change. These changes can be detected as large shifts in average annual temperature, the distribution of land cover and forest types, and other variables. They should not be confused with changes that are within natural bounds for a given forest type. A major consideration is choosing a reference period on which to base comparisons between current and historical forest condition. Some forms of global change, such as urbanization, deforestation, and loss of wetlands, can happen within weeks or months. Others, such as changes in climate and the thinning of the atmosphere's stratospheric ozone layer, are measurable over a span of decades or centuries.

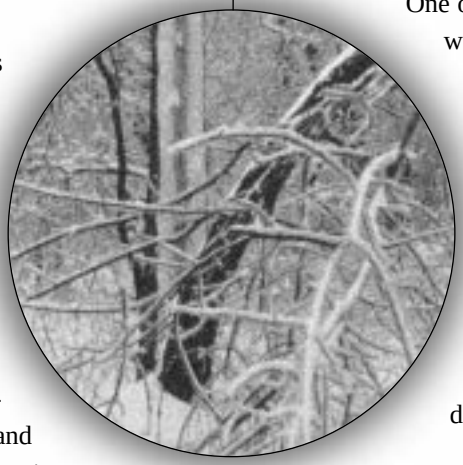
Some effects of global change on Canada's forests may have implications that go beyond forest health. For instance, scientists predict that the southern edges of the boreal forest will be supplanted by grasslands and temperate deciduous forests as a result of climate change. It is not clear whether northern forests of the future will be less resilient to stresses and less productive than they are at present. Similarly, deforestation is not strictly a forest health issue.

Land Cover Change

Land cover change, or the change in the distribution of vegetation, water, desert, ice, and other physical features, including those created by human activities, is largely brought about by changes in land use patterns. Land cover change greatly affects the hydrology, climate, and global biogeochemical cycles, as well as biodiversity and ecological structure and functioning. It is a major influence on the carbon balance and climate change.[2] For instance, deforestation results in the release into the atmosphere of carbon stored in aboveground biomass and in the soil organic matter. The resulting increase in the concentration of carbon dioxide in the atmosphere contributes to global warming. As such, land cover change is an issue with far-reaching policy implications, internationally, nationally, and locally.

Atmospheric Change

Atmospheric change, which includes stratospheric ozone depletion and increased ultraviolet radiation, and various ground-level air pollutants (NO_x, SO_x, "acid rain", volatile organic compounds or VOCs, tropospheric ozone)[3], affects the productivity, functioning, and health of forest ecosystems. Pollutant emissions associated with increased industrialization, resource consumption, and other human activities are expected to continue to increase nationally and globally. The capability to understand and to predict the consequences of the long-range transport of air pollutants on forests and to pinpoint the sources of air pollutants is essential for achieving the sustainable management of forests.



Several international conventions and associated protocols deal with atmospheric change:

- the Convention on Long-Range Transboundary Air Pollution, a framework convention for developing protocols for addressing a number of airborne pollutants including "acid rain", NO_x, and SO_x;
- the Canada–United States Air Quality Agreement[4]; and
- the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol, which set targets and conditions for reduction of substances that deplete the atmospheric ozone layer.

Climate Change

The Kyoto Protocol to the United Nations Framework Convention on Climate Change requires that Canada report on the state of its forests as carbon sinks and the effects of reforestation, afforestation, and deforestation on the forests. Key indices include changes in the extent of forest, influences on carbon stocks related to management practices, and natural influences related to fire and insects.

The Intergovernmental Panel on Climate Change, which advises the world's governments on climate change, concluded in 1995 that scientific evidence suggests a discernable human influence on global climate. One outstanding issue is whether extreme weather is increasing in severity and frequency. Another issue is the effect of climate change on the frequency of forest fires, and, in turn, the release of carbon stored in forest carbon reservoirs. A vigorous forest acts as a sink, or a fixer of carbon, whereas deteriorating forests give up carbon, or become sources of atmospheric carbon dioxide as they decay.

Biological Diversity

The International Convention on Biological Diversity defines "biological diversity" as "the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems." More simply, biodiversity means "the variety of life." It can be addressed in terms of genes, species, ecosystems, and landscapes and therefore through the scientific disciplines of genetics, taxonomy, and ecology.

Canada, as a signatory to this Convention, is committed to managing and using its natural resources in a sustainable manner, to conserving its biodiversity, and hence to

maintaining the productivity and resilience of its forests. Biologically diverse ecosystems tend to be more productive and resilient than those with less diversity. Diverse forests can be maintained nearer to their ecological potential and can recover more readily from perturbations (Tilman and Downing 1994).

Criteria and Indicators of Sustainable Forest Management

In 1995, the Canadian Council of Forest Ministers released *Defining Sustainable Forest Management: A Canadian Approach to Criteria and Indicators,* to help guide and assess Canada's progress in achieving sustainable forest management (CCFM 1995). It followed this two years later with a technical report on data availability and reporting capacity for forest values (CCFM 1997). A parallel international initiative by the Montreal Process Working Group (1997a,b) produced *Progress on Implementation of the Montreal Process on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forest* and the *First Approximation Report of the Montreal Process*. Since sustainability of forests is based on the forests being healthy, many of the criteria are useful for assessing forest health.

Scientists and others are working to supply the needed information and to develop new ways to measure and report on forest sustainability in Canada. Their work will also contribute to continued progress at the international level.

Adaptive Forest Management

Provincial and local forest policies and practices influence forest health. Understanding the impacts of forest policies and practices helps avoid unwanted side-effects on forest ecosystems. Adaptive forest management policies and practices also are needed to adjust to changing growing conditions for Canada's forests. Adaptive management is a process of hypothesis testing for whole systems. It continually evaluates and adjusts management relative to predicted responses, objectives, and predetermined thresholds of acceptable change (AFMSC 1997).

Emerging Issues

Pressure is growing to ensure that forest health information is verifiable. Monitoring systems may have to be revised so that they provide for acceptable baseline conditions and impact-damage thresholds against which to assess and predict forest health conditions and test adaptive forest management strategies and practices. Some emerging issues include

- the influence of exotic insects and diseases on the health of the forest and on market access for Canadian forest products, which requires targeted monitoring and surveys to detect and quantify potential problems;
- the increasing role for traditional environmental knowledge in all aspects of forest management;
- the effects of multiple and cumulative stressors on forests, especially
  - the possible combined impacts on forest productivity of the high ground-level ozone levels and high carbon dioxide, and
  - the connections between climate change, insect outbreaks, extreme weather, and forest decline;
- early indications of impact on the forest by climate change.

Notes

1. See Jenkins (1997) for a useful discussion of this issue.
2. See *Understanding Our Changing Planet: An Overview of Global Change Research in Canada* (Shillington 1996), a report prepared for the Canadian Global Change Program. The Canadian Global Change Program includes the following components: climate change, stratospheric ozone loss, air pollution, biodiversity loss, soil degradation, and ocean pollution.
3. See Hall et al. (1998) for a comprehensive discussion of acidic depositions on Canada's forests and Wardle et al. (1997) for a discussion on ozone.
4. See the International Joint Commission's progress report (1996) on this agreement.

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Scientific Names of Organisms Mentioned in the Text

Balsam fir, *Abies balsamea* L.

Eastern spruce budworm, *Choristoneura fumiferana* (Clem.)

Lodgepole pine, *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.

Mountain pine beetle, *Dendroctonus ponderosae* Hopk.

Pinewood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle

White spruce, *Picea glauca* (Moench) Voss