CRITERIA AND INDICATORS

OF SUSTAINABLE FOREST MANAGEMENT IN CANADA

TECHNICAL REPORT

1997

Canadian Council of Forest Ministers

Conseil canadien des ministres des forêts

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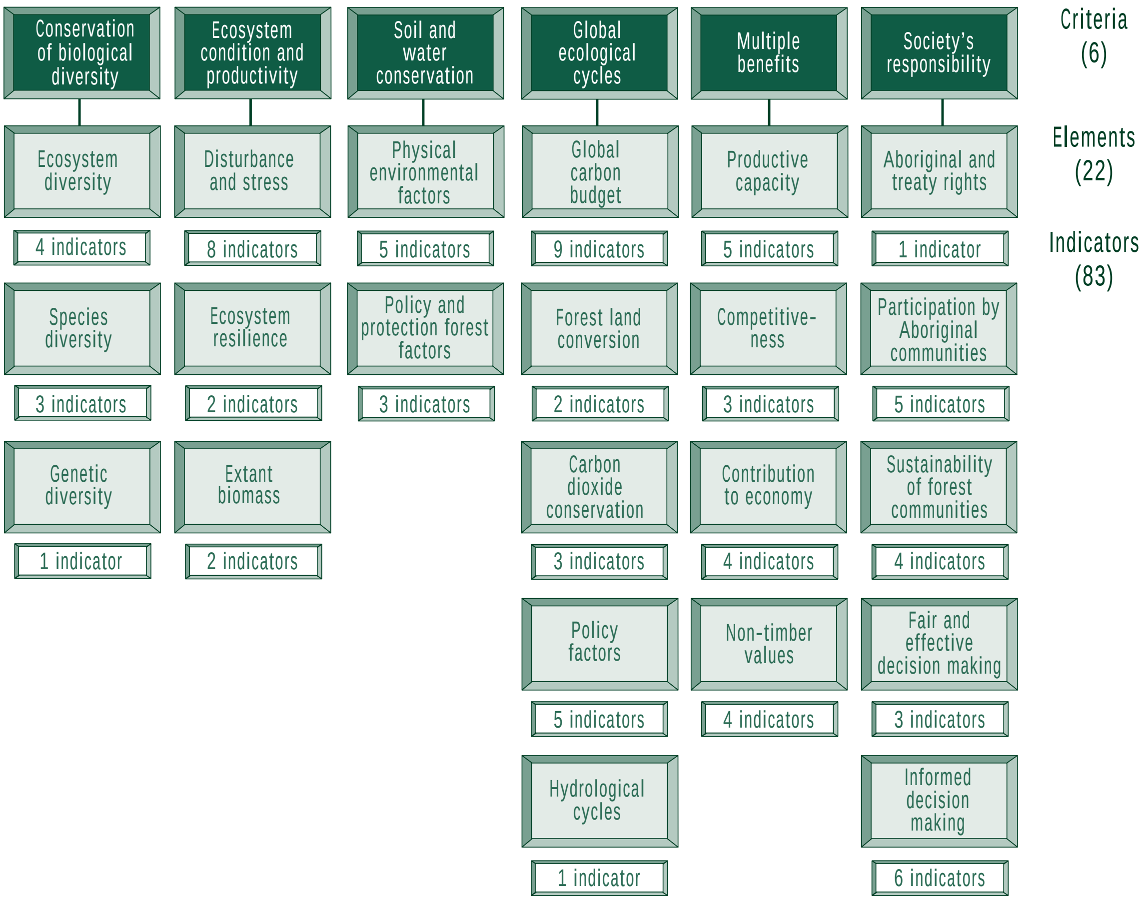
CRITERIA AND INDICATORS FRAMEWORK

Action 3.5: "Canada...will develop a system of national indicators to measure and report regularly on progress in achieving sustainable forest management."

– *Sustainable Forests: A Canadian Commitment*
Canada's National Forest Strategy



Forests are a major consideration in global discussions on sustainable development. Because Canada accounts for 10% of the world's forest land and almost 20% of global trade in forest products, our decisions and actions with regard to sustainability can have a major impact on global economic, social and environmental systems.

In 1993, the Canadian Council of Forest Ministers (CCFM) embarked on an initiative to define, measure and report on the forest values Canadians want to sustain and enhance. With the support of technical and scientific advisors, the CCFM consulted extensively with officials and scientists from the federal, provincial and territorial governments, as well as with experts from the academic community, industry, non-governmental organizations, the Aboriginal community and various other interest groups.

The results were reflected in *Defining Sustainable Forest Management: A Canadian Approach to Criteria and Indicators*, which was published in March 1995. The development of these criteria and indicators (C & I) is an important step in meeting Canada's domestic commitments on sustainable forest management.

Our domestic commitment to sustainability was enshrined in the National Forest Strategy, entitled *Sustainable Forests: A Canadian Commitment*, which was endorsed in March 1992 by federal, provincial and territorial governments and by other interested groups (e.g., industry, Aboriginal peoples and environmental associations). Later that year, at the United Nations Conference in Environment and Development (UNCED), Canada successfully argued for recognition of the importance of sustainable forest management through the adoption of a statement of forest principles.

Over the years, governments across Canada have been rethinking their forest policies to better reflect the principles of sustainable management. Activities range from revising forest legislation to take into account a wide array of forest values, to developing programs that involve the public in ecosystem management plans and resource strategies.

The C & I are intended to provide a common understanding and scientific definition of sustainable forest management in Canada. Together they serve as a framework for describing and measuring the state of our forests, forest management practices, values and progress toward sustainability. This information and data are needed to shape forest management policies and to focus research on areas where we need to improve our technology and knowledge. The C & I framework reflects an approach to forest management which is based on the recognition that forests are ecosystems that provide a wide range of environmental, economic and social benefits to Canadians and that sustainable forest management demands an informed and participatory public, as well as the best available information and knowledge.

The six sustainable forest management criteria that have been identified include traditional concepts, such as timber values, but go beyond economics to encompass—among others—environmental, social and Aboriginal values. Each criteria is subdivided into elements, and from those elements, 83 indicators have been established to help track the nation's progress in achieving sustainable development and balancing

Montreal Criteria and Indicators Process

In addition to measuring our progress on sustainable forest management within our national borders, Canada is playing a leadership role in international efforts to measure forest sustainability. Of particular importance is the Montreal C & I Process, so named because the first meeting sponsored by the Conference on Security and Cooperation in Europe took place in Montreal in 1993. This initiative involves 12 countries that together represent 90% of the world's boreal and temperate forests. Argentina, Australia, Canada, Chile, China, Japan, Korea, Mexico, New Zealand, Russia, Uruguay and the United States are collaborating to develop national C & I for the conservation and sustainable management of all boreal and temperate forests.

environmental, economic and social objectives. No single criterion or indicator is a measure of sustainability on its own, but together they can highlight trends or changes in the status of forests and forest management over time.

Soon after the release of the C & I framework, the CCFM created a task force to report on Canada's ability to measure the various indicators. The CCFM C & I Task Force included representatives from the federal government and each provincial and territorial forest jurisdiction. Teams of experts (supported by a technical committee representing many forest interests) drafted Canada's first report on the C & I using data collected from a wide range of sources. The report was then reviewed by all jurisdictions and approved by the Task Force.

This first C & I report describes our present ability to measure the forest values that Canadians want to sustain and enhance. Generally speaking, the most current data available describe traditional timber management. This is because values such as forest type and age, and the incidence of natural and human disturbances have been measured and monitored for many years. Economic factors, such as employment trends in the forest sector and the value of timber exports, can be reported at a national level. Some indicators, such as the carbon budget, which is measured through computer models, also can be reported on nationally.

In other areas, national and quantitative data do not exist. Currently, efforts are underway to determine means of addressing the lack of information on such topics as biodiversity at the genetic level and measures of soil and water quality. There are also gaps in data for some socioeconomic indicators. Canada is presently unable to provide national economic analyses of non-timber values, such as the recreational, subsistence and Aboriginal use of forests, nor can we fully report on the in-depth public involvement at various levels in planning and monitoring forest practices. Qualitative descriptions or case studies are used to provide some level of understanding of the status of indicators that lack data.

There has been a great deal of progress in developing measures of Canada's achievements in sustainable forest management, but more work remains to be done. Future CCFM efforts will focus on maintaining and expanding current databases, developing methodologies to collect data for such areas as the social elements of sustainability, and improving our understanding of forest ecosystems. The framework will be updated to include only those indicators that provide a comprehensive picture of the sustainability of our forests and can be reported on nationally.

Canada views the C & I as an important policy tool that will help guide and assess our progress toward sustainable forest management. Moreover, like many other countries, Canada recognizes that development and implementation of the C & I will require continuous refinement as public values change and as we acquire new knowledge of forest ecosystems.

Criteria and Indicators

OF SUSTAINABLE FOREST MANAGEMENT IN CANADA

Technical Report 1997

TABLE OF CONTENTS

CRITERION 1.0

CONSERVATION OF BIOLOGICAL DIVERSITY

INTRODUCTION

Biodiversity is the variability among living organisms and the ecological complexes of which they are a part. It can be viewed in the context of three elements: ecosystems, species and genes.

Many different types of forest ecosystems are found throughout the world, and they contain the majority of the Earth's plants, animals and microorganisms. The conservation of biodiversity makes forests productive and resilient, while enabling them to cycle nutrients and to provide clean water, oxygen and other life-support services.

Biodiversity and natural systems are dynamic. The populations, species, forest types and age classes that comprise Canada's forests are determined by the processes of disturbance and renewal. Maintaining biodiversity entails examining ecosystems at many levels of organization and at different time and space scales. It also involves making land-use and resource management decisions that incorporate biodiversity needs, such as limiting the conversion of forests to agricultural and urban lands, creating protected areas, managing the harvest of forest plants and animals, preventing the invasion of foreign insects and diseases, and protecting wildlife habitat through careful timber harvesting.

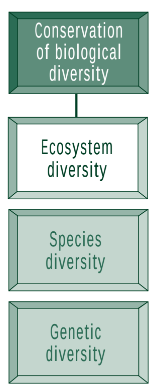
Viewed at the national level, Canada has highly diverse forest ecosystems. They span wide temperature and precipitation ranges—from the Carolinian forest in southwestern Ontario to the narrow strings of trees growing along Arctic rivers, and from the West Coast rainforests to the dry ponderosa pine forests. Even boreal ecosystems are diverse, with their complex mixtures of bogs, lakes and sparsely vegetated rocks, and their coniferous stands at varying stages of development following fires and insect infestations. Element 1.1 (Ecosystem diversity) measures and reports on this diversity and its importance for sustainable forest management.

Estimates suggest that Canada is home to approximately 140 000 species of plants, animals and microorganisms, only half of which are classified by science. (If viruses are included, the total number could rise to nearly 300 000.) Approximately two-thirds of these species are found in forests or dependent on a forest habitat. Roughly 180 species of trees grow in Canada's forest. Element 1.2 (Species diversity) focuses on the status of better known groups of plants and animals.

Genetic diversity is the ultimate basis for the variety of species and ecosystems. It enables organisms to respond to environmental change and shape the ecosystems in which they live. Distributions of genes are ever changing as individuals and populations respond to such factors as weather, food availability and predators. Despite this complexity, practical measures to conserve forest ecosystem types and tree species populations also help conserve the genetic diversity of other organisms. Element 1.3 (Genetic diversity) describes genetic conservation strategies for commercial and endangered forest vegetation species.

More knowledge is required of all three forest biodiversity elements; however, Canada still has almost its entire original complement of forest species and ecosystems. With appropriate management, monitoring and research strategies, it should be possible to conserve this forest biodiversity for future generations.

ELEMENT 1.1
ECOSYSTEM DIVERSITY



What are we measuring?

An ecosystem consists of plants, animals and microorganisms interacting with their physical and climatic environment in a given area. Each forest ecosystem in Canada has its own set of species adapted to regional climate, habitat type and disturbance patterns. Because species populations change in response to such biotic factors as food availability and predators, ecosystems also are constantly changing. For example, the boreal ecosystems that comprise roughly three-quarters of Canada's timber producing forests regularly experience major fires and insect outbreaks, and the species that grow in these ecosystems have adapted to these natural disturbances.

Added to natural disturbances are human pressures. Comparing the current status of Canada's forest ecosystems with their status prior to large-scale human disturbances is one way to assess the impact of these disturbances on ecosystem diversity. The area of protected forests can be used to measure how a natural range of ecosystems is being maintained. The density of roads in forested areas is used as a substitute for data regarding the fragmentation of forest ecosystems.

How does ecosystem diversity relate to the sustainability of Canada's forests?

When forests are converted to agricultural or urban areas, biodiversity is clearly altered. More subtle changes occur when forests are affected by human impacts, such as air pollution, timber harvesting and the introduction of exotic species (e.g., Dutch elm disease).

Age-class information is important for the conservation of biodiversity because it enables timber harvests to be planned so as to maintain a full range of successional habitats for wildlife and ecosystem types over the long term. Protected areas are useful too because they act as ecological benchmarks for assessing the impacts of forest management on biodiversity. They also maintain habitat for rare and endangered species, and ideally allow evolutionary and adaptive processes to continue unimpeded.

Fragmentation is another indicator of changes to forest biodiversity. For example, when forests are fragmented into isolated units, the associated increase in "edge habitat" can lead to greater changes in biodiversity than would be predicted based solely on the total area harvested. By designing harvesting and other silvicultural activities to minimize edge habitat or to emulate natural disturbances, forest managers may help minimize the impacts of these activities on biodiversity. This requires information on the frequency, intensity, pattern and predisposing factors of natural disturbances.

What data are available?

Percentage and extent, in area, of forest types relative to the historical condition and total forest area (1.1.1)

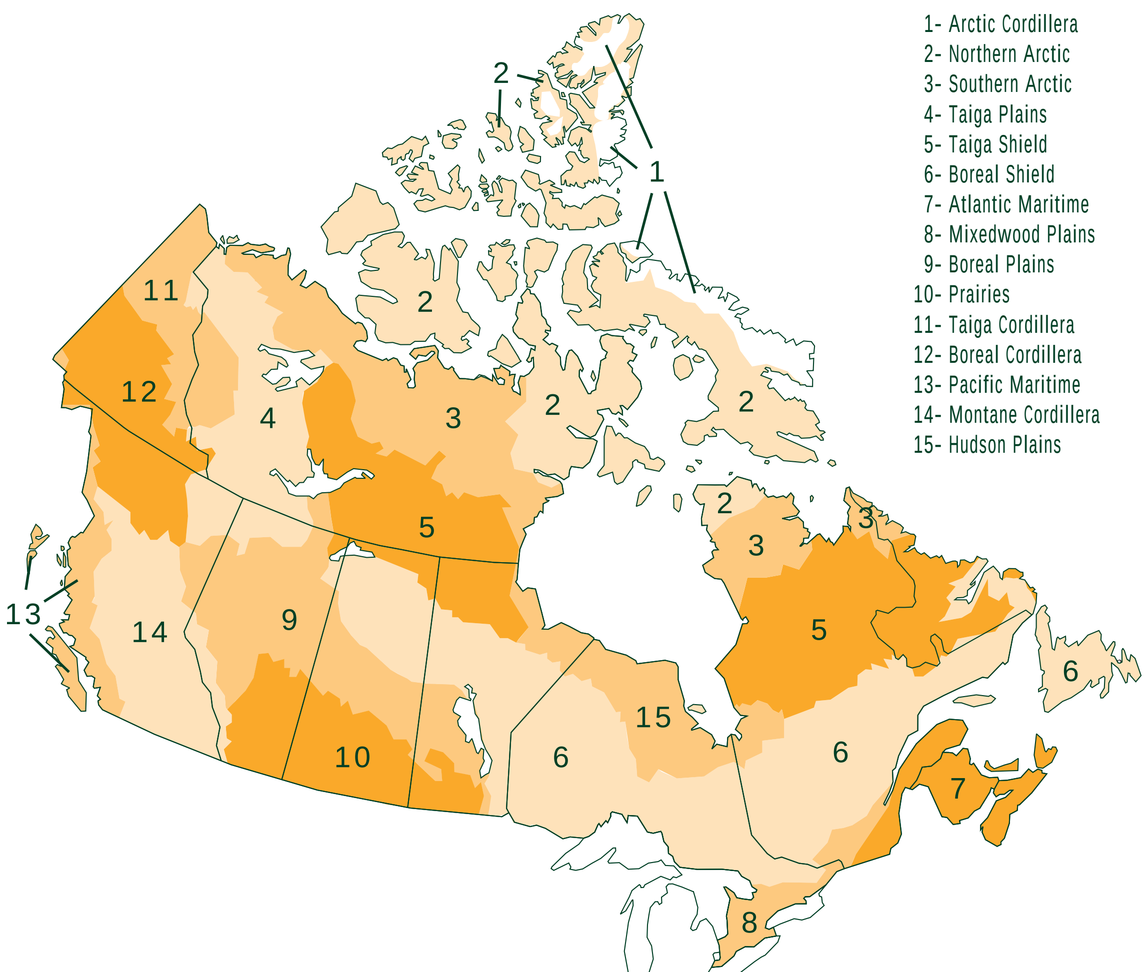
Various sources can be used to reconstruct the historical condition of Canada's forests, including early forest inventory data, land survey records, and analyses of tree pollen in lakes and peat bogs.

To complete the portrait, research is required to determine the former range of the species, based on their known climate and soil preferences.

The 1996 National Ecological Framework divides Canada into 15 terrestrial ecozones, 194 ecoregions and more than a thousand ecodistricts. Figure 1.1a shows the location of the ecozones. *The ecozones are also shown in the tear-out map at the end of the report.*

Figure 1.1b provides an overview of the ecozones based on data from the 1991 national

1.1a Terrestrial ecozones



Source: Ecological Stratification Working Group, 1995

1.1b Overview of Canada's forests by terrestrial ecozone

ECOZONE	TOTAL AREA million hectares	TOTAL FOREST million hectares	TOTAL FOREST %	"PRODUCTIVE" FOREST million hectares	"PRODUCTIVE" FOREST %
Arctic Cordillera	25.06	0.01	0.0	0.00	0.0
Northern Arctic	151.09	0.00	0.0	0.00	0.0
Southern Arctic	83.24	3.24	3.9	0.00	0.0
Taiga Plains	64.70	50.02	77.3	17.08	26.4
Taiga Shield	136.64	52.68	38.6	10.21	7.5
Boreal Shield	194.64	151.08	77.6	106.10	54.5
Atlantic Maritime	20.38	16.03	78.7	15.57	76.4
Mixedwood Plains	19.44	3.66	18.8	3.30	17.0
Boreal Plains	73.78	49.82	67.5	33.80	45.8
Prairies	47.81	2.08	4.4	1.78	3.7
Taiga Cordillera	26.48	8.49	32.0	0.58	2.2
Boreal Cordillera	46.46	28.82	62.0	13.91	29.9
Pacific Maritime	21.90	10.06	45.9	8.56	39.1
Montane Cordillera	49.21	34.86	70.8	32.13	65.3
Hudson Plains	36.24	6.71	18.5	1.54	4.2
CANADA	**997.06**	**417.58**	**41.9**	**244.57**	**24.5**

Source: Natural Resources Canada–Canadian Forest Service

forest inventory. Of the 15 ecozones in Canada, 11 have 15% or more forest cover, and 8 have at least 15% "productive" forest cover (i.e., forest capable of producing a harvestable volume of timber within a reasonable length of time).

Ecozones and ecoregions are valuable for reporting and analysis, but have limited use in decision making at the level of forest management units. More detailed classifications identify forest ecosystems wherever they occur in the landscape, based on similarities in topographic position, soil, geological properties and vegetation. Such forest ecosystem classifications have been completed for most of Canada's commercial forests, and they are a valuable resource for the practising forester, especially when accompanied by field guides that provide identification keys and silvicultural interpretations.

Data on dominant tree species are obtained from aerial photographs and are available from provincial and territorial timber inventories. A national overview of the state of Canada's forest ecosystems is compiled every five years from these provincial and territorial databases. From a biodiversity perspective, however, this national inventory has significant limitations. For example, it cannot be used to assess trends in species composition. Also, younger forests are underrepresented, and species are sometimes grouped under general headings, such as "spruces" or "unspecified broadleaves." More detail is needed to assess the conservation status of various forest types and species.

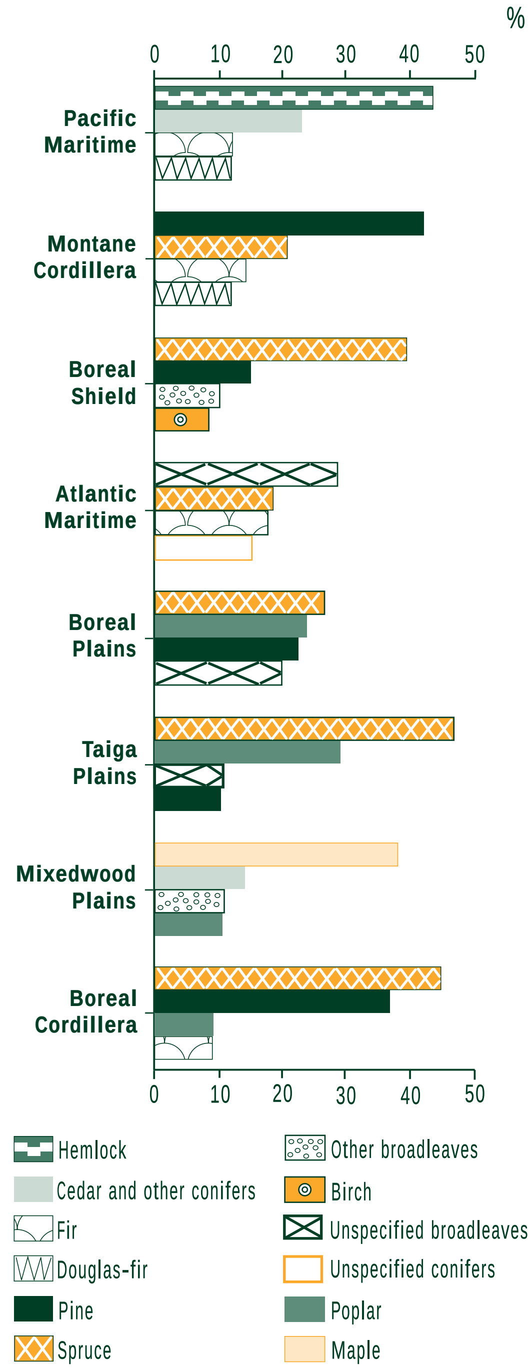
Despite these shortcomings, the national inventory provides the best available overview of forest types in Canada. Figure 1.1c shows the most common types in each ecozone. Pacific Maritime forests are dominated by western and mountain hemlock, western red cedar, various true fir species and Douglas-fir. Montane Cordillera forests have lodgepole pine, Engelmann and white spruce, subalpine fir and Douglas-fir. Forests of the Boreal Cordillera are dominated by white and black spruce, lodgepole pine and subalpine fir, occasionally mixed with poplars. White and black spruce and poplars dominate the Boreal Plains and Taiga Plains, in either pure or mixed stands; lodgepole and jack pine also are common.

Dominant Atlantic Maritime species include black, white and red spruce; balsam fir; sugar and red maple; white birch; and trembling aspen. The abundance of some species, such as white cedar, white pine and red spruce, may have declined considerably during the past 200 years of harvesting, but better data on historical forest composition are needed to assess these changes.

The Boreal Shield is Canada's largest ecozone (195 million hectares). Approximately 40% of the forest is dominated by black and white spruce. Jack pine occupies roughly 15% of the forest area, while balsam fir, poplar and birch make up most of the remainder.

The Mixedwood Plains ecozone has the greatest diversity of tree species in Canada—more than 100 in total. Sugar maple is the most common species, with white cedar, trembling aspen and white birch as major secondary species. Roughly 10 million hectares of forests have been cleared in this ecozone, largely for agricultural and urban development. Of particular concern is the disappearance of the Carolinian forest in southwestern Ontario: less than 10% forest cover remains, and roughly 60% of Canada's endangered forest-dwelling species are found there. (Healthy populations of many of these endangered species are still found in the United States.)

1.1c Dominant forest types by ecozone



Source: Natural Resources Canada–Canadian Forest Service

Percentage and extent of area by forest type and age class (1.1.2)

Most of Canada's forests are composed of even-aged stands that were established following major disturbances, such as fires, insect outbreaks and harvesting. These stands are dominated by species that grow best in full sunlight: jack pine, lodgepole pine, black spruce, trembling aspen and white birch. The age of the stands is generally estimated from aerial photographs.

A small, but economically significant portion of Canada's forests is composed of species that commonly reproduce in the shade and grow in uneven-aged stands. These forests include the mixed conifer forests in the Pacific Maritime ecozone and the northern hardwood forests in the Atlantic Maritime and Mixedwood Plains ecozones.

Age class data in the national inventory need to be improved to more accurately reflect the composition of Canada's forests. Not all provincial inventories are updated regularly to reflect fires, insect outbreaks and timber harvesting. For example, areas surveyed to obtain timber volume data for harvesting may not be resurveyed for decades. Hence, the inventory data reflect a strong bias toward semi-mature and mature stands. This picture is complicated by the differing upper limits for age data. Accurate dating of older stands has not been a priority, and old-growth features, such as snags, coarse woody debris and multiple canopy layers, have not been identified.

Some differences in age class structure among ecozones are nonetheless evident (Figure 1.1d). Forests whose age exceeds 160 years are common only in the Pacific Maritime ecozone, where major fires and insect outbreaks are rare. Tree species in those forests commonly live for several hundred years. In the Boreal Cordillera and Montane Cordillera ecozones, a large proportion of the forests (39% and 47%, respectively) is more than 120 years old. The proportion of forests in that age class is much smaller in the Boreal Shield (10%) and Boreal Plains (10%), and is even lower in the Atlantic Maritime (3%) and Mixedwood Plains (2%) ecozones.

The lower age of eastern forests only partly reflects harvesting activity. Some tree species, such as trembling aspen and balsam fir, are short lived—rarely reaching 100 years of age. Furthermore, the probability of major natural disturbances, such as fires and severe insect outbreaks, is high in eastern Canada.

Figure 1.1d also shows a decline in the proportion of hardwoods in older age classes of the Boreal Plains and Taiga Plains ecozones. The composition and age class structure of Canada's forests are continually changing, owing to the varying frequency of fires, insect outbreaks and harvesting. The National Forestry Database indicates that the average area affected annually by harvesting and fire has increased since 1970. This should in turn increase the proportion of younger age classes in Canada's forests.

Area, percentage and representativeness of forest types in protected areas (1.1.3)

Representative protected forest areas provide ecological benchmarks, which enable the biodiversity in undisturbed ecosystems to be compared with that in areas managed for forest products. Protected areas also provide wilderness experiences and other recreational benefits.

1.1d Age class distribution by ecozone and forest cover type

Source: Natural Resources Canada–Canadian Forest Service

Different categories of protected areas have been identified by the World Conservation Union (IUCN). Logging may occur in some protected areas, provided that it does not conflict with the overall objective of conserving natural systems. In November 1992, representatives of the Councils of Environment, Parks and Wildlife Ministers signed a statement of commitment to complete Canada's networks of protected areas by 2000. These networks are representative of Canada's land-based natural regions.

According to Environment Canada's Canadian Conservation Areas Database, in 1995, approximately 7.6% of Canada's forest land was located in protected areas—an increase of 11% since 1985; roughly half of these protected forests are considered "strictly protected," excluding them from such industrial activities as logging and mining. However, because of the discrepancies regarding data and definitions, more analysis is needed to accurately determine the exact number, location and size of protected forest areas in Canada.

Increases in the amount of protected forests have been even greater in some ecozones (Figure 1.1e). In the Pacific Maritime, for example, the protected forest area more than doubled between 1985 and 1995—to 6.6% of the total forest area. Virtually all of this area is strictly protected (no logging is permitted). In other ecozones, such as the Boreal Shield or Atlantic Maritime, less than half the protected area has the same degree of protection.

Policies and programs to conserve biodiversity in forests outside protected areas also are being put in place. In addition to influencing the management of publicly owned forest lands under timber tenures, these programs can provide important benefits in ecozones, such as the Mixedwood Plains or Atlantic Maritime, where a large percentage of forest land is privately owned.

Level of fragmentation and connectedness of forest ecosystem components (1.1.4)

When ecosystem components become separated in time and space, the integrity of the ecosystem is challenged. This fragmentation can affect critical connections within an ecosystem. For example, the association between mature pine forests and recent fires influences natural regeneration, landscape diversity and wildlife habitats. Fragmentation of this association will have consequences for ecosystem functioning. From ecological modeling and baseline studies in natural forested landscapes, it may be possible to derive critical thresholds for levels of fragmentation below which there is no known adverse effect on the sustainability of an ecosystem.

The first requirement for obtaining data on fragmentation is mapping the spatial location of ecosystem components. This has been done for individual study sites, but not on the wider scale suitable for national reporting. As a proxy indicator, we can look at human intrusion into landscapes by reporting on the densities of roads in New Brunswick and British Columbia. Although road density is also a function of terrain, it is one type of distribution with significant consequences for landscape fragmentation.

In most parts of Canada, roads are a precursor to human activity. The density of roads clearly illustrates the intensity of human activities, ranging from urban areas with very high densities, to remote areas with sparse or nonexistent road networks. Density is expressed

1.1e Protected forest areas by ecozone

Source: Environment Canada–Canadian Conservation Areas Database

as the length of all existing roads divided by the surface area of the ecoregion in question.

Some wildlife species are highly sensitive to roads. Wolves, for example, are almost never found where there is more than 0.45 km of roads per km^2. While the Atlantic Maritime ecozone has a moderate road density throughout (>0.25 km/km^2), in the Taiga Plains and Boreal Cordillera ecozones of British Columbia, there are vast stretches with sparse road densities (<0.25 km/km^2). Comparative figures are available for Alaska (0.08 km/km^2), Maine (0.53 km/km^2), the United Kingdom (2.29 km/km^2), and Connecticut (8.76 km/km^2).

The only areas that can claim status as undisturbed (non-fragmented) are those located at a certain distance from any road. Because most human influences occur close to roads and decline rapidly with distance, 1 km can be assumed to be the critical distance. In British Columbia, roughly 22% of the landscape is within this distance; the remaining 78% has less human disturbance.

Summary

Conifers are abundant in Canada, notably in the vast spruce and pine forests of the Boreal Shield, and in the hemlock, cedar, fir and Douglas-fir forests of the western mountains. Poplars are commonly found mixed with spruces in the Boreal Plains and Taiga Plains, and mixed with a variety of other conifers and hardwoods (mostly birch and maple) in eastern forests.

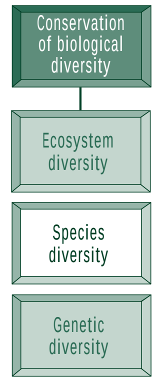
The average age of Canada's forests decreases from west to east, reflecting natural variations in species longevity and differences in the frequency of disturbances (e.g., fires, insect outbreaks and timber harvesting). Forests exceeding 160 years of age are common only in the Pacific Maritime ecozone.

Approximately 7.6% of Canada's forests are in protected areas, and logging is prohibited in more than half of these areas—in forests classified as "strictly protected." Between 1985 and 1995, there was an overall gain of 11% in the amount of protected forests in Canada, including a doubling of the protected forest area in the Pacific Maritime ecozone.

Densities of road networks can be used as a proxy for forest fragmentation. However, more work is needed to establish the relationship between road densities and the fragmentation of forest ecosystems.

ELEMENT 1.2

SPECIES DIVERSITY



What are we measuring?

Each of Canada's major forest regions is inhabited by a distinct group of species whose diversity is primarily affected by ecosystem productivity and is influenced by geography, history, soil nutrients, mean temperature, growing season and moisture levels. ("Species diversity" refers to the variety of plants and animals in a particular area.) To date, few provinces have selected species to monitor as indicators of functional forests, although many are in the process of doing so. In many parts of the country, the Model Forest Program has provided the incentive to examine the role and validity of these indicators in forest management.

Limited sources and studies provide information on the changes over time in the population levels of various species, and some data exist that enable a comparison to be made between the current ranges of particular species and their known historical ranges. The provincial, territorial and federal governments maintain lists of species that are classified as extinct, endangered, threatened and vulnerable.

How does species diversity relate to the sustainability of Canada's forests?

Conservationists worldwide agree that humans have a responsibility to maintain all life-forms. How populations of species are affected by environmental change is key to assessing the impact of human activities. Therefore, an important objective of sustainable forest management is ensuring that populations of species are not put at risk as a result of forest harvesting and regeneration.

A component of biodiversity monitoring is to follow species or groups to determine whether they face long-term changes in population size or distribution. Species extinction is the ultimate sign of environmental degradation and unsustainable resource use.

What data are available?

Number of known forest-dependent species classified as extinct, threatened, endangered, rare or vulnerable relative to the total number of known forest-dependent species (1.2.1)

"Extinct" refers to species that no longer exist. Two forest-dependent species in Canada have become extinct due to overhunting: the passenger pigeon (1914) and the Queen Charlotte Islands caribou (1935). Endangered species are those facing imminent extinction or extirpation (extinction in Canada); threatened species could become endangered if limiting factors are not reversed; and vulnerable species are those that are especially sensitive to human activities or natural disturbances.

Some provinces and territories and the federal government—through the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)—maintain lists of animals and plants falling into the above categories. Provincial, territorial and national lists do not always correspond because species may be endangered in one province but not another, or because national assessments are as yet incomplete for some species. Figure 1.2a *(see page 13)* lists forest dependent species that fall into these categories at the national level.

The national list now includes nine endangered animal species and ten endangered plant species that need forest conditions for all or part of their feeding, breeding or shelter requirements. The two forest types that contain the most species at risk are those with the most restricted distribution in Canada: the temperate rainforests of British Columbia (Pacific Maritime ecozone) and the Carolinian forests within the Mixedwood Plains. Both forest types are heavily used and in the latter, clearing for agriculture began more than 300 years ago. Some of the most endangered species are highly dependent on old-growth forests. They include the pine marten in Newfoundland, the prothonotary warbler and Acadian flycatcher in Ontario, the woodland caribou in the Gaspé region of Quebec, and the spotted owl in British Columbia. (Recent research in Newfoundland, however, indicates that it is the forest structure that is important to the pine marten, not the age of the forest stand. Thus, consideration is being given to modifying harvesting and silvicultural practices to manipulate young stands to create the forest structure preferred by the marten.)

The two most widespread forest species at risk are the woodland caribou and wolverine. Woodland caribou require mature or old-growth coniferous forests, which are disappearing in many areas of their range. Indeed, there is considerable concern over caribou habitat loss in Quebec, Ontario, Saskatchewan, Alberta and British Columbia. Wolverines, on the other hand, use a variety of forest habitats. However, like grizzly bears, they are negatively affected by low levels of disturbance, occur naturally in low abundance, and have been heavily trapped throughout the past century. Wolverines are listed as endangered in Ontario, Quebec and Labrador. In Alberta, where approximately 1 000 individuals are estimated to exist, they are listed as vulnerable.

Population levels and changes over time for selected species and species guilds (1.2.2)

Species populations fluctuate in response to many factors, often in combination. Therefore, it is not always possible to attribute simple cause and effect between such factors as habitat and population.

The decline of woodland caribou in the interior montane region of British Columbia provides an example of the interactions among species, habitat and functional relationships. In that region, harvesting increased the amount of food available in young regenerating forests and resulted in an expanded moose population. In turn, the larger moose population supported an increase in wolves, which meant higher predation rates and lower populations of caribou than would have been expected based solely on the remaining suitable habitat. An understanding of this situation was made possible only by the constant monitoring of all of the species in the study area, and this amount of data is rare.

An important consideration is that all forests are modified regularly by disturbances, and species have adapted to those disturbances *(see Criterion 2 [Maintenance and enhancement of forest ecosystem condition and productivity])*. For example, much of the boreal forest is naturally composed of younger age classes, so many boreal plants and animals inhabit early successional forests.

While some species prefer mature stands, a significant number of species benefit from forest harvesting, including some of the large ungulates (e.g., moose and elk) and many species of passerine birds (e.g., yellow warbler and most forest sparrows). Therefore, sustainable forest use requires the monitoring of species and communities in all forest age classes.

At specific study areas throughout the country, individual species or groups of species have been monitored for a number of years, or there are indirect indices of their populations. Examples include breeding songbirds, certain furbearers (e.g., marten in Newfoundland), and moose and deer in most provinces.

Ideally, a pool of species for each forest age class would be chosen and monitored to report on the functioning of an ecosystem. Criteria for species selection would include: functional links between species (e.g., predator and prey), body size (to reflect various spatial scales), breeding and feeding requirements, use of specialized habitat features, trophic levels and possible keystone roles (i.e., whether loss of the species would have an impact on several other species).

Figure 1.2b *(see page 14)* lists the species that could be monitored for the various forest ages and ecozones. A more definitive list will be developed following consultations with wildlife biologists across Canada. Data exist for the trees and most of the large-bodied animals, and provincial agencies are beginning to accumulate data for other species. However, not all Canadian species have been identified (especially invertebrates), and historical data for most species are not available.

Forest harvesting operations concentrate on coniferous species. As a result primarily of early

1.2a Forest-dependent species by ecozone that are listed by COSEWIC as vulnerable, threatened or endangered

ECOZONE	ANIMALS			PLANTS		
	Vulnerable	Threatened	Endangered	Vulnerable	Threatened	Endangered
Pacific Maritime	grizzly bear, wolverine, ermine *(Queen Charlotte Island's population)*, Keen's long-eared bat, Pacific giant salamander, Queen Charlotte goshawk	marbled murrelet	Vancouver Island marmot, spotted owl	phantom orchid, cryptic paw lichen, oldgrowth specklebelly lichen, seaside bone lichen	yellow montane violet, white-top aster	seaside centipede lichen, deltoid balsamroot, prairie lupine
Montane Cordillera	grizzly bear, wolverine, Nuttall's cottontail, fringed myotis bat, pallid bat, spotted bat, flammulated owl	yellow-breasted chat, white-headed woodpecker	spotted owl	—	—	—
Great Lakes–St. Lawrence[a]	southern flying squirrel, wood turtle, red-shouldered hawk, cerulean warbler, red-headed woodpecker	eastern Massasauga rattlesnake	Kirtland's warbler	broad beech fern, green dragon	blunt-lobed woodsia, deerberry, ginseng, white wood aster	spotted wintergreen
Carolinian[b]	southern flying squirrel, wood turtle, cerulean warbler, yellow-breasted chat, prairie warbler, Louisiana waterthrush, red-headed woodpecker, grey fox, eastern mole	hooded warbler	blue racer snake, prothonotary warbler, Acadian flycatcher	Shumard oak, common hop tree, dwarf hackberry, American columbo, broad beech fern, false rue-anemone, few-flowered club rush, green dragon, wild hyacinth	American chestnut, blue ash, Kentucky coffee tree, red mulberry, ginseng, bird's-foot violet, deerberry, golden seal, nodding pogonia, purple twayblade, round-leaved greenbriar, white wood aster	cucumber tree, heart-leaved plantain, large whorled pogonia, small whorled pogonia, spotted wintergreen, wood poppy, drooping trillium
Boreal Shield	woodland caribou, wolverine *(western population)*, Gaspé shrew	woodland caribou *(Gaspé population)*	cougar, wolverine *(eastern population)*, Newfoundland pine marten	—	—	—

(Continued on page 14)

1.2a Forest-dependent species by ecozone that are listed by COSEWIC as vulnerable, threatened or endangered (continued from page 13)

ECOZONE	ANIMALS			PLANTS		
	Vulnerable	Threatened	Endangered	Vulnerable	Threatened	Endangered
Boreal Plains	woodland caribou, wolverine	wood bison	—	—	—	—
Atlantic Maritime	southern flying squirrel, Gaspé shrew, wood turtle	Blanding's turtle *(Nova Scotia population)*	cougar	—	—	—

[a] the Great Lakes–St. Lawrence forest, which includes the northern portion of the Mixedwood Plains ecozone and the southern portion of the Boreal Shield ecozone in extreme southeastern Manitoba, Ontario and Quebec, has its own characteristic group of species
[b] the Carolinian forest, which is part of the Mixedwood Plains ecozone in extreme southwestern Ontario, has a unique and characteristic group of species

1.2b Animal indicator species in forest ecozones by age of stand

ECOZONE	FOREST STAGE		
	Young	Mature	Old growth[a]
Pacific Maritime	black-tailed deer, Vancouver Island marmot, black bear, Roosevelt elk, Lewis' woodpecker, hairy woodpecker	black-tailed deer, Queen Charlotte goshawk, Peale's peregrine falcon, red crossbill, Yuma myotis, Pacific jumping mouse	marbled murrelet, tailed frog, Pacific giant salamander, clouded salamander, Keen's long-eared myotis, spotted owl, Roosevelt elk, Trowbridge's shrew, silver-haired bat
Montane Cordillera	moose, mule deer, lynx, Rocky Mountain elk, black bear, northern long-eared myotis, Lewis' woodpecker, hairy woodpecker	mule deer, grizzly bear, red crossbill, flammulated owl, Hammond's flycatcher, fringed myotis, western small-footed myotis, Coeur d'Alene salamander	Williamson's sapsucker, Rocky Mountain elk, caribou, mountain chickadee, silver-haired bat, tailed frog, white-headed woodpecker

(Continued on page 15)

1.2b Animal indicator species in forest ecozones by age of stand (continued from page 14)

ECOZONE	FOREST STAGE		
	Young	Mature	Old growth[a]
Montane Cordillera (subalpine)	moose, lynx, mule deer, black bear, golden-crowned sparrow	caribou, grizzly bear, mountain chickadee, red crossbill	caribou, marten, black-backed woodpecker, three-toed woodpecker, spotted owl, Hammond's flycatcher
Boreal Plains (includes Alberta Montane and aspen parkland)	moose, wapiti, lynx, ruffed grouse, hairy woodpecker, snowshoe hare	caribou, elk, grizzly bear, flying squirrel, varied thrush, barred owl, boreal chickadee, red crossbill, Cooper's hawk, wolverine, long-eared bat	marten, wood bison, black-backed woodpecker, boreal owl, three-toed woodpecker, silver-haired bat
Boreal Shield (north)	moose, lynx, snowshoe hare, ruffed grouse, hairy woodpecker	caribou, northern flying squirrel, barred owl, boreal chickadee, red crossbill, wolverine, long-eared bat, rock vole	marten, black-backed woodpecker, three-toed woodpecker, boreal owl, silver-haired bat
Boreal Shield (Newfoundland)	moose, lynx, snowshoe hare, ruffed grouse, hairy woodpecker	caribou, red crossbill, boreal chickadee, ovenbird	marten, black-backed woodpecker, grey-cheeked thrush, meadow vole
Great Lakes–St. Lawrence[b]	moose, white-tailed deer, lynx, snowshoe hare, ruffed grouse, hairy woodpecker	fisher, red-shouldered hawk, red crossbill, Cooper's hawk, barred owl, pileated woodpecker, long-eared bat	marten, pileated woodpecker, silver-haired bat, southern flying squirrel, small-footed bat
Carolinian[c]	white-tailed deer, grey fox, hooded warbler	white-tailed deer, woodland vole, red-bellied woodpecker, cerulean warbler, Acadian flycatcher	southern flying squirrel, prothonotary warbler, screech owl
Atlantic Maritime	white-tailed deer, lynx, snowshoe hare, hairy woodpecker	white-tailed deer, Bicknell's thrush, red crossbill	marten, black-backed woodpecker, barred owl

[a] "old growth" is defined as stands in which there is a net annual loss of the standing biomass of mature trees; many old-growth species are also found in older mature forests
[b] the Great Lakes–St. Lawrence forest, which includes the northern portion of the Mixedwood Plains ecozone and the southern portion of the Boreal Shield ecozone in extreme southeastern Manitoba, Ontario and Quebec, has its own characteristic group of species
[c] the Carolinian forest, which is part of the Mixedwood Plains ecozone in extreme southwestern Ontario, has a unique and characteristic group of species

logging practices, the distribution of some tree species has been reduced, notably that of white pine throughout eastern Canada (especially Quebec), and hemlock and black spruce in Ontario. Garry oak ecosystems have been reduced substantially on Vancouver Island and in the Georgia Depression.

Number of known forest-dependent species that occupy only a small portion of their former range (1.2.3)

"Small portion" can be defined as a reduction of at least 50% in the range of a given species, compared with its known historical range within Canada (Figure 1.2c). Many species currently occupy a small portion of their former range, and most of the reductions result from habitat loss. Other factors, such as hunting and trapping, may also contribute to reduced distributions of species.

Over the past 150 years, another important factor has been temperature fluctuations. During the warming trend that occurred from 1900 to 1940, an expansion was recorded in the ranges of white-tailed deer, bobcat and grey fox in Ontario; during the subsequent cooling period, their ranges were reduced. The species named in Figure 1.2c, however, are known to have been affected primarily by habitat loss—through clearing of forest lands for agriculture and settlement—and by reductions in the amount of forests in the older age classes.

Although all species at risk are discussed in this indicator, some more common species also are included. For example, in the eastern boreal forests, the amount of black and white spruce in older age classes has declined considerably. In Newfoundland, white pine was heavily harvested during the late 1800s and early 1900s to meet the demands of the shipbuilding trade in England. The species, which was never abundant in Newfoundland, has not regenerated to its former levels because of the blister rust—a pest that continues to limit regeneration efforts even today. Two years ago, the Government of Newfoundland and Labrador established the White Pine Advisory Group to protect and increase the white pine on the Island. In Ontario, white pine forests now support a harvest that is 75% smaller than the harvest in 1900. Currently, the Government of Ontario is moving to maintain some of the remaining old-growth red and white pine forests in the province.

Summary

With the exception of the Carolinian forest, the vast majority of species in Canada's forests are not in danger of extinction. Most species use young forests, and with proper planning to maintain sufficient old-growth forests and the habitat features needed by imperiled species, Canada should be able to maintain all of its forest species. Several approaches are being taken to protect species that are becoming more rare, including: developing management plans to maintain and develop habitats; incorporating ecosystem and species concerns into forest planning; monitoring populations to ensure that further declines do not occur; and protecting species and their habitats from further destruction due to poaching and development.

1.2c Forest-dependent species by ecozone that occupy only a small portion of their former range (excluding species listed by COSEWIC)

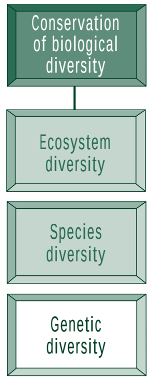
ECOZONE	ANIMALS	PLANTS
Pacific Maritime	black-tailed deer, Roosevelt elk, Townsend's chipmunk, Trowbridge's shrew, Sitka mouse, Pacific jumping mouse, shrew-mole, Townsend's big-eared bat, Yuma myotis bat, silver-haired bat, sharp-tailed snake, clouded salamander, varied thrush, ancient murrelet, Vaux's swift, Peale's peregrine falcon, Lewis' woodpecker	Garry oak, yellow-cedar
Montane Cordillera	Rocky Mountain elk, fisher, silver-haired bat, Yuma myotis bat, Townsend's big-eared bat, gopher snake, tailed frog, Coeur d'Alene salamander, varied thrush, three-toed woodpecker, Williamson's sapsucker, Lewis' woodpecker, Vaux's swift, mountain chickadee	ponderosa pine
Great Lakes–St. Lawrence[a]	Canada lynx, wapiti, river otter, silver-haired bat, small-footed bat, brown snake, spring salamander, pickerel frog, bald eagle, golden eagle, peregrine falcon, Cooper's hawk, great gray owl, barred owl, spruce grouse, black-backed woodpecker	white pine, red pine, eastern hemlock, white spruce, wild leek, autumn coral-root
Carolinian[b]	bobcat, fisher, marten, river otter, woodland vole, wild turkey, screech owl	all forest-dependent species
Boreal Shield	silver-haired bat, barred owl, boreal owl, black-backed woodpecker, three-toed woodpecker, grey-cheeked thrush, red crossbill	white pine, black spruce, white spruce
Boreal Plains	silver-haired bat, barred owl, boreal owl, black-backed woodpecker, three-toed woodpecker, varied thrush	green ash, white spruce
Atlantic Maritime	fisher, lynx, marten, barred owl, black-backed woodpecker, three-toed woodpecker	white pine, red pine, red spruce, eastern hemlock

[a] the Great Lakes–St. Lawrence forest, which includes the northern portion of the Mixedwood Plains ecozone and the southern portion of the Boreal Shield ecozone in extreme southeastern Manitoba, Ontario and Quebec, has its own characteristic group of species

[b] the Carolinian forest, which is part of the Mixedwood Plains ecozone in extreme southwestern Ontario, has a unique and characteristic group of species

ELEMENT 1.3

GENETIC DIVERSITY



What are we measuring?

Genetic diversity is the assortment of genes that have arisen in Canada's native species through generations of migration and selection, and have enabled those species to adapt to their native environment.

This element describes the genetic diversity of forest plants (mostly trees) in Canada and the activities conserving that diversity. In situ (on-site) conservation of genetic diversity is provided by parks and other protected areas, genetic and ecological conservation areas, reserved stands and planned natural regeneration. Ex situ (off-site) conservation measures include seed banks, seed orchards, clonal archives (produced by grafting or other means of asexual propagation), provenance tests and arboretums.

How does genetic diversity relate to sustainable forest management in Canada?

Genetic diversity is one of three levels identified in most definitions of biodiversity. The genetic diversity of Canada's forests is truly an inheritance from previous generations, and we are responsible for passing it on unimpaired to future generations.

Conserving genetic diversity is key to ensuring that species retain their capacity to evolve and adapt to change. It sustains the productive capacity and resilience of forest ecosystems, and it can be viewed as the fundamental basis of the diversity of all species and the ecosystems of which they are a part.

Sustainable forest management requires a commitment by forest agencies to conserve locally or regionally adapted populations of Canada's major commercial tree species using a combination of in situ and ex situ approaches. It also requires special conservation measures for rare and endangered vegetation species. A third key requirement is genetics research—an understanding of gene–environment interactions provides a basis for both commercial tree improvement and endangered species conservation.

Conserving and managing genetic diversity is a key element in operational forest management planning. One task of foresters is to ensure that seedlings thrive when planted in harvested areas. They must track seed sources for greenhouse- and nursery-grown seedlings, and not plant them in areas where they will be exposed to climatic conditions vastly different from those experienced by their parents. Most provinces have designated seed-transfer zones for this purpose.

Foresters must also consider genetic diversity in planning for natural regeneration. In white pine stands, for example, it has been found that "seed tree" cuts (i.e., where only a few widely spaced mature trees remain in harvested areas) do not allow sufficient cross-pollination to avoid inbreeding and serious growth loss in seedlings. Other silvicultural systems, such as shelterwood cuts, are now preferred for this species.

What data are available?

Implementation of an in situ/ex situ genetic conservation strategy for commercial and endangered forest vegetation species (1.3.1)

Canada's major commercial softwood species—white spruce, black spruce, jack pine, balsam fir and lodgepole pine—all have high levels of genetic diversity. Unlike tropical forest trees, these species are pollinated by the wind and do not require insects, birds or bats for cross-pollination. However, many Canadian tree species benefit when animals, such as squirrels, blue jays and crossbills, spread their seeds.

It is thought that Canada's most widespread broadleaved tree species—trembling aspen—is one the world's most diverse plants. Aspen is capable of both sexual and asexual reproduction. Its habit of sprouting from its roots after major disturbances (e.g., fires and harvesting) means that numerous locally adapted and genetically distinct clones are found throughout its range. Certain aspen clones are likely the world's largest living organisms—a single root system extending over tens of hectares may support thousands of mature stems, all genetically identical.

Not all of Canada's tree species have high levels of genetic diversity. Red pine, for example, is thought to have gone through a "genetic bottleneck" during its evolutionary history. That may be why this species is confined to a relatively narrow ecological niche (i.e., sandy, drought-prone soils with frequent ground fires).

Red spruce and western red cedar are two examples of tree species that have been successful in Canada's forests despite lower overall levels of genetic diversity. However, they may be less able to adapt to harvesting activities, and special silvicultural treatments may be needed to retain viable populations of these species in managed forests.

Although tree species in Canada's Boreal and Taiga ecozones are genetically diverse and adapted to a wide range of environmental conditions, other ecozones have tree species with relatively narrow ecological ranges. For example, several tree species, such as Sitka spruce, Pacific silver fir, yellow-cedar and red alder, are restricted to the Pacific Maritime ecozone. Many of Canada's threatened and endangered forest vegetation species are found in the Mixedwood Plains ecozone. These include some tree species (e.g., blue ash, Shumard oak, cucumber tree and Kentucky coffee tree) whose ranges barely extend into the Carolinian forest of extreme southern Ontario, and are found only in restricted habitats throughout their ranges. Several dozen more common tree species of eastern North America have their northern limits in the Mixedwood Plains and Atlantic Maritime ecozones. Many of these species are pollinated by animals, and may have complex and poorly understood patterns of genetic diversity.

A framework for a national strategy on forest genetic resource conservation and management was developed at a November 1993 workshop that was attended by representatives of industry and provincial and federal governments. Certain elements of this strategy are in place, but much work remains to be done.

Most provinces and territories do not have a genetic conservation strategy in place, although they have all established some elements of a strategy (e.g., parks and other protected areas, genetic conservation areas, reserved stands, seed

1.3a Summary of ex situ conservation activities

PROVINCE/ TERRITORY	PROVENANCE TESTS		SEED ORCHARDS				CLONAL ARCHIVES		SEED BANKS	ARBORETA
			SEEDLING		CLONAL					
	Nº of prov.	Area	Nº of families	Area	Nº of clones	Area	Nº of archives	Area	Nº of seedlots	Nº of species
Y.T.	40	–	–	–	–	–	–	–	108	–
N.W.T.	–	–	–	–	–	–	–	–	–	–
B.C.	511	297	156	11	1 729	200	12 302	85	7 520	25
Alta.	226	35	450	14	298	9	736	4	3 722	–
Sask.	399	29	104	9	162	10	678	2	130	–
Man.	101	4	1 147	22	–	–	1 147	2	1 989	–
Ont.	2 757	305	7 354	778	1 772	515	5 831	–	4 852	38
Que.	3 876	337	13 204	877	7 101	193	18 088	185	15 474	110
N.B.	798	67	2 678	145	694	104	3 177	5	698	–
N.S.	151	4	2 400	24	2 846	40	1 078	3	1 907	–
P.E.I.	210	7	230	7	140	11	250	2	497	–
Nfld.	547	45	400	25	400	14	650	14	65	–
CANADA	**9 616**	**1 131**	**28 123**	**1 912**	**15 142**	**1 096**	**43 937**	**302**	**36 962**	**173**

Source: Natural Resources Canada–Canadian Forest Service

orchards, tree seed banks or provenance tests). For example, British Columbia has surveyed the species composition of its protected areas to assess their ability to conserve the genetic resources of the province's conifers and to identify conservation gaps.

The best examples of genetic conservation areas in Canada are those for remnant red pine populations in Newfoundland. Ideally, genetic conservation areas would be designated across the range of a particular tree species. Certain management activities (e.g., prescribed fires and selection harvesting) would be permitted with a view to maintaining naturally regenerating populations of species of interest.

The Mixedwood Plains ecozone is a special genetic conservation priority. Less than 20% of the native forest cover remains, largely owing to forest land conversion for agricultural and urban development, and less than 1% of the ecozone is in highly protected areas. Conservation stewardship programs on private lands are an alternative to protected areas and are helping protect many Carolinian plant species.

All provinces have ex situ facilities (e.g., seed orchards and tree seed banks) that are used primarily for breeding genetically superior trees and providing seeds for faster-growing or disease-resistant plantation stock (Figure 1.3a). The trees found in seed orchards can themselves be derived from either seed or asexually propagated materials (e.g., clonal seed orchards produced by grafting).

Provenance tests play a special role in genetic conservation programs. Much of what geneticists know about the relationship between a tree's genetic diversity and its ability to adapt to environmental variation comes from these long-term experiments. Ideally, carefully designed plantations would be established across the range of a species, and seed would be collected from a similar range. Knowledge of gene–environment interactions derived from provenance tests can guide in situ conservation efforts, as well as tree breeding programs.

Provenance tests often reveal unique genetic properties of populations at the margin of a species' range, including hybrids that may form where ranges of closely related species overlap. Valuable genetic properties may also be found in populations growing on unusual soil types (e.g., limestone ecotypes of white spruce). Range-wide provenance tests often cross provincial and even international borders. All of the provinces are involved in provenance tests, with as many as 12 native species under study in a single province (e.g., Quebec).

Summary

Genetic diversity is fundamental for populations of forest dwelling organisms to be able to adapt to changing environmental conditions, and as such, it underlies species as well as ecosystem diversity.

Simple, practical measures can conserve genetic diversity where it occurs naturally and in ex situ settings, such as seed banks and seed orchards. Governments and industry are applying some of these measures, but coordinated forest genetic conservation strategies are not yet in place, either nationally or provincially.

A general description has been provided of the nature of genetic diversity in Canada's major commercial tree species, and some conservation priorities for threatened and endangered species have been identified. Genetics research would enable cost-effective conservation strategies to be designed.

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CRITERION 2.0

MAINTENANCE AND ENHANCEMENT OF FOREST ECOSYSTEM CONDITION AND PRODUCTIVITY

INTRODUCTION

Forests dominate the world's terrestrial biosphere. They cover 21% of the continental area, and account for 76% of terrestrial biomass and 37% of bioproductivity. Canada's forests encompass approximately half (417.6 million hectares) of the country's land area and represent 10% of the world's forests. Thus, the health and management of Canada's forests will contribute to maintaining a viable global environment.

Biological elements that strongly influence forest sustainability and conservation include levels of disturbance and stress, ecosystem resilience and extant biomass (biota). Biological elements are regulated by a myriad of biological processes operating through time and space to govern how forest ecosystems function. Appropriate measures of these elements indicate whether ecosystems are functioning normally—whether there is sufficient energy transfer, nutrient cycling, recovery potential and species productivity to ensure sustainability.

Element 2.1 (Incidence of disturbance and stress) measures such influences as pollutant deposition, insect and disease infestation, and fire to determine their impact on Canada's forest ecosystems. Element 2.2 (Ecosystem resilience) is a measure of the ability of forests to recover from those disturbances, both naturally and through such activities as planting and seeding.

Element 2.3 (Extant biomass) explores the condition of the forest in terms of the biomass production of all species and types, including rarer species.

ELEMENT 2.1
INCIDENCE OF DISTURBANCE AND STRESS

What are we measuring?

Sources of disturbance and stress include insects, diseases, fires, pollutants, ozone and exotic pests. These sources may act alone or in concert to influence the development, structure and functioning of forest ecosystems. Climate change interacts with these disturbances to further impact on the condition and productivity of forests. *Human activities also influence the condition and productivity of forests. Element 3.1 (Physical environmental factors) and Element 4.2 (Forest land conversion) provide information on some of these activities.*

Historically, provincial disturbance and stress data were reported nationally through the cooperative efforts of the Forest Insect and Disease Survey of Natural Resources Canada–Canadian Forest Service (CFS), the provinces and other agencies. In the future, national assessments of forest health will be achieved through negotiated partnerships and alliances with the provinces and other agencies. In particular, the CFS will work with the provinces to compile disturbance information from across the country, to improve mapping capabilities, and to enhance national databases.

How does the incidence of disturbance and stress relate to the sustainability of Canada's forests?

Disturbances and stress strongly influence the health, vitality and productivity of forests, and they are fundamental to the maintenance and enhancement of forest ecosystems. Maintaining ecosystem integrity and forest health is essential for the sustainable management and conservation of our forests.

The nature, extent and impact of disturbances on forested ecosystems are all highly variable. Natural and human-induced disturbances both occur as a continuum, and they may range in size, severity, duration and frequency. While most disturbance and stress events are fundamental to the recovery and maintenance of forested ecosystems, others may impede resilience, impact on extant biomass, or alter patterns and processes, leading to new successional trends. Forest ecosystems are never static; rather, they are constantly changing through the cycle of death and renewal.

Measuring the disturbance and stress caused by biotic (e.g., insects and disease) and abiotic (e.g., wind and ice) factors provides a basis for sustainable forest management. For example, improved decision making and sound policy decisions require knowledge of the effects of disturbance and stress on forest condition and productivity, the ability to forecast disturbances, and greater predictive powers.

What data are available?

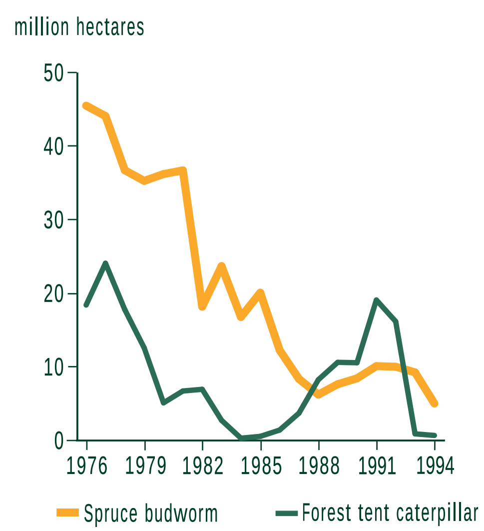
Area and severity of insect attack (2.1.1)

Insects and diseases remain the dominant causes of natural disturbances in most of Canada's forests, and their distribution is largely influenced by the nature of those forests. The provinces collect disturbance data primarily by forest districts, and historical databases for major insects date back to 1936.

Figure 2.1a shows the areas infested with two important defoliators—spruce budworm *(Choristoneura fumiferana)* and forest tent caterpillar *(Malacosoma disstria)*—from 1976 to 1994. These areas are quantified as having moderate to severe defoliation.

The population dynamics of these insect species varies considerably, as does the extent and nature of their impacts on forests. Spruce budworm occurs predominantly in the boreal forest region, from the Northwest Territories

2.1a Areas infested with spruce budworm and forest tent caterpillar



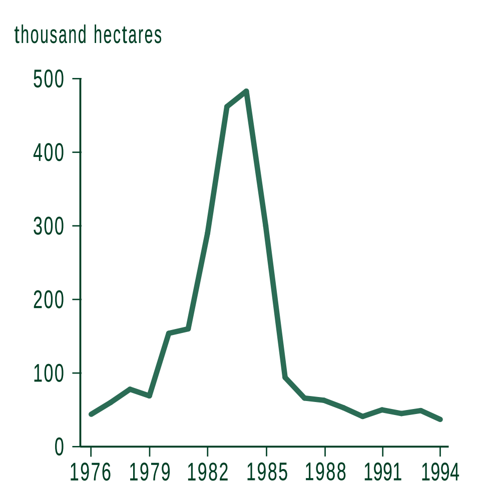
Source: Natural Resources Canada–Canadian Forest Service

to Newfoundland, but most tree mortality occurs east of the Manitoba–Ontario border. The budworm has been particularly significant in the Atlantic Maritime ecozone; currently, however, populations are low and few areas are affected.

The forest tent caterpillar also is widely distributed from coast to coast and is a serious pest of trembling aspen. In 1994, moderate to severe defoliation encompassed 785 000 hectares of forests in Ontario.

One of the most destructive forest insects in western Canada is the mountain pine beetle *(Dendroctonus ponderosae)*, which principally attacks lodgepole pine in the montane forests of Alberta and British Columbia. Unlike the spruce budworm, which kills trees only after consecutive years of severe defoliation, the mountain pine beetle can kill trees in just one year. In 1984, moderate to severe defoliation in British Columbia occurred over 483 000 hectares; however, since 1985, defoliation has been limited to less than 50 000 hectares (Figure 2.1b).

2.1b Area infested with mountain pine beetle



Source: Natural Resources Canada–Canadian Forest Service

Two other insects—hemlock looper *(Lambdina fiscellaria)* and jack pine budworm *(Choristoneura pinus pinus)*—are both highly destructive and also are capable of causing severe and extensive mortality in less than a year. In 1994, the hemlock looper caused moderate to severe defoliation on approximately 20 000 hectares, and the jack pine budworm, on 420 000 hectares.

Area and severity of disease infestation (2.1.2)

Native diseases often are chronic, and with the exception of some foliage diseases, they are slow in manifesting their effects on trees and ecosystems. However, the average annual tree mortality and growth loss from diseases in Canada amounts to 51.2 million m^3, which is equivalent to 29% of the total annual harvest.

Two non-native diseases of concern—in addition to the diseases listed in Figure 2.1c—are scleroderris canker *(Gremmeniella abietina)* and Dutch elm disease *(Ophiostoma ulmi* and *Ophiostoma novo-ulmi)*. Figure 2.1d illustrates the location of the canker, which is found most commonly east of Manitoba. Dutch elm disease is transmitted by elm bark beetles and is reported throughout Canada, with the exception of British Columbia, Alberta and Newfoundland.

There is a need to gather and report on disease infestations by ecozone and to maintain adequate data coverage.

2.1c Average annual depletions caused by major forest diseases and abiotic factors, 1982–1987

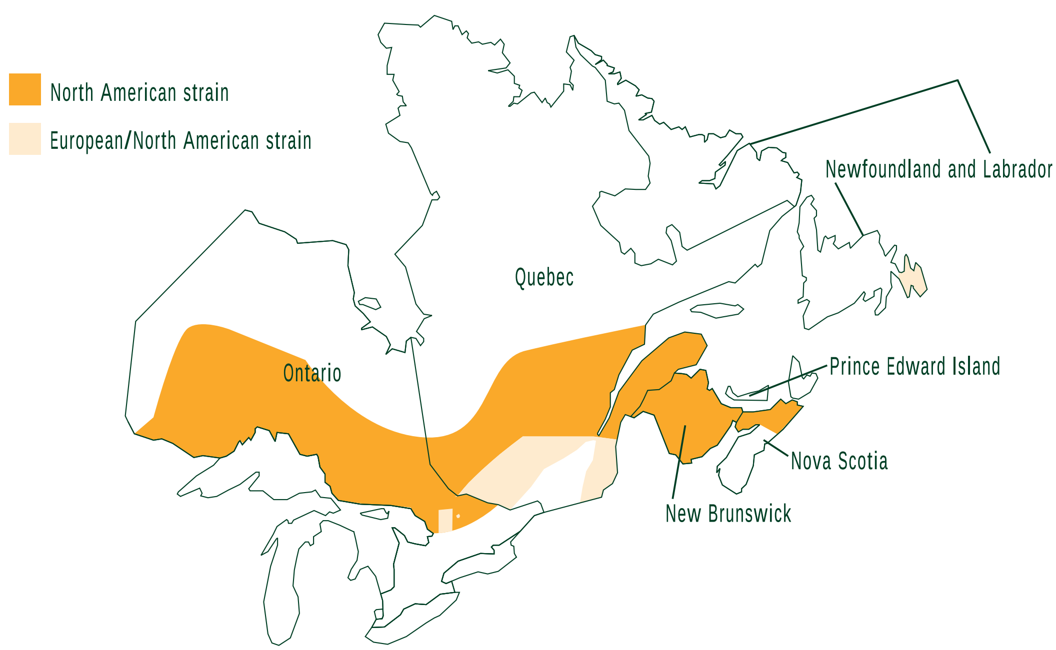
DISEASE	TREE MORTALITY	GROWTH LOSS
	thousand m³	
Hypoxylon canker *(Hypoxylon mammatum)*	3 107	–
Dwarf mistletoe	–	1 819
Maple decline	1 689	1 596
White pine blister rust *(Cronartium ribicola)*	–	84
Root rot	8 020	669
Stem and root decays	–	30 924
Dieback	3 168	–
Abiotic losses	102	–
TOTAL	**16 086**	**35 092**

Source: Natural Resources Canada—Canadian Forest Service

Area and severity of fire damage (2.1.3)

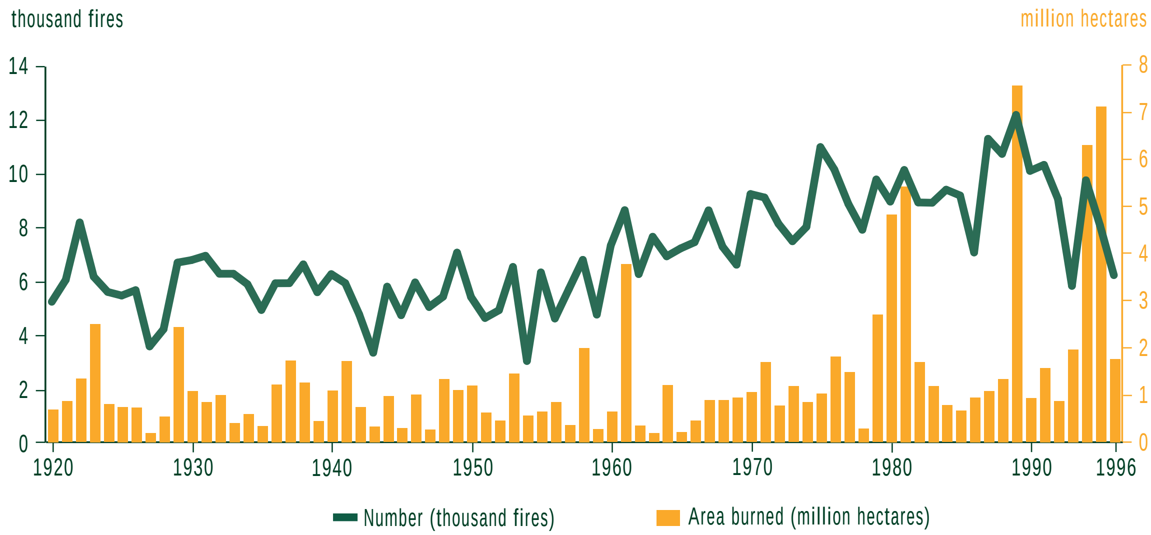
Wildland fire consumes nearly as much wood in Canada as is harvested, and it constitutes a dominant ecological and environmental disturbance. Fire management accounts for 16% of the annual cost of forest management ($386 million of the $2.4 billion spent per year), yet it is neither physically possible, ecologically desirable, nor economically feasible to prevent fires in forest ecosystems. In assessing the effects of wildland fires, the following indirect measures are used: fire occurrence, fire environment (i.e., weather, fuels and topography), area burned, fire management expenditures and fire severity (i.e., the magnitude of significant negative impacts on other systems).

2.1d Distribution of scleroderris canker in eastern Canada, 1977–1993



Source: Natural Resources Canada–Canadian Forest Service

2.1e Annual variability of forest fires in Canada



Source: Natural Resources Canada–Canadian Forest Service

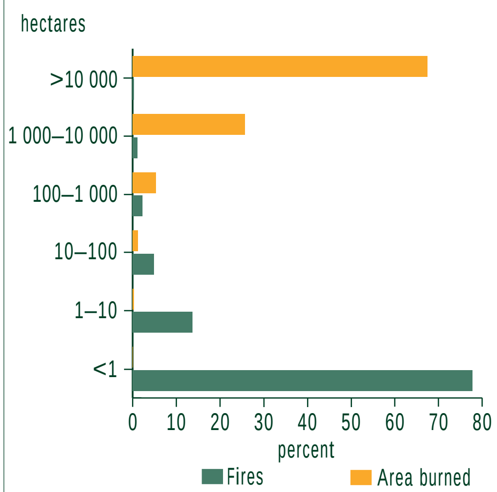
The fire environment controls the fire behaviour (i.e., rate of spread and intensity), which in turn affects the difficulty of control. During the fire season, national maps of fire danger and behaviour indices are produced daily; however, no systems have been put in place to integrate the spatial and temporal distribution of this environmental information, nor to evaluate the severity of the fire season.

The following systems are affected by wildland fires: ecosystems (i.e., area burned and fire severity), geosystems (i.e., area subject to erosion), atmosphere (i.e., smoke emissions), fire management (i.e., interagency resource sharing and costs), forest management (i.e., wood loss and value) and society (i.e., evacuations, deaths and injuries, and economic losses).

Over the past 10 years, an average of 9 600 fires per year have burned 2.9 million hectares in Canada (0.6% of the total forested land). On average, one-quarter of the area burned has been commercial forests (0.4% of the commercial forest land).

Figure 2.1e shows the annual variability in forest fires. Since 1960, the number of forest fires and the area burned have both increased dramatically. For example, the number of fires recorded between 1960 and 1995 was 60% higher than the total for 1920–1960. This increase may reflect the mounting pressures on our forests that are associated with population growth. Although the area burned appears to have jumped substantially since 1980, statistics prior to that date only included full-suppression fires. (The response to forest fires ranges from full suppression, in which adequate resources are allocated to suppress the fire quickly, to modified suppression, in which fewer resources are allocated.) Currently, modified-suppression fires, which represent 6.5% of all fires, account for 60% of the total area burned.

2.1f Fires and area burned by size class and percent



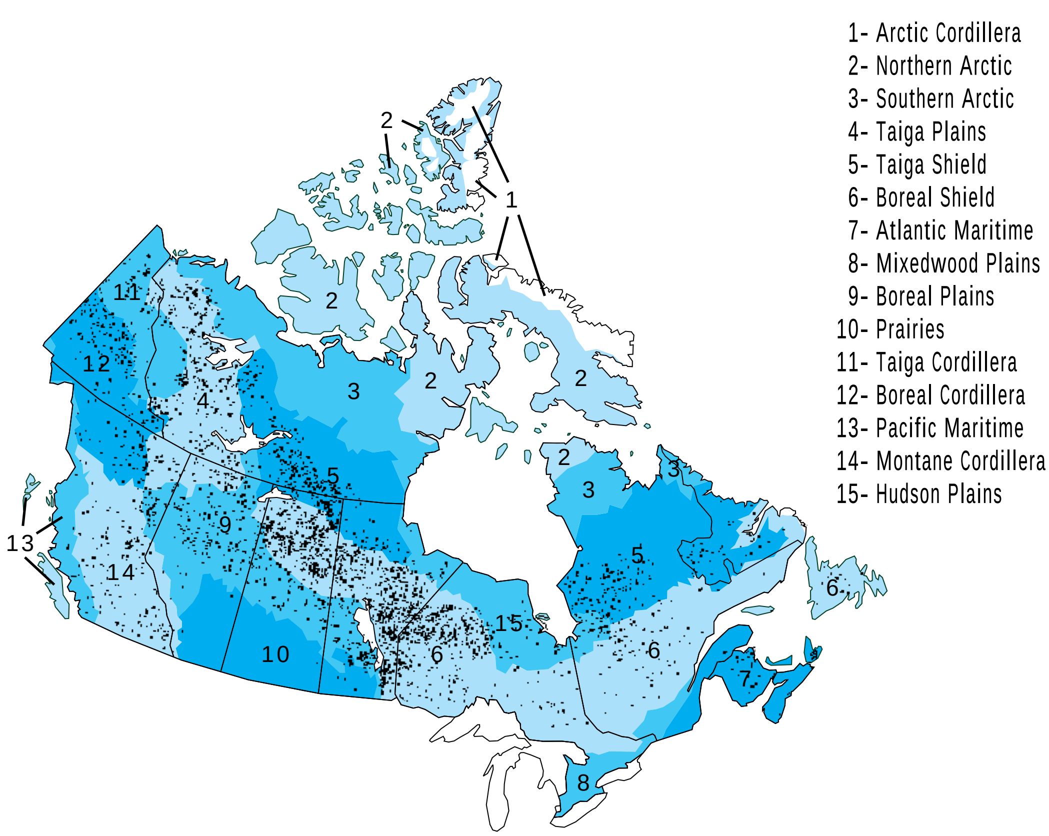
Source: Natural Resources Canada–Canadian Forest Service

Figure 2.1f indicates that 91.5% of fires burn less than 10 hectares each. Although just 1.5% of fires exceed 1 000 hectares, they account for 93.1% of the total area burned in Canada.

Large fires occur in all ecozones, but not in agricultural or arctic regions. Figure 2.1g shows the distribution of large fires across Canada during the 1980s.

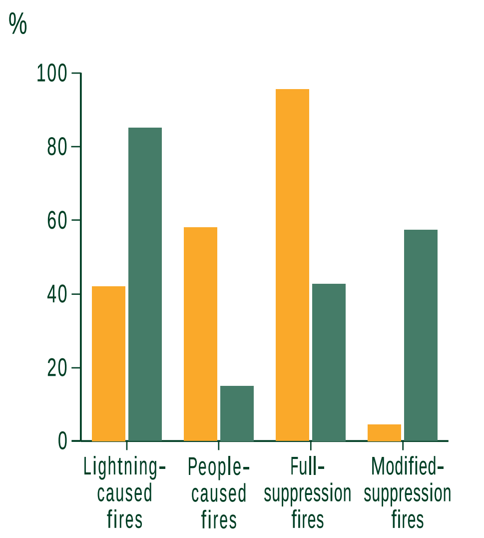
People start 58% of all fires in Canada, but those fires consume only 15% of the total area burned, whereas lightning starts 42% of fires and accounts for 85% of the area burned (Figure 2.1h).

2.1g Distribution in Canada of fires exceeding 200 hectares by ecozone, 1980–1989



Source: Natural Resources Canada–Canadian Forest Service

2.1h Comparative fire statistics



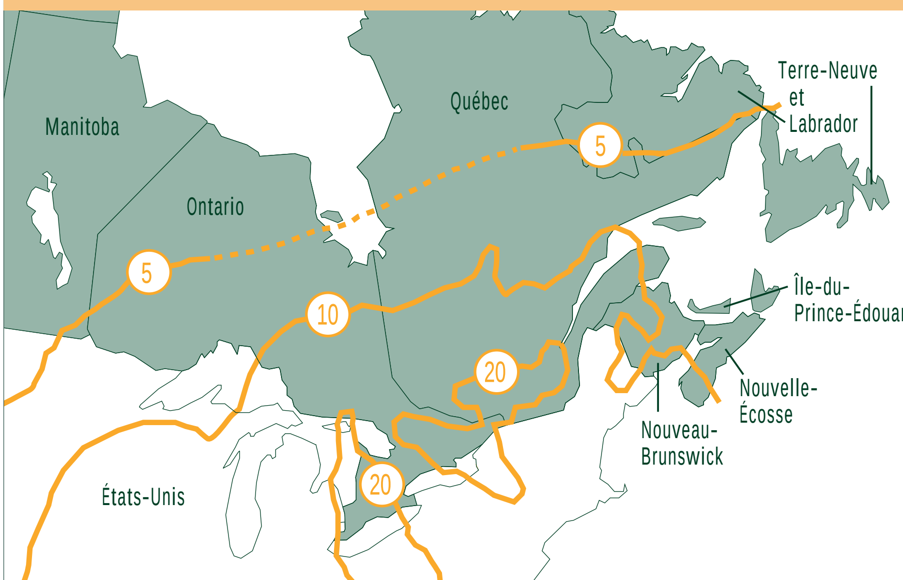
Source: Canadian Interagency Forest Fire Centre

Rates of pollutant deposition (2.1.4)

Pollution, acting alone or in combination with other stressors, affects ecological systems in general and forests in particular. Two of the most common types of air pollutants in Canada's forest ecosystems are sulphur dioxide (SO_2) and nitrogen oxides (NO_x), along with their oxidation products: sulphuric acids and nitric acids. The Canadian Air and Precipitation Monitoring Network (CAPMON) and the provinces have been providing data on these pollutants from 11 sites for more than 13 years.

Pollutants impact on forest ecosystems via dry and wet deposition pathways. Dry deposition is very costly to measure and is usually calculated from available air concentrations of sulphur dioxide (SO_2), particulate sulphate (SO_4), nitric acid (HNO_3), particulate nitrate (NO_3) and ammonia (NH_4). Air concentrations of

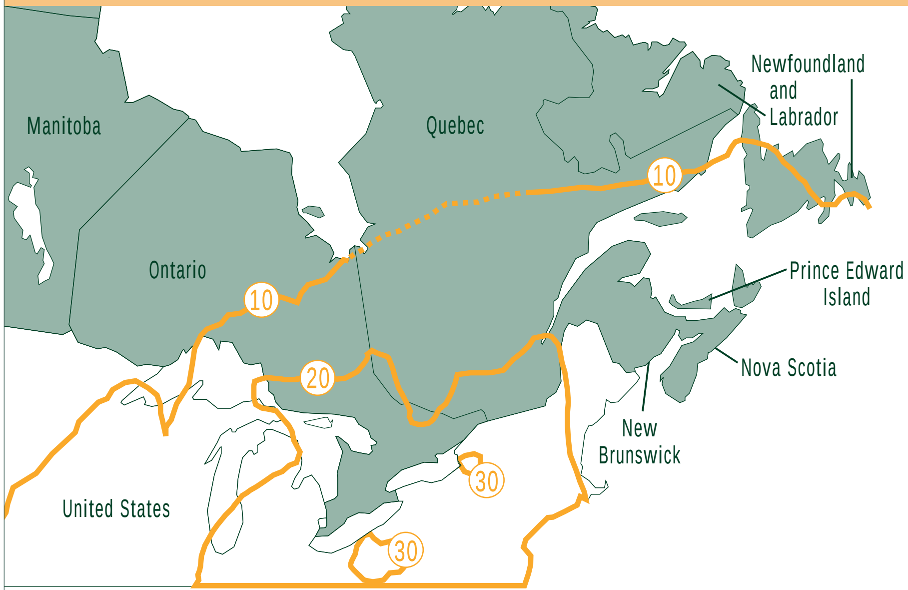
2.1i Amount of nitrate deposition (kg/hectare/year), 1990–1993



Note: The contour lines indicate the average wet nitrate depositions that occur within the areas delineated. A dotted line is used to indicate estimated amounts.

Source: Environment Canada

2.1j Amount of wet sulphate deposition (kg/hectare/year), 1990–1993



Note: The contour lines indicate the average wet sulphate depositions that occur within the areas delineated. A dotted line is used to indicate estimated amounts.

Source: Environment Canada

these pollutants are generally greatest in the Mixedwood Plains ecozone (located in southern Ontario) and decrease with distance east, west and north. Figure 2.1i depicts the distribution of NO_3 for the period 1990–1993.

Wet deposition includes precipitation in the form of rain, snow and fog; it is commonly referred to as “acid rain.” Despite substantial progress in reducing SO_2 emissions, both unilaterally and in cooperation with the United States (USA), acid rain remains a threat to forest ecosystem condition and productivity in the Boreal Plains, Mixedwood Plains and Atlantic Maritime terrestrial ecozones. For example, the condition of maples and birches is deteriorating in portions of the two latter ecozones, where wet deposition is the highest. Figure 2.1j depicts the distribution of wet SO_4 for the period 1990–1993.

Forest ecosystem sensitivity to acid deposition is dependent on a number of factors, including physical and chemical soil characteristics. Research to determine the critical loads of acid deposition for forest soils is nearing completion.

The need to understand pollution–forest interactions is paramount in view of the increasing evidence linking the long-term effects of acid deposition to the disruption of biogeochemical processes and the decline of annual forest biomass and accumulation.

Ozone concentrations in forested regions (2.1.5)

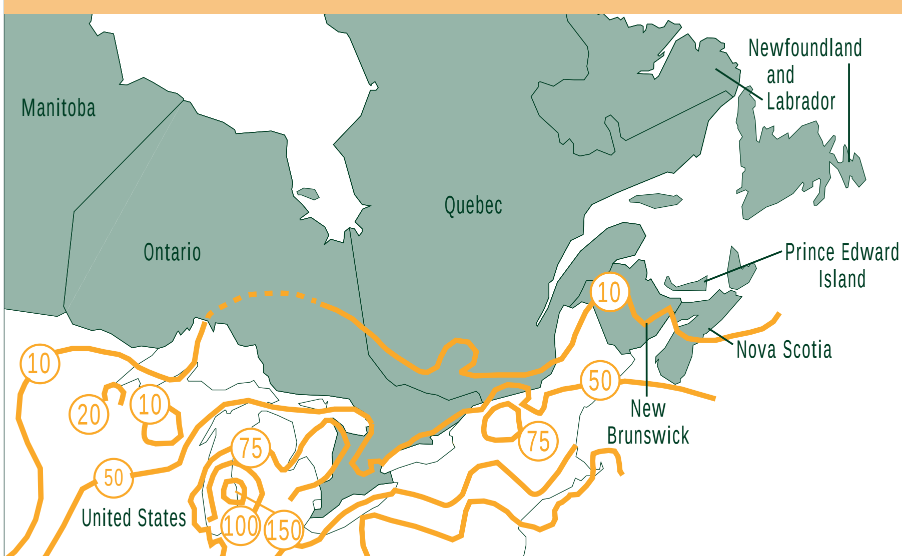
Tropospheric or ground-level ozone may adversely affect the metabolic systems of plants, and when present in the atmosphere at or above critical levels, it is known to be phytotoxic to trees. Plant exposure to ozone that exceeds 2–3 times background levels over a number of growing seasons may result in changing patterns of carbon allocation, premature defoliation, and loss of plant productivity. Ecosystem structure and function also may be altered, depending on the sensitivities of different species.

Federal and provincial ozone-monitoring agencies have been collecting hourly ozone concentration data since 1980. This information is reported by Environment Canada's Environmental Protection Service. Data are currently available from 153 sites, 112 of which are considered "urban" and 41, "rural." (Ozone is a regional-scale pollutant subject to long-range transport. For this reason, data from 120 rural U.S. sites also are used in the mapping of ozone concentrations in Canada.) Figure 2.1k shows the ozone concentration levels in eastern Canada from 1986 to 1993.

The current National Ambient Air Quality Objective for Ozone and Vegetation is set at 82 parts per billion ozone per hour, above which plants are predicted to suffer injury. Forests in four terrestrial ecozones (Atlantic Maritime, Mixedwood Plains, Pacific Maritime and Boreal Shield) have been exposed to concentrations of ozone above this critical level. And at some health-monitoring plots in eastern and western Canada, ozone-like symptoms have been detected in white pine. Declines are also occurring in areas with sugar maple and white birch where critical levels have been exceeded.

There are too few monitoring stations in forested ecozones west of Ontario to permit regional-scale mapping of ozone concentrations. However, in 1996, passive ozone monitors were introduced to allow for an initial assessment of ozone concentrations throughout selected forested areas.

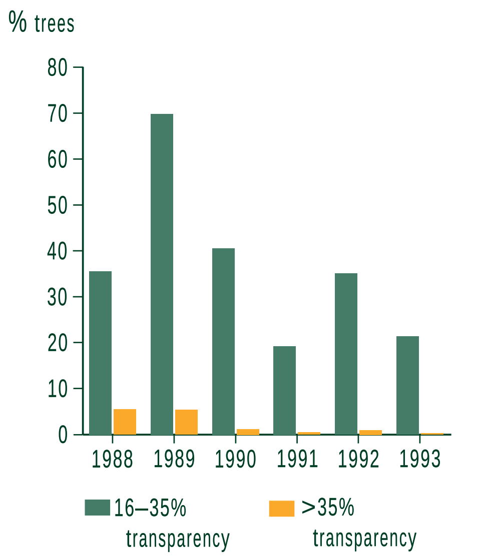
2.1k Distribution of average hours with ozone exceeding 82 parts per billion, 1986–1993



Note: The contour lines indicate the average hourly concentrations of ozone that occur within the areas delineated.

Source: Environment Canada

2.1l Moderate and high levels of transparency for sugar maple in Canada



Source: Natural Resources Canada–Canadian Forest Service

Crown transparency in percentage by class (2.1.6)

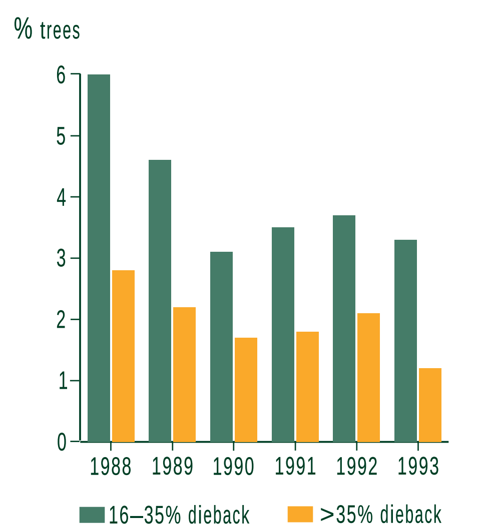
A number of factors can be used to assess the health of trees. Crown transparency, in combination with dieback, is one of the most commonly used indicators for assessments of the condition of hardwood crowns. Defoliation is the more frequently used indicator for assessments of conifer crowns.

"Transparency" is defined as the amount of skylight visible through the foliated portion of the crowns of dominant and co-dominant trees. A crown transparency of less than 25% is considered normal for a healthy sugar maple, for example, while a higher transparency may indicate significant stress. Incidence of crown deterioration in sugar maple and other broad-leaved trees is known to signal a trend toward decreasing growth and productivity. Transparency data acquired from the North American Maple Project, which involves more than 200 sites in eastern North America, indicate that high transparency values occurred in 1988 and 1989 (Figure 2.1l); Quebec levels were particularly high in 1988.

"Dieback" is defined as branch mortality that begins at the terminal portion of a branch and progresses downward. Figure 2.1m illustrates the frequency of dieback for sugar maples in Canada from 1988 to 1993. Dieback and transparency data indicate that the health of maple trees in Ontario, Quebec, New Brunswick and Nova Scotia has generally improved since 1989; however, isolated areas of decline persist.

Future reporting on forest health will employ a range of variables, including crown transparency, dieback and defoliation. In 1996, the CFS Forest Health Network began a pilot study to develop more extensive monitoring and improve crown rating schemes.

2.1m Moderate and high levels of dieback for sugar maple in Canada



Source: Natural Resources Canada–Canadian Forest Service

Area and severity of occurrence of exotic species detrimental to forest condition (2.1.7)

For the past 50 years, the Forest Insect and Disease Survey has been collecting detailed information on various pests in Canada. Approximately 400 exotics (non-native species) are known to attack woody plants in this country and the continental USA, including balsam woolly adelgid *(Adelges piceae)*, pine shoot beetle *(Tomicus piniperda)*, beech scale *(Cryptococcus fagisuga)* and gypsy moth *(Lymantria dispar)*.

The vast majority of these pests are insects and diseases that arrived accidentally in North America over the past 100 years, primarily via the shipping containers and packaging used for forest and agricultural products. Largely in response to the introduction of these pests in the early 1900s, the CFS has developed biological control programs and survey systems for detecting and monitoring exotics in forested ecosystems. Moreover, Agriculture and Agri-food Canada has established strict regulations to control the entry and movement of plant and animal materials into and within this country.

The scarcity of taxonomic expertise is a major impediment to addressing the threats from exotics. Effective partnerships between federal and provincial departments also will be required to provide early detection and response to exotics and to maintain the long-term sustainability of our forested ecosystems. The current efforts to monitor import sites are one example of such partnerships.

Climate change as measured by temperature sums (2.1.8)

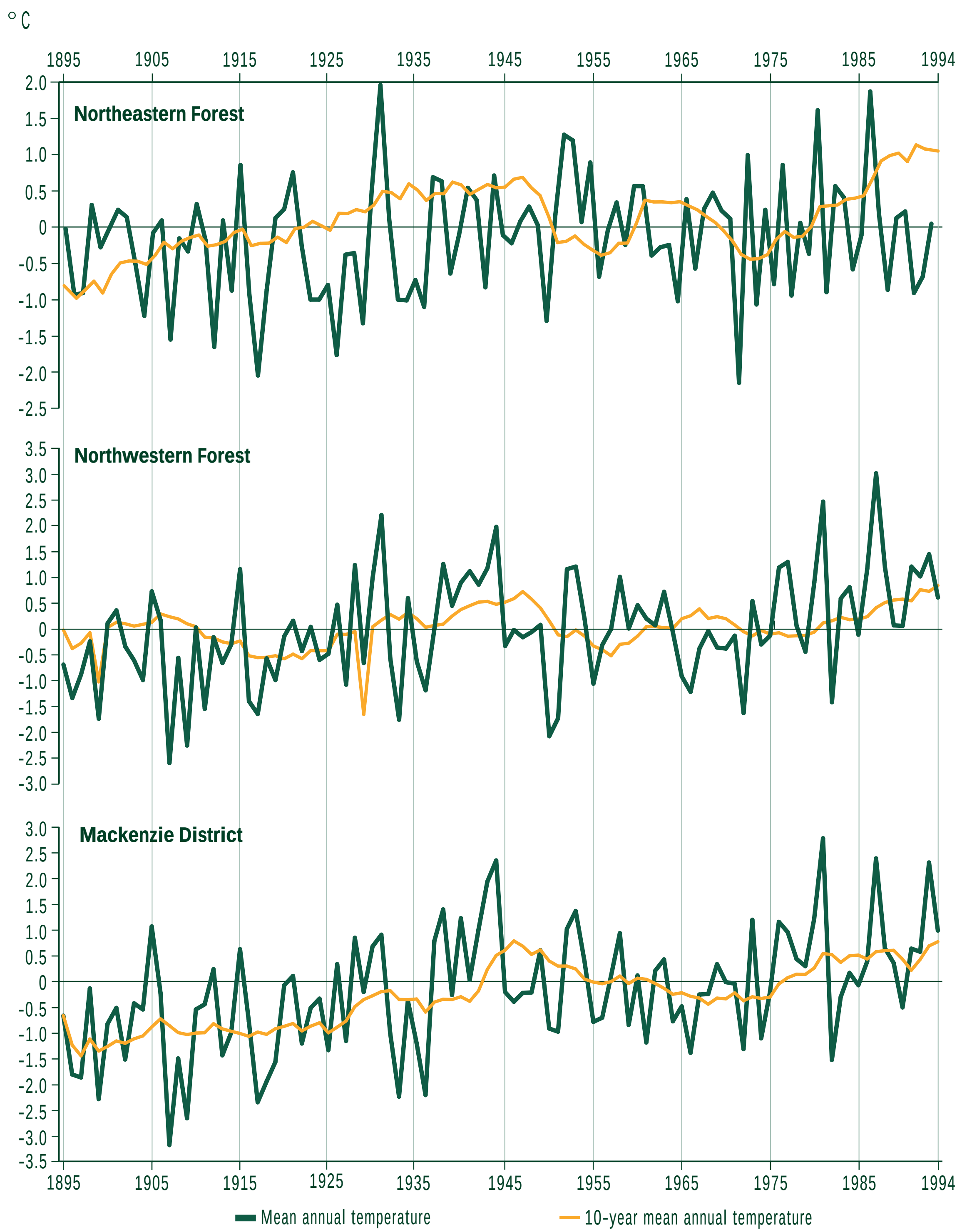
Climate change as indicated by temperature is a major factor determining the sustainability of Canada's forests. It influences the range of tree species and affects the growth and productivity of forests. Climate also plays a role in disturbances (e.g., fires and drought) that affect forest ecosystems, and thus it could have major implications for the long-term sustainability of our forests.

Figure 2.1n outlines changes in the mean annual temperatures of three regions of the boreal forest between 1895 and 1994, as well as changes in the 10-year mean annual temperatures of those regions. The Northeastern Forest includes much of the Canadian Shield, as well as the Hudson Bay Lowlands. The Northwestern Forest stretches from the northern boundary of the Prairies to the Mackenzie District, and from the foothills of the Rocky Mountains to the Manitoba–Ontario border. And the Mackenzie District takes in a major portion of the Mackenzie River drainage basin, including the Great Bear and Great Slave lakes. Over the past century, the general trend has been toward increasing temperatures: the Northeastern Forest has recorded an overall warming trend of approximately 0.5ºC; the Northwestern Forest, 1.4ºC; and the Mackenzie District, 1.7ºC.

Moisture is another key climate element influencing growth, productivity, species range and disturbances (e.g., fires, insects and diseases). As such, it too impacts on the sustainability of our forests.

In future assessments of forest health, a combination of temperature and moisture indices will be used to more fully describe climate change and trends in the forest regions of Canada.

2.1n Temperature deviations in three regions of the boreal forest



Source: Carbon Dioxide Information Analysis Center

Summary

Healthy forest ecosystems are essential to the sustainability of forests. In a living system, normal functioning implies appropriate levels of health, vitality and productivity of the various components.

Pollutants, fires, unfavourable climatic conditions, and infestations by insects and diseases often interact to stress forests. Measuring and reporting on the severity and extent of disturbances and stress provide an important ecological measure of the condition, productivity and overall health of forest ecosystems.

Canada's forests are generally healthy, and few large-scale declines have been observed. Tree mortality (caused primarily by competition and natural thinning) ranges from 1–3% annually; although the effects of insects, diseases and windstorms occasionally cause higher rates of mortality. Recent findings in eastern North America, however, suggest that the long-term impact of acid deposition, and possibly ozone concentrations, may lead to the degradation of forest ecosystems.

Data gathered through a national monitoring system and a directed research program will provide information on major forest stressors and on the changes occurring —or anticipated—in the health of our forests. The resulting knowledge will enable Canada to contribute to the stewardship of forest ecosystems, most notably by enhancing forest management regimes, assessing the impacts of pollutants on forests, and integrating non-timber values into forestry decision making.

ELEMENT 2.2
ECOSYSTEM RESILIENCE

What are we measuring?

Evolution has provided forest ecosystems with elaborate mechanisms for recovery from disturbances. This capacity for recovery may be described in terms of resilience (return time) and is a measure of the ability of ecosystems to maintain their integrity despite perturbations.

To date, no common method exists for determining resilience. Return time following disturbances can be measured experimentally in two ways. First, it can be assessed by the time it takes for populations to return to some pre-disturbance condition. However, a serious gap in this approach is the difficulty in determining when a population has recovered. A second measure of resilience is to estimate variability in population densities. (Greater resilience implies a greater tendency for populations to move toward mean densities.) A variation on the second method is to estimate resilience using energy and nutrient flows through different functional groups in the community.

In this report, the resilience of Canada's forest ecosystems will be determined, in part, using the first method—measuring the successful regeneration of areas harvested since 1975.

How does ecosystem resilience relate to the sustainability of Canada's forests?

Resilience reflects the persistence of ecosystems and their capacity to absorb changes and disturbances while maintaining productivity levels and relationships among populations. Ecosystems with greater regenerative capacity and a balanced distribution of forest types and age classes are considered to be more resilient and therefore more sustainable.

What data are available?

Percentage and extent of area by forest type and age class (2.2.1)

This indicator is discussed under Indicator 1.1.2 (Percentage and extent of area by forest type and age class).

Percentage of area successfully naturally regenerated and artificially regenerated (2.2.2)

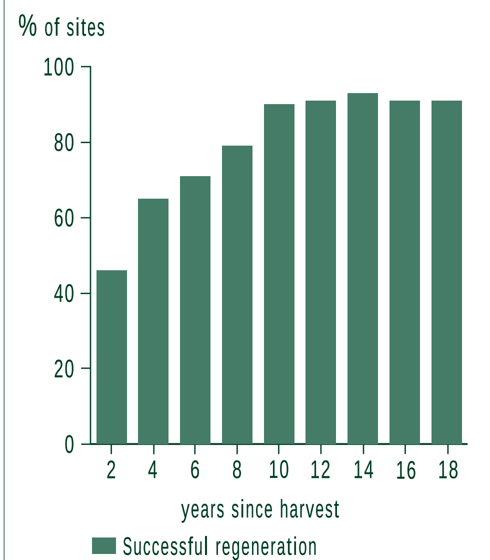
The most widely used silvicultural system in Canada is clearcut harvesting, which creates open environments that favour seedling growth. Most of our forests are even-aged and comprise species that regenerate following major disturbances, such as fire and clearcut harvesting.

Since 1975, other harvesting techniques have been used increasingly in some regions of Canada. For example, in 1992, selection harvesting accounted for approximately 8% of the total area harvested. This technique creates relatively small openings in the forest canopy, which allow for continuous regeneration, and it is commonly used in uneven-aged forest stands.

In Canada, 60% of harvested areas are left to regenerate naturally. Although harvesting systems encourage this process, on the remaining 40% of harvested areas, planting and direct seeding are carried out to hasten regeneration. Regeneration efforts increased substantially in the 1980s, peaking in 1991 at approximately 460 000 hectares of Crown land. (Planting accounted for roughly 90% of that area; the remaining land was regenerated by other methods, such as aerial seeding.) In the early 1990s, when planting and seeding programs had largely eliminated the backlog of treatable understocked sites across the country, several provincial forest management agencies began scaling back their planting programs.

A significant proportion of recently harvested areas will always be reported as understocked because a time lag occurs between harvesting and the observable results of silvicultural treatments (e.g., planting and seeding) or natural forest stand development. This lag is evident in Figure 2.2a, which illustrates the regeneration status in 1992 of the areas harvested since 1975. However, the figure also shows that silvicultural programs ensured the successful regeneration of 90% of sites within 10 years of harvesting.

2.2a Regeneration status



Source: National Forestry Database, REGEN

The data for this element are derived from the National Forestry Database Program (NFDP) REGEN project. The NFDP, which collects and reports on regeneration following harvesting on provincial Crown lands, is currently working to extend REGEN to report on private lands. Information on the regeneration status of those forest lands will be reported in the future.

Summary

Maintaining the health and productivity of forest ecosystems is one important prerequisite to sound stewardship and the sustainable development of forest land. Evidence that forests are resilient and therefore persistent implies that the integrity of the forests is being maintained.

Regeneration of forest lands following human activity, such as harvesting, is a good indication of the sustained productivity of forest ecosystems. In Canada, the vast majority of harvested areas regenerate successfully.

ELEMENT 2.3
EXTANT BIOMASS

What are we measuring?

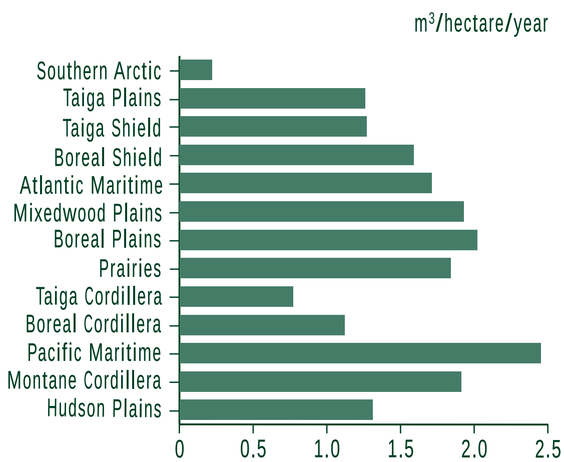
Forest condition is a measure of relative freedom from stress (health) and relative level of physical/biological energy (vitality) within a forest ecosystem. Biomass represents the mass of living organisms inherent in an ecosystem and is considered a measure of forest ecosystem condition. “Forest ecosystem condition” refers to the condition of the forest in terms of all species and types, and it includes the ability of ecosystems to support rarer species. As such, extant biomass is an integrating measure of forest ecosystem condition and is a reliable indicator of net performance (biomass accumulation), as well as trophic status. Increased trophic web complexity is associated with increased ecological stability. Thus, there are reciprocal relationships between ecosystem resilience (Element 2.2 [Ecosystem resilience]) and rates of accumulation of biomass, disturbance and stress (Element 2.1 [Incidence of disturbance and stress]).

The mean annual increment (MAI) is the average net annual increase in the yield (expressed in terms of volume per unit area) of living trees to a given age, and is calculated by dividing the yield of a stand of trees by its mean age. The MAI is dependent on a number of factors, including climate and elevation, soil conditions and forest management practices. MAI is a measure of the net biomass production of the forest and can be used to indicate its productivity. However, production loss due to mortality, insects and diseases is not included; therefore, total growth before losses generally is considerably larger than net growth.

How does extant biomass relate to the sustainability of Canada’s forests?

A measure of the frequency of biota occurrence within selected indicator species, in combination with a measure of MAI by forest type and age class, provides a reliable measure of forest ecosystem condition. A forested ecosystem that is healthy, vital and self perpetuating is considered to be functioning normally. The sustainable development of an ecosystem implies normal functioning over the long term.

2.3a Net mean annual increment by ecozone



Source: Canada's Forest Inventory*

*relational database of provincial and territorial forest inventories

What data are available?

Mean annual increment by forest type and age class (2.3.1)

The ideal source of information for this indicator would be tree measurements taken every 5–10 years on permanent sample plots located in a variety of forest conditions. This would reveal changes over time in forest ecosystem productivity, health and vitality. Such information exists regionally, but is not available in a format suitable for national reporting. Measures of forest ecosystem productivity may be enhanced for future editions of this report.

The MAI from the national forest inventory database is being used for the purposes of this report. This MAI was calculated for stands at the time of maturity, and thus is a long-term average that may differ from the current growth rate of our forests. For now, the inventory data serve as a general overview of growth rates in Canada's ecozones, based on the most current inventory area and the calculated MAI at maturity.

Analysis of MAI by ecozone (Figure 2.3a) indicates that the northernmost ecozone with forests (Southern Arctic) has the lowest MAI (0.2 m^3/ha/yr), and the second lowest MAI (0.8 m^3/ha/yr) is in the mountainous area at the Yukon Territory–Northwest Territories border (Taiga Cordillera). That is expected, given the climate and short growing season in those areas. The Pacific Maritime ecozone on the west coast of British Columbia—an area known for its long growing season and favourable climatic conditions—has the highest MAI (2.45 m^3/ha/yr).

The forest type information has been expanded to include predominant genus because MAI varies more by species than by forest type. This will give a better measure of the variety of species and their rate of growth. Figure 2.3b shows that poplar has the fastest growth rate in four ecozones; spruce in three; pine in two; and fir, birch and larch in one each.

Frequency of occurrence within selected indicator species (vegetation, birds, mammals and fish) (2.3.2)

This indicator is discussed under Indicator 1.2.2 (Population levels and changes over time for selected species and species guilds).

Summary

MAI is a measure of the net biomass production of a forest. Canada's forests can be broken down into three broad types. The MAI of our softwood forests, which are composed of such species as fir, spruce and pine, indicate that they are

2.3b Mean annual increment by ecozone and species

ECOZONE	SPRUCE	PINE	FIR	HEMLOCK	DOUGLAS-FIR	LARCH	POPLAR	BIRCH	MAPLE
	m³/hectare/year								
Taiga Plains	1.55	1.19	2.35	–	–	0.85	1.98	0.91	–
Taiga Shield	1.07	0.95	0.99	–	–	–	0.79	1.51	–
Boreal Shield	1.21	1.84	1.56	1.52	–	1.31	2.94	1.46	1.57
Atlantic Maritime	1.76	1.76	1.94	1.60	–	1.87	2.00	1.83	1.59
Mixedwood Plains	1.40	2.87	1.68	1.75	–	1.89	2.93	1.87	1.77
Boreal Plains	1.63	2.26	2.04	–	–	0.87	2.22	1.38	1.82
Prairies	2.14	1.70	2.03	–	1.72	1.23	1.89	1.71	1.76
Taiga Cordillera	0.73	1.95	–	–	–	–	0.64	–	–
Boreal Cordillera	1.30	1.11	1.46	1.20	–	1.57	0.69	1.17	–
Pacific Maritime	3.80	1.62	3.04	2.45	2.81	–	1.72	1.71	2.87
Montane Cordillera	2.69	1.73	1.98	2.47	1.41	1.87	1.36	1.71	2.11
Hudson Plains	1.25	1.47	1.34	–	–	0.94	2.58	1.00	–

Source: Canada's Forest Inventory*

*relational database of provincial and territorial forest inventories

generally long lived and slow growing (MAI = 1.69 m^3/ha/yr). In contrast, our hardwood forests comprise species, such as poplar, aspen and white birch, that are short lived and faster growing (MAI = 1.92 m^3/ha/yr). Our mixedwood forests consist of a combination of coniferous and broadleaved species with growth rates (MAI = 1.78 m^3/ha/yr) between those of the other two forest types.

The biomass production of tree species is one indicator of the ability of ecosystems to support and maintain life forms. In future, as forest inventories are enhanced and common measurement standards are adopted across Canada, actual growth may be derived using growth models based on such inputs as climate, site characteristics and forest type.

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CRITERION 3.0

CONSERVATION OF SOIL AND WATER RESOURCES

INTRODUCTION

This criterion includes physical environmental indicators and policy indicators that are related to soil and water characteristics. Physical environmental indicators are essential in tracking sustainable forest management because the maintenance of appropriate levels of soil oxygen, nutrients, moisture and organic matter is key to the long-term productivity and resilience of forest ecosystems.

Natural fluctuations in the quantity and quality of water occur as a result of annual and seasonal variations in precipitation and temperature. Also, forest mortality caused by fires, insects and diseases can naturally impact the chemical composition and flow rates within watersheds.

Man has influenced soil and water by logging and by clearing land for settlements, agriculture and other uses, such as recreational activities. In addition, water flow rates are controlled for hydro power generation, irrigation, habitat "improvement," flood control and human consumption. The direct discharge of sewage, industrial effluents, and fertilizers and pesticides from agricultural activities also can have a pronounced impact on water quality.

Other, indirect effects occur as a result of the atmospheric pollution associated with fossil fuel combustion. Acidification of water bodies causes decreased biological activity, and overfertilization or eutrophication may result from increased nutrient inputs in the runoff from forest ecosystems and agricultural lands.

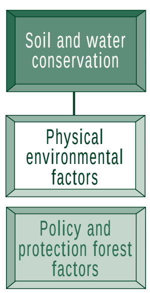
Thus, while water quality provides a good measure of the condition of forest watersheds, care must be exercised in separating the impacts of forest practices from those of other industrial, recreational, agricultural and urban activities. It is also imperative that the approach and methodology applied to monitoring the sustainable management of soil and water be sensitive to the host of influences described above.

Forest practices, including the construction of access roads, may impact on the quantity and quality of soil and water in a number of ways. The following are a few examples of potential impacts: soil erosion and compaction, siltation of aquatic habitats, flooding and increased water temperatures. In addition, the rapid regeneration of forests following harvesting is essential to maintain the normal flow rates and nutrient levels that prevent eutrophication.

In recent decades, researchers have gained a better understanding of the important interrelationships between the soil and water in forest ecosystems. This knowledge has enabled the provinces and territories to improve their forest practices codes and guidelines to promote the conservation of these two components. *Element 3.2 (Policy and protection forest factors)* *discusses the guidelines that are currently in place.*

Criterion 3 cannot be fully reported on nationally, because not all provinces and territories have specific processes in place for monitoring soil and water indicators. For this reason, progress is measured using case studies and proxy data. The application of national measures for the indicators is made even more difficult by the variations in climate, geology and forest practices across Canada. Currently, data from the provinces, territories and industry are being collected and analyzed to identify common policy directions and to demonstrate trends related to improved codes of practice.

ELEMENT 3.1
PHYSICAL ENVIRONMENTAL FACTORS



What are we measuring?

This element deals with the characteristics of soil, water and biota that serve as indicators of long-term ecosystem sustainability. Topics include soil disturbances (e.g., compaction, erosion and loss of organic matter) related to forest activities, effects of forest activities on aquatic fauna, changes in the quality and quantity of water in forested watersheds, and conversion of forest lands to other uses.

Reporting on these indicators presents a unique challenge to environmental monitoring—a limited number of sites are currently monitored, and the impacts of traditional harvesting methods, such as clearcutting, are measured on an even smaller number of sites. Furthermore, there is a lack of data regarding the impacts of alternative harvesting practices, such as variable-retention silvicultural systems. Also, in aquatic ecosystems, it is essential to screen the monitoring data to differentiate forestry impacts from those associated with other land uses, such as agriculture, hydro, mining, urban development and industrial activities.

How do physical environmental factors relate to the sustainability of Canada's forests?

Physical soil disturbances affect forest sustainability by decreasing the land area suitable for forest growth, and by reducing the potential productivity of forest soils and adjacent aquatic systems. The most dramatic examples of these impacts occur when forests are removed for agricultural use, settlement, transportation corridors, pipelines, mining or hydro reservoirs. In addition, forest cover may be lost as a result of certain forest management activities, including the construction of roads and landings essential for harvesting. During harvesting activities, off-road machinery—if used improperly—can reduce forest productivity through soil compaction and the displacement or removal of organic matter. (Wide, flexible tires are now being used on some harvesting machinery to prevent this type of disturbance.) However, monitoring can ensure that appropriate planning and construction techniques are employed to minimize such losses.

In recent years, the public's perception of sustainability and its concern regarding the appearance of cutovers have led to further reductions in the amount of land available for harvesting, as well as greater constraints on where and how that harvesting can take place.

Aquatic ecosystems within forests reflect the overall condition of watersheds and thus provide another important measure of sustainability. Nutrient levels and flow rates that are elevated over long periods of time in forest streams are a clear indication of a major forest ecosystem malfunction, because the water and nutrients that should be utilized in forest growth are instead moving rapidly into drainage systems. This threatens the sustainability of not only the forests, but also the aquatic systems themselves (through eutrophication), as well as downstream agricultural and urban areas (through flooding).

What data are available?

Percentage of harvested area having significant soil compaction, displacement, erosion, puddling, loss of organic matter, etc. (3.1.1)

The Forest Engineering Research Institute of Canada (FERIC) has studied the impact of various harvesting methods on ground disturbance in eastern Canada. According to FERIC, manual felling with skidding to the roadside causes severe ground disturbance on 7.4% of moderate slopes (an incline of 10–20%) and on 14% of steep slopes (an incline of 20–30%). Mechanical harvesting with transportation (rather than skidding) to the roadside causes severe ground disturbance on 0.1–2.4% of areas with a broad range of terrain conditions.

A study in the interior of British Columbia found that the extent of severe ground disturbance increases with the degree of slope and is partially determined by the season in which harvesting occurs. On slopes with an incline of less than 45%, the level of disturbance is less severe in winter (6.7–10.8%) than in summer (10.6–13.7%).

Ground disturbance is markedly reduced by the implementation of guidelines and codes of practice. For example, with the introduction of provincial guidelines in Alberta, the level of disturbance associated with aspen harvesting decreased from 25% of harvested areas in the mid-1980s, to 10% in 1990, and 3.5% in 1993.

In Quebec and British Columbia, ground disturbance is systematically monitored for compliance with forest practices codes. Some of the information gathered by these provinces include the time of harvesting, the percent of area compacted, and the percent of humus removed. In most other provinces and territories, measurements usually are taken in the context of ad hoc surveys related to equipment trials or special research projects.

Certain kinds and amounts of soil disturbance are essential for the restoration of forest ecosystems and favour more adequate levels of regeneration on sites that would otherwise revert to non-commercial tree species. For example, in the absence of fire, ground disturbance is essential for the regeneration of some black spruce ecosystems.

Existing data point to the range of disturbances that occur under different conditions; however, in most instances, these data reflect past, rather than current, practices. Thus, while there are a few sites that can serve as case studies, in most jurisdictions, data are not available to help determine whether forest practices are sustainable with respect to the level of soil disturbance.

Area of forest converted to non-forest land use, e.g., urbanization (3.1.2)

The data and information relating to this indicator are found under Indicator 4.2.1 (Area of forest permanently converted to non-forest land use, e.g., urbanization).

Water quality as measured by water chemistry, turbidity, etc. (3.1.3)

Studies indicate that when roads are constructed through areas with acidic soil, or when these areas are clearcut, the quality of water decreases in terms of both chemistry and turbidity. This decline is reflected in higher concentrations of dissolved nutrients and organic chemicals, and decreased pH levels. These changes are usually small and short-lived.

Results of catchment studies in Canada, the United States and overseas show that harvesting of forests leads to an increase in nutrients and organic chemicals in stream water for a period of three to five years. *(See Experimental Lakes Watershed case study below.)* This change reflects the higher levels of these substances in the forest floor that result from the removal of the biological demand of trees and other vegetation, and to a lesser extent, the disturbance of the ground.

Ground disturbance on the cutover and construction of roads on adjacent areas can lead to increased turbidity due to soil erosion and

Case study: Experimental Lakes Watershed, northwestern Ontario

Changes in the quantity of nutrients and suspended sediments were monitored in the Experimental Lakes Watershed near Dryden, Ontario, between 1973 and 1976. The site is dominated by jack pine and black spruce on coarse-textured shallow soils. These conditions are considered among the most sensitive for nutrient loss following forest ecosystem disturbance. (At the time of the study, no stream crossing or road construction guidelines were in place for forestry operations.)

Results for dissolved nitrogen and suspended sediments clearly demonstrate that changes after clearcutting are not excessive and that concentrations return to near background levels within five years (Figure 3.1a). Even the maximum concentrations for dissolved nitrogen do not exceed Ontario's drinking water standards and are well below the nitrogen loadings associated with other land uses (e.g., pastures, 3–14 kg/ha/yr; croplands, 7–21 kg/ha/yr; industries, 8 kg/ha/yr; and residences, 6 kg/ha/yr).

3.1a Dissolved nitrogen and suspended sediments in the Experimental Lakes Watershed

Source: Natural Resources Canada–Canadian Forest Service

siltation. Secondary succession after harvesting restores the biological demand for nutrients, resulting in near background levels of nutrients in the water within three to five years. Increased streamflow after harvesting can be attributed to less biological demand and reduced evapotranspiration, due to a smaller foliage surface area. Return of the streamflow to near background levels usually takes at least 20 years, depending on the height and complexity of the forest canopy.

Trends and timing of events in stream flows from forest catchments (3.1.4)

Methodologies for collecting national data on the trends and timing of events in stream flows from forest catchments are at the early stages of development. For the purposes of this report, some key factors are identified that will likely be considered in future assessments of this indicator.

As mentioned in the introduction to this criterion, stream flows can be impacted dramatically by control structures for hydro power generators, flood control measures, agricultural irrigation and human consumption levels. Natural catastrophes (e.g., an unusually high rainfall or spring melt) also can cause extreme fluctuations. Increased stream flows can lead to erosion and stream sedimentation, which can in turn lead to reduced water quality and aquatic habitat for fish and other organisms. (Soil disturbance, particularly erosion, also leads to sedimentation and a reduction in water quality and aquatic habitat.)

The extent and severity of impacts that may result from road construction near streams and other forestry activities depend on the site, the conditions at the time of harvest, and the logging methods employed. Typically, there is a pronounced change immediately after harvesting, followed by a period of recovery that may take anywhere from a few years to decades, depending on the site conditions and the indicator being measured. Site conditions vary considerably within and between forest ecosystems and across ecoregions. Key variables include slope, soil texture and amount of organic matter.

Each logging method has been developed for use in a particular set of conditions and is best suited to those conditions. Regional climatic differences and seasonal weather conditions at the time of harvest can, however, result in radically different impacts from the same harvesting system. The most important factors are the amount of rain, frost and snow cover.

Examples of degradation that can arise from poor harvesting practices include landslides on unstable slopes, the removal of organic material from unfertile sites, and the rutting and puddling that disrupt surface hydrology.

Changes in the distribution and abundance of aquatic fauna (3.1.5)

Most aquatic organisms are sensitive to changes in the temperature, chemical composition and particulate matter in water bodies. These factors can be affected by the discharge of municipal wastes, atmospheric pollutants, industrial effluents, and pesticides and fertilizers from agricultural activities.

Specific impacts from forest harvesting activities include increased water temperatures, eutrophication, siltation of river gravels, and reduced oxygen levels. A few species of aquatic fauna benefit from these changes, but most are negatively impacted. For fish populations, the recovery of riparian vegetation is important in mitigating water temperature and sedimentation factors. Invertebrate species that form the basis of aquatic food chains also are sensitive to the physical and chemical alterations in streams caused by sedimentation and changes in riparian vegetation.

The situation regarding to aquatic habitat has improved over the past decade with the development and implementation of riparian buffer zones and other forest practices. Data on current practices are being collected and will be reported on in the next few years.

Summary

Soil and water conservation are critical to sustainable forestry. The physical environmental indicators included in this element are intended to monitor the implementation of guidelines and planning aimed at maintaining the productivity of forest soils and water.

There is no formal process or protocol in place across Canada for monitoring water quality, flow rates and aquatic biota in relation to forest practices. However, Environment Canada and numerous provincial agencies maintain extensive databases on streamflow, water chemistry and fish populations.

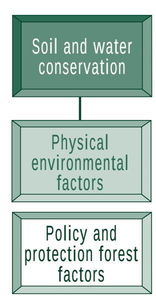
Nevertheless, care must be exercised in separating the impacts of forest practices from those of other industrial, recreational, agricultural and urban activities. This may be achieved by stratifying the data to include only those streams in which changes can be attributed directly to such forestry activities as harvesting or road building. Traditionally, studies of this type have focused on remote headwater streams in areas not affected by other forms of human intervention.

Few provinces or territories have aquatic monitoring systems in place that cover extensive areas, as well as variations in approaches and methods. Therefore, national data on these indicators are not readily available. Furthermore, while most provinces have collected data on fish populations, the relative impacts of recreational use versus forest practices are difficult to separate, as is the impact of pollution. (Moreover, many fish species have a high tolerance for disturbances and are not always the most sensitive indicators of habitat deterioration. Thus, the damage may be well advanced before symptoms are detected.)

The sustainability of our forest practices is now determined on the basis of qualitative data obtained from case studies, as well as data recorded at a limited number of long-term research sites. However, most of the available data reflect past practices or, in the case of water quality, a mixture of impacts.

Currently, water quality is monitored at a few fixed stations within a watershed, and comparisons between watersheds cannot be made because of the lack of data. Biological and chemical monitoring protocols need to be developed that would rely on key indicator organisms and elements, based on the findings obtained at existing research sites.

ELEMENT 3.2
POLICY AND PROTECTION FOREST FACTORS



What are we measuring?

This element monitors three policy indicators related to sustaining soil and water productivity: the amount of land managed primarily for soil and water protection; the percentage of forested areas with guidelines in place for road construction and stream crossings; and the area, percentage and representativeness of forest types in protected areas.

How do policy and protection forest factors relate to the sustainability of Canada's forests?

Soil and water are essential components of the forest ecosystem. To ensure that terrestrial systems are maintained, it is important to implement policies that provide for specific management practices to protect sensitive sites. Sensitive site conditions include riparian zones, steep slopes, wet and poor soils, and shallow soils over bedrock. With respect to aquatic systems, policies that address stream crossings, watershed management and riparian areas will assist in maintaining natural water-flow patterns and water levels and quality.

What data are available?

Percentage of forest managed primarily for soil and water protection (3.2.1)

Municipal watersheds, riparian buffer zones, and areas managed by water conservation authorities are all aimed at promoting soil and water conservation. Municipal watersheds and managed areas represent a very small proportion of the productive landbase in Canada. The creation of riparian buffer zones is now standard practice throughout most of the country, but their small scale makes them difficult to quantify. It is known, however, that the 30–50-metre riparian zones currently utilized in most regions of Canada amount to 60–100 hectares of reserve per kilometre of stream.

Percentage of forested area having road construction and stream crossing guidelines in place (3.2.2)

Guidelines for general-purpose roads have existed in Canada since the mid-1970s, and in recent years, many jurisdictions have begun to apply them to forest operations. There is a need to identify the guidelines in every province and territory to calculate the percentage of forest lands where such guidelines are in place. There is also a need to determine similar reporting mechanisms across jurisdictions to determine what information could be reported at the national level.

Area, percentage and representativeness of forest types in protected areas (3.2.3)

Data and information relating to this indicator are reported under Indicator 1.1.3 (Area, percentage and representativeness of forest types in protected areas).

Summary

Collectively, these indicators reflect the value of forest soil and water conservation in Canada. Policies aimed at conserving soil and water within forested ecosystems are being developed and implemented across the country for many forest-related activities. Currently, all public forest land is covered by guidelines for road construction, stream crossings and riparian buffer zones. Soil and water values are further safeguarded by municipal watershed conservation authorities and in protected areas.

In most provinces, the existing network of water monitoring stations was not designed to monitor trends in water quality and flow rates attributable to forest practices. Nevertheless, stations located in headwater streams that are isolated from other impacts (e.g., fires, control structures and settlements) may provide good historical trend data. This information needs to be screened and analyzed to determine its value. In addition, to track trends arising from improved forest practices and policies, chemical and biological monitoring protocols need to be developed based on experience obtained from existing, long-term watershed research.

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CRITERION 4.0

FOREST ECOSYSTEM CONTRIBUTIONS TO GLOBAL ECOLOGICAL CYCLES

INTRODUCTION

Forests occupy 4 billion hectares, or roughly one-third of the Earth's land surface. (Canada's forests cover 417.6 million hectares—almost half the country's land mass.) Because of their size, forests play a major role in the functioning of the Earth's biosphere, and they contribute to and regulate global biological cycles related to carbon (the carbon cycle) and water (the hydrological cycle). Understanding the role of forests in these cycles is vital to develop forest management practices that are sustainable in the long term. The purpose of Criterion 4 is to describe and measure the effects of forests and their use on these important cycles.

Element 4.1 (Contributions to the global carbon budget) outlines the overall contribution of the boreal forest to atmospheric carbon dioxide levels. In a process referred to as the "carbon cycle," forests exchange large amounts of carbon dioxide with the atmosphere as they grow (through photosynthesis and respiration) and die (through decomposition).

Natural disturbances, such as fires, insects and diseases, affect the movement of carbon from the forests to the soil and atmosphere. Harvesting and other forestry activities (e.g., planting and slash burning) represent yet another disturbance influencing the movement of carbon within and from forest ecosystems.

In the case of harvesting, carbon moves from the trees to wood and paper products. Disposal of these products in landfill sites results in the carbon being returned to the atmosphere through decomposition. Recycling of wood and paper products plays an important role in the forest carbon budget by reducing the requirement for harvesting and ultimately, the amount of material ending up in landfill sites. Thus, recycling helps lower the amount of carbon returning to the atmosphere.

Given that forests and their soils represent large reservoirs of carbon accumulated over decades, centuries or even millennia, the conversion of land to or from forests also has an important effect on the global carbon balance. This issue is discussed in Element 4.2 (Forest land conversion).

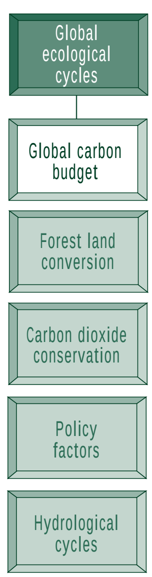
In managing and utilizing our forest resources, we consume considerable quantities of energy in the form of fossil and non-fossil fuels. Element 4.3 (Forest sector carbon dioxide conservation) discusses the forest sector's energy use in the context of its impact on the carbon budget.

Understanding the impact of forests and their soils on the global carbon balance is vital in determining how we can best manage Canada's forests to reduce or mitigate climate change. It is important to know whether our management and use of forests are contributing to increased atmospheric carbon dioxide concentrations or are helping to reduce them. Element 4.4 (Forest sector policy factors) reviews the forest legislation, policies and inventories that are currently in place across Canada.

Another major global cycle in which forests play an important role is the hydrological cycle. As with carbon, forests exchange large amounts of water with the atmosphere through evapotranspiration. Forests also recycle water, and by acting as storage areas, they regulate the flow in most major streams and rivers. These activities are measured and discussed in Element 4.5 (Contributions to hydrological cycles).

To ensure that our forests and the demands we place on them are sustainable, we must learn as much as possible about the role of forests in the carbon and hydrological cycles. Criterion 4 measures our current knowledge on this subject and highlights areas where more research is required.

ELEMENT 4.1
CONTRIBUTIONS TO THE GLOBAL CARBON BUDGET



What are we measuring?

The global carbon cycle is the most important set of processes linking forests with climate change. The main factor driving climate change is society's influence on the natural greenhouse effect through changes in atmospheric concentrations of greenhouse gases, such as carbon dioxide, methane and nitrous oxide.

Forests in Canada cover 45% of the nation's land and account for 10% of the world's forested area. Hence, the carbon budget of Canada's forests plays an important role in the global carbon cycle.

In the context of sustainable forestry, the carbon budget also represents a balance sheet in terms of our forest assets. Carbon in the form of standing biomass (e.g., tree trunks, branches, leaves and roots) is a measure of the timber volume available and is reported on in this element.

In the context of climate change, our forests both absorb and release carbon, thus contributing to changes in the overall atmospheric concentrations of carbon dioxide. This element focuses on the role of forests in the carbon budget.

A carbon budget model for Canada's forests is being developed under the leadership of Natural Resources Canada–Canadian Forest Service. Results are not yet complete, but estimates are available for the carbon currently stored in Canada's forests and for the changes in the carbon budget in the boreal and subarctic forest regions over the period 1920–1990. As these regions constitute three-quarters of our forests, they provide a good indication of the status of the carbon budget of Canada's forests as a whole.

Forest products also contribute to the carbon cycle (Indicator 4.3.2 [Fossil carbon products emissions]). Conversion of trees to wood and paper shifts carbon from the standing biomass pool to the forest products pool. Recycling plays an important role in the products pool (Indicator 4.4.1 [Recycling rate of forest wood products manufactured and used in Canada]).

Because Indicators 4.3.2 and 4.4.1 contribute to the carbon cycle, data for these indicators are reported as part of the carbon budget model. For solid wood products, recycling is only in its infancy and no national statistics are yet available. However, we can describe the developments, infrastructure and practices that are shaping the efficient use, reuse and recycling of wood.

The nine indicators (4.1.1–4.1.9) for this element represent key factors in the carbon budget. This report does not describe the condition of each one individually; rather, it provides information regarding the combined effects of these factors on the net exchange of carbon between the forest ecosystem and the atmosphere.

How does the global carbon budget relate to the sustainability of Canada's forests?

In the context of sustainable forests, the carbon budget represents a balance sheet for our forest assets. Carbon in the form of standing biomass is a measure of the timber volume available. Assuming no change in forest structure, a constant or increasing volume of standing biomass shows that the forest can sustain the wood supply indefinitely at current levels of use. On the other hand, a declining volume of biomass would indicate that our forest is losing trees faster than it can replace them. These losses cannot be sustained indefinitely without affecting the economic, social, cultural, recreational and environmental benefits the forest provides.

In Canada, we dispose of nearly 5 million tonnes of used paper products every year—approximately 35% (by weight) of solid wastes in municipal landfill sites. Recycling can reduce our demands on the forest, improve wood fibre utilization, reduce waste, and lengthen the time carbon is stored in forest products.

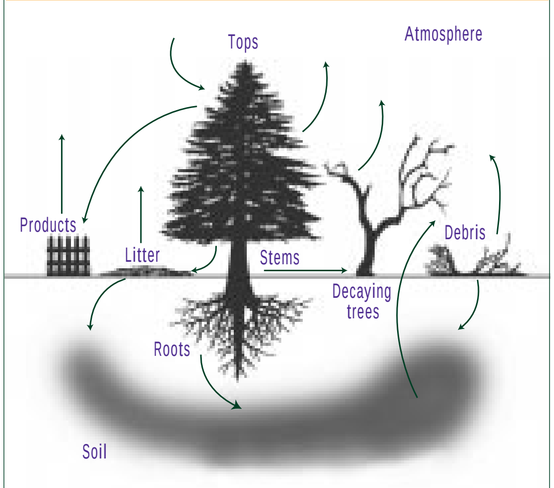
What data are available?

Forest sector carbon budget (4.1.1–4.1.9)

Forests are vast, ever changing pools of carbon. As trees grow, they absorb carbon dioxide (CO_2) from the atmosphere, convert it into carbohydrates, and store it in roots, leaves, branches and trunks (i.e., the standing biomass). During the life cycle of a tree, the carbon it contains is distributed as it grows, and as it becomes diseased, dies or is killed by fire, windthrow or other natural causes (Figure 4.1a). When a tree is disturbed, some of the carbon it contains is released back into the atmosphere; however, even in the case of fire, only a small portion is released immediately. The rest of the carbon ends up on the forest floor or in the soil, where it decomposes slowly.

Trees that are converted into forest products represent another form of carbon storage. When the products are disposed of in landfill sites, where they decompose over time, the carbon they contain is released back into the atmosphere.

4.1a Forest carbon cycle

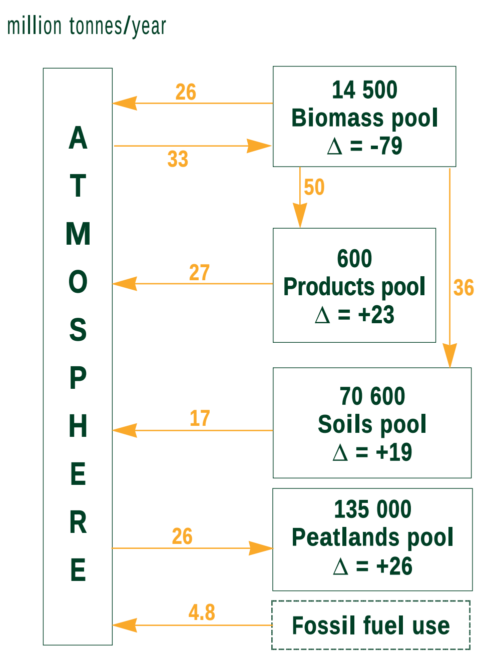


Source: Natural Resources Canada–Canadian Forest Service

CO_2 is one of the principal greenhouse gases in the atmosphere, and roughly half the annual exchange (100 000 million tonnes/year) of this gas is attributed to global forest ecosystems. These ecosystems also represent vast carbon pools, containing large amounts of carbon in their soils and standing biomass—some 1 500 000 million and 650 000 million tonnes, respectively.

In Canada, approximately 221 000 million tonnes of carbon are stored in our forest ecosystems. Figure 4.1b outlines the principal carbon pools: standing biomass, forest products (e.g., building materials, and wood and paper products), forest soils (e.g., litter and coarse woody debris) and peatlands.

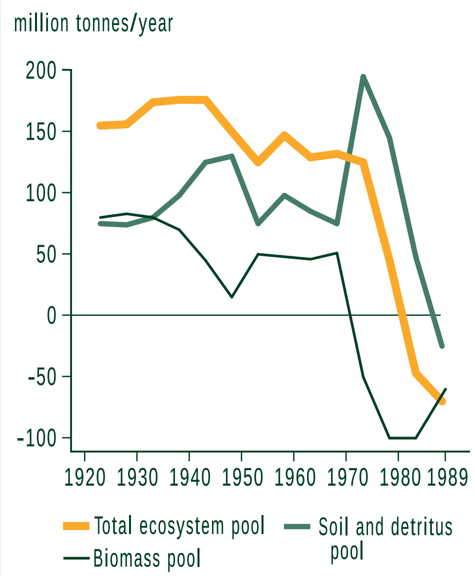
4.1b Overview of the major carbon pools and net fluxes in Canada's forests, 1985–1989



Note: the Δ is used to indicate the net flux in the carbon pool; the dotted line indicates the carbon flux that results when fossil fuels are burned by the forest sector.

Source: Natural Resources Canada–Canadian Forest Service

4.1c Changes in the carbon storage in the boreal and subarctic forests



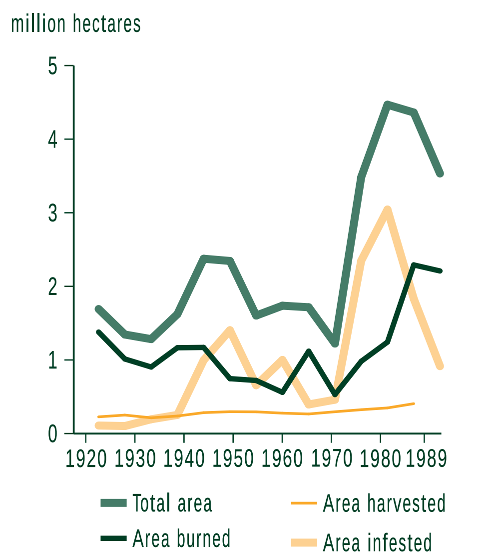
Source: Kurz & Apps

The carbon budget model for Canada indicates that the products carbon pool (i.e., the amount of carbon stored in forest products after 40 years of harvesting, minus the carbon released during decomposition and burning) is small (0.3% of the total carbon stored) compared to other carbon pools (e.g., forest soils, standing biomass and peatlands). It is important, however, in terms of the annual movement (flux) of carbon between pools.

On a daily, seasonal and annual basis, carbon moves among these pools and the atmosphere in a variety of ways. The difference between the amount of carbon entering and leaving a pool determines whether it is considered to be gaining carbon (i.e., a "sink") or losing carbon (i.e., a "source").

Currently, models are the only method available to estimate the exchange of carbon in forest ecosystems. Figures 4.1c, d and e were generated by the forest carbon budget model.

4.1d Area disturbed in the boreal and subarctic forests



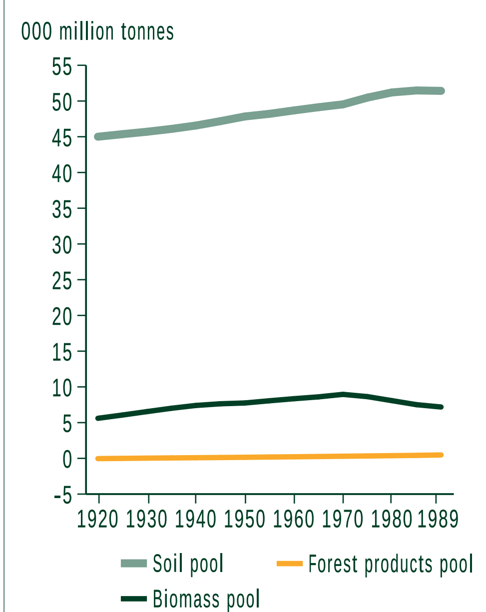
Source: Kurz & Apps

They describe the area disturbed, as well as the total carbon stored in Canada's boreal and subarctic forests over the period 1920–1989. The results of the model are outlined below.

- Averaged over the 70-year period, the boreal and subarctic forests were a net sink for carbon, although the strength of the sink changed markedly over time (Figure 4.1c).
- These forests became a source for atmospheric carbon during the 1980s, apparently due to a large increase in fire and insect disturbances (Figure 4.1d). Harvesting appears to have played a minor role in the change from carbon sink to source, as it increased only slightly during that decade.
- The amount of carbon stored in the biomass pool increased by 55% from 1920 to 1970; however, the pool subsequently declined by 18% from 1970 to 1989 (Figure 4.1e). Much of this loss, however, was not to the atmosphere, but rather to the soil pool, which also increased over the period 1920–1970 and continued to increase until 1985. Since 1985, the soil pool and the standing biomass pool have both lost carbon.
- Of the total carbon transferred from the biomass pool to the forest products pool (Figure 4.1e), an estimated 36% was retained in forest products and landfills. The remainder was released into the atmosphere through decomposition.

In response to the changes in disturbance regimes, the age class structure of the boreal forest has changed markedly since 1920. Over the period 1920–1969, the average age of the forest increased from 60.9 to 82.5 years, which suggests that the rate of disturbance was lower during this period than it had been previously. An apparent increase in natural disturbances since 1970 lowered the average age to 76.4 years by 1989.

4.1e Total carbon stored in the boreal and subarctic forests



Source: Kurz & Apps

The age of the forest has a significant influence on carbon sequestering. Although young, fast growing trees absorb more carbon, the older the forest ecosystem, the more carbon it contains in its standing biomass and soil. This is illustrated in Figure 4.1e for 1920, 1970 and 1980, at which times the forest biomass pool contained an estimated 5 600 million, 8 700 million and 7 100 million tonnes of carbon, respectively.

Another important factor in the carbon cycle is the rate at which wood and paper products are recycled. Carbon is stored in these products, and by expanding the level of recycling, less carbon is released into the atmosphere than would occur if the products were disposed of in landfill sites.

Recycling rate of forest wood products manufactured and used in Canada (4.4.1)

Data for this indicator are also included in the forest sector carbon model discussed in Indicators 4.1.1–4.1.9.

Recycling efficiency for paper products is measured by comparing the quantity recovered with the quantity used or consumed—the "recovery rate." Another way of measuring this efficiency is the "utilization rate," which is obtained by comparing the quantity of paper recovered with the quantity of pulp and paper produced.

In 1995, 18.6 million tonnes of paper and paperboard were produced in Canada. The pulp utilized to manufacture these products incorporated 4.1 million tonnes of recycled wood fibre (2.2 million tonnes recovered in Canada and 1.9 million tonnes imported from the United States [USA]). The proportion derived from post-consumer waste is not known.

Canada has made great strides in recycling. Currently, 42% of all paper consumed is recovered, and our paper products now contain 22% recycled content, up from 10% in 1990. Recycled-material content in paper is not regulated in Canada, but voluntary national goals have been established.

From 1990 to 1995, Canada's forest industries invested $1.2 billion to increase their recycling capacity, mostly in recycled newsprint production. Some 60 of the country's 110 paper and paperboard mills now use recovered paper for all or part of their supply. Of these, 23 mills produce newsprint with old newspapers and magazines as an important component of the total fibre supply.

Some recent data and trends on recycled products are shown in Figure 4.1f. Total mill receipts of old newspapers and corrugated containers, which each exceeded 1.5 million tonnes, increased in 1995 compared with the previous year. Imports of U.S. newspapers represented more than 55% of consumption and containers, 30%. Among other products, receipts of high-grade de-inked papers fell in 1995; imports accounted for 57%. Total receipts of old magazines also declined overall, but domestic receipts increased, whereas imports—which represented 75% of the total supply used by mills—decreased.

Wood products, which are relatively inexpensive in Canada, have long been the residential building material of choice. Construction generally produces 4–7 tonnes of waste materials, of which wood products account for 35–45%. Recently, competition has brought down the cost allowance for off-cuts and waste from 15%, to 5% or less. Also, on-site separation of wood wastes has made it possible to reuse and sell construction debris. In one instance,

4.1f Total and domestic mill receipts of recycled products, 1995

PRODUCT	TOTAL RECEIPTS thousand tonnes	CHANGE 1994–1995 %	DOMESTIC RECEIPTS thousand tonnes	CHANGE 1994–1995 %	IMPORTED FROM USA %
Old newspapers	1 518	+5	675	+2	55
Old corrugated containers	1 512	+5	1 040	+5	30
Hi-grade de-inked papers (e.g., computer print outs and sorted office waste)	527	-1	224	–	57
Old magazines	195	-5	50	+9	75

Source: Canadian Pulp & Paper Association

framers and carpenters were able to reuse approximately 500 kilograms of dimensional lumber that might otherwise have gone to a landfill site—a 20% reduction in wood waste. This saving, added to an already reduced allowance for construction wastes, generated an on-site reduction of at least 30% in wood waste.

Today, a market is emerging for recycled wood materials. The effects of recycling—although small in terms of the overall carbon budget of the forest sector—help lower emissions to the atmosphere. In the context of climate change, they also enable Canada to reduce its total carbon emissions as part of its international obligations.

For every six homes built in Canada, one is demolished. Recycling of demolition waste is a growing market. With 10-fold or higher increases in landfill tipping fees, 50 material recycling facilities have opened since 1988 in major urban markets. Approximately a third operate retail outlets. Not only have they created a market in Canada for value-added wood products (e.g., large timbers, doors, windows, architectural millwork, cabinetry and hardwood flooring) at prices 30–50% below those of new materials, they have also spawned technologies to manufacture new products (e.g., mulches, animal bedding, fibre-based boards and mats for further manufacture by the automotive industry) from demolition waste.

Wooden pallets, which account for 90% of container production, are no longer accepted at many urban landfill sites. However, they may be reused up to 50 times, and each year, the Canadian Pallet Council repairs almost a million pallets for reuse by industry members. (The Council has grown from 200 members in 1983, to more than 800 in 1996.) Pallets that are beyond repair are now recycled as mulch, wood fibre for new-age building products, and chips for composting municipal sewage sludge.

Summary

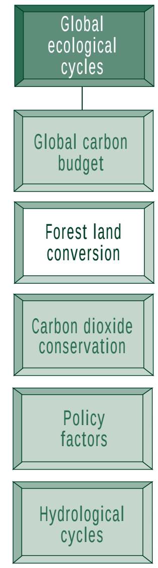
Current estimates suggest that since the second half of the 1980s, Canada’s boreal and subarctic forests have been a net source for atmospheric carbon. The precise magnitude of the carbon release is uncertain, but it seems fairly clear that after acting as a sink for atmospheric carbon for much of this century, these forests have reversed their role in the global carbon cycle.

Recent investigations into the carbon budget suggest a number of important relationships. First, the budget is not constant, but changes over time in response to a number of factors that affect forest productivity, including forest management practices, and fires, insects and diseases. Secondly, the amount of carbon in a forest is strongly influenced by the age distribution of its trees. Hence, the timing and rate of disturbances are important in determining whether our forests are a sink or source for atmospheric carbon. Lastly, changes in a forest's uptake or release of carbon are primarily the result of fluctuations in natural disturbance regimes. For example, the recent 20-year period of high disturbances in the boreal forest will likely affect the dynamics of the forest carbon budget for decades. Consequently, over the long-term, it is unclear whether Canada's forests can be considered significant sinks for the atmospheric carbon released by society's use of fossil fuel energy sources.

Economics and a growing environmental awareness are shaping the use, reuse and recycling of wood and paper products. The infrastructure for reusing and recycling wood products is swiftly emerging, but data availability will remain a problem until this new market segment establishes reporting standards and protocols.

Development of the carbon budget model of Canada's forests is not complete—research to improve various components is continuing. Changes in the carbon estimates can be expected as new data are obtained, improvements to the model are made, and our understanding of the carbon cycle increases.

ELEMENT 4.2
FOREST LAND CONVERSION



What are we measuring?

In Canada, forest lands are being permanently converted to purposes that serve our growing population—to residential areas, agricultural lands, roadways, pipeline corridors, hydroelectric right-of-ways, reservoirs, mining areas, airports, etc. There is concern that the magnitude of the conversion is affecting the global carbon and hydrological cycles, which are linked to climate change and global warming.

Comprehensive, current information on land use changes in Canada is not available. However, to give a general idea of the magnitude of the conversion of forest lands to other uses, rough estimates can be made from related statistics and proxies in selected areas, and they can then be extrapolated to the country as a whole.

How does forest land conversion relate to the sustainability of Canada's forests?

The issue of land conversion is important to the sustainability of our forests, because if forest lands are being permanently lost, the decline in forested area will ultimately affect the amount of wood that can be extracted for societal uses. It will also affect the ability of the forest to provide environmental, social, cultural and recreational benefits to society.

When forests are converted to other uses, there is usually a net loss of carbon from the trees, vegetation and soils. The carbon moves to the atmosphere, increasing concentrations of CO_2. When other lands (e.g., agricultural lands) are converted to forests, however, the lands incur a net carbon gain, which helps reduce atmospheric concentrations. (Forest lands contain more carbon than agricultural lands.) Knowing whether our forested area is contributing to or reducing atmospheric carbon is an important element of Canada's reporting commitments under the Framework Convention on Climate Change.

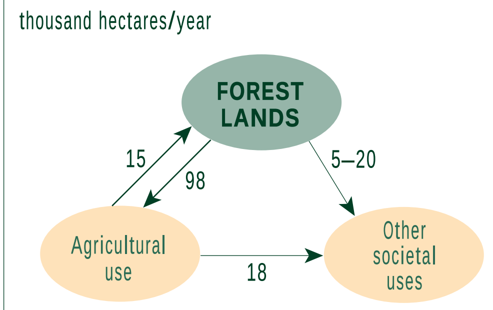
What data are available?

The data currently available on forest land conversions in Canada do not distinguish between permanent and semi-permanent or temporary conversions. For this reason, Indicators 4.2.1 and 4.2.2 are being addressed together in this report.

Area of forest permanently converted to non-forest land use, e.g., urbanization (4.2.1) and Semi-permanent or temporary loss or gain of forest ecosystems, e.g., grasslands and agriculture (4.2.2)

In Canada, since European settlement began in the 17th century, the largest conversion of forest lands to other uses has been to agricultural lands—some 23 million hectares. Another million hectares have been converted to urban settlements, roadways, hydro right-of-ways, pipeline corridors, and so on.

4.2a Estimated conversion of forest lands in Canada to agricultural and other societal uses, 1986–1991



Source: Natural Resources Canada–Canadian Forest Service

Today, Canada's forest lands continue to be converted to other uses; however, of the forested area at settlement, 94.6% is still under forest cover. Figure 4.2a illustrates the estimated annual change in forest, agricultural and other land uses from 1986 to 1991. The annual increase in agricultural lands from forests is approximately 83 000 hectares, while 18 000 hectares of agricultural lands are converted to other societal uses.

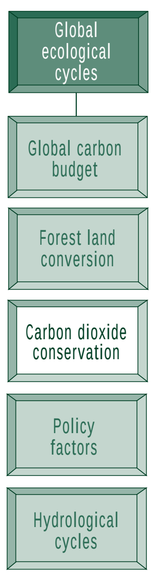
Not all conversion of forest lands to agricultural lands is permanent. Some lands cannot sustain economically viable agricultural use, and so are abandoned and intentionally or naturally changed back to forests at a rate of approximately 15 000 hectares per year.

In total, each year, some 88 000–103 000 hectares of forests are converted permanently to non-forest land uses. However, with Canada's current forested area of 417.6 million hectares, the significance of this conversion is diminished by the size of our forests—the annual rate of conversion is roughly equal to 0.02% of the resource.

Summary

Comprehensive, current information on land use changes in Canada is not available. Estimates suggest that some 24 million hectares of forest lands have been converted to agricultural or other land uses since European settlement began. Forest lands continue to be permanently and semi-permanently converted to other land uses; however, given the vastness of the forest resource in Canada, the overall impact of these conversions is negligible. Nevertheless, the implications of this change for the global carbon and hydrological cycles are not well understood.

ELEMENT 4.3
FOREST SECTOR CARBON DIOXIDE CONSERVATION



What are we measuring?

Energy use by the forest sector for the conversion of raw materials to manufactured products, and the storage and disposal of these products, all contribute to the global carbon cycle. For example, the forest sector uses energy in the production of lumber, paper and other wood products, which release CO_2 into the atmosphere. At the same time, forest products (e.g., buildings, furniture and paper) store carbon and contribute to reduced emissions. However, these products become a source of carbon emissions over time—after disposal. *Because of the relationship between the forest products carbon pool, the standing biomass pool and the forest soils pool, this topic is discussed in Element 4.1 (Contributions to the global carbon budget).*

Statistics Canada collects data quarterly and annually on the energy used by the forest sector and the quantities of fuel it consumes. Statistics are available on the pulp and paper industries and wood industries for the period 1980–1993. This element outlines the energy (including non-fossil fuels) used by the forest industries, the CO_2 emissions to the atmosphere that are associated with fossil fuel use, and the changes that occurred between 1980 and 1993. *For the purposes of this report, Indicator 4.3.1 (Fossil fuel emissions) and Indicator 4.3.3 (Percentage of forest sector energy usage from renewable sources relative to the total energy requirement) are discussed together. Indicator 4.3.2 (Fossil carbon products emissions) is covered in the discussion on the forest sector carbon budget in Element 4.1 (Contributions to the global carbon budget).*

How does carbon dioxide conservation relate to the sustainability of Canada's forests?

Rising concentrations of greenhouse gases in the atmosphere have been linked to global warming. The burning of fossil fuels is regarded as the major source of the most significant of these gases—CO_2.

As a signatory to the Framework Convention on Climate Change, Canada is committed to stabilizing its greenhouse gas emissions at 1990 levels by 2000. Increasing the use of renewable or non-fossil fuel energy sources (e.g., biofuels, and hydro and nuclear power) is one way to reduce these emissions.

What data are available?

Fossil fuel emissions (4.3.1) and Percentage of forest sector energy usage from renewable sources relative to the total energy requirement (4.3.3)

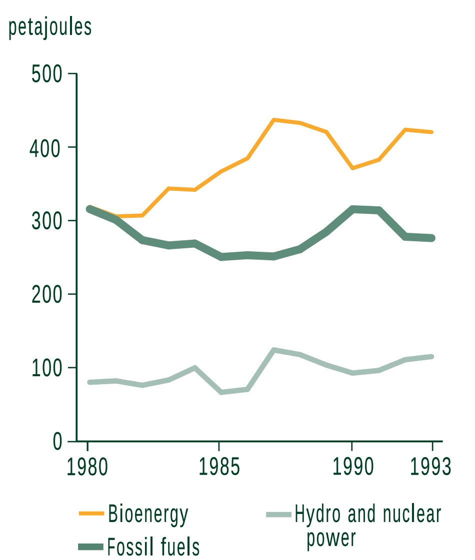
Fossil fuels utilized to produce energy include coal and coke, natural gas and refined petroleum products, as well as the portion of electricity that is derived from coal and coke and natural gas. Non-fossil fuels include hydro and nuclear power, as well as the energy derived from biomass and spent pulping liquor.

Figure 4.3a outlines changes in the specific energy sources used by the forest sector between 1980 and 1993. Non-fossil energy derived from biofuels rose by 32%, and hydro and nuclear energy increased by 38.2%. Energy from fossil fuels, on the other hand, decreased by 12.5%. Overall, from 1980 to 1993, the use of fossil fuel energy declined to 34% of total energy use, whereas the use of non-fossil energy sources increased to 66%, bioenergy rose to 51.8%, and hydro and nuclear power grew to 14.2%.

Although total energy use by the forest sector increased by approximately 13.5%, total CO_2 emissions decreased by 15.1% (Figure 4.3b). These effects resulted from replacing fossil fuels with biomass-derived fuels, using more hydro and nuclear power, and switching from coal, coke and heavy fuel oil to less carbon-intensive fuels, such as natural gas.

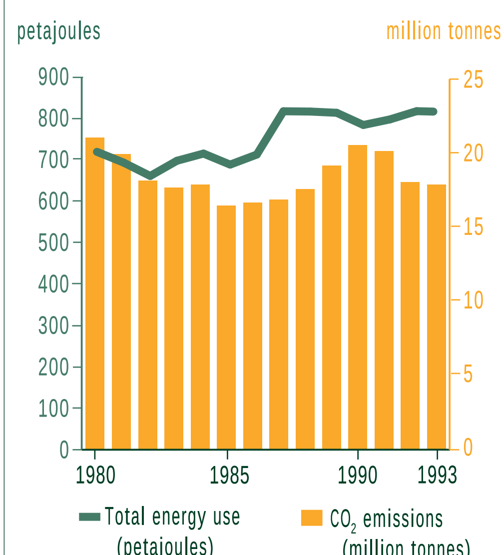
The decline in CO_2 emissions from fossil fuels is broken down by major fuel type in Figure 4.3c. In 1993, coal and coke accounted for 2% of these emissions; natural gas, 34%; refined petroleum products, 32%; and fossil fuel electricity, 32%. Between 1980 and 1993, emissions from the use of refined petroleum products declined by almost half, and from the use of coal and coke, by roughly

4.3a Source of energy used by the forest sector



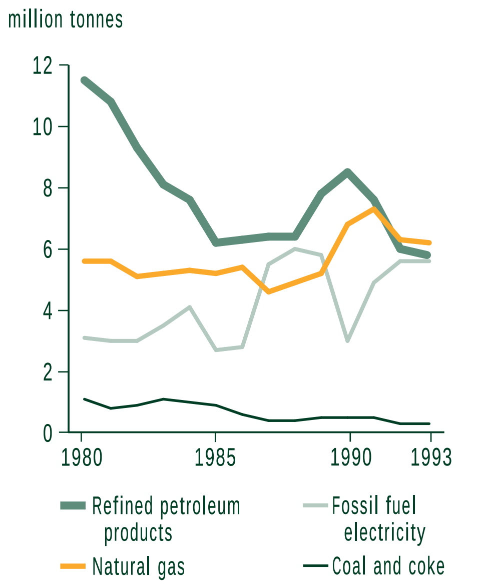
Source: Statistics Canada

4.3b Total energy use and total CO_2 emissions in the forest sector



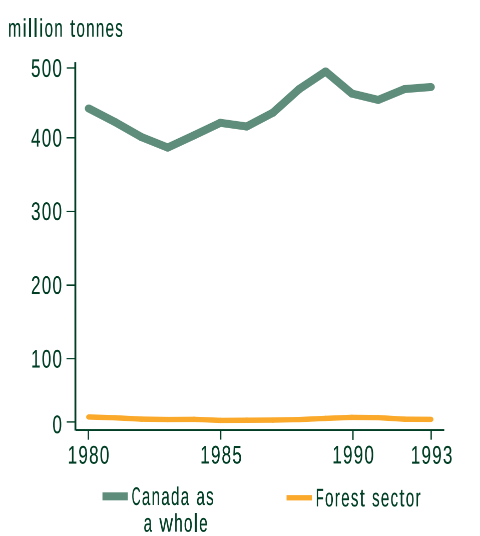
Source: Statistics Canada

4.3c CO_2 emissions by fuel type



Source: Statistics Canada

4.3d CO_2 emissions from fossil fuel used by Canada as a whole and by the forest sector



Source: Statistics Canada

three-quarters. However, emissions from the use of natural gas and fossil fuel electricity increased by 11% and 86%, respectively.

Between 1980 and 1993, CO_2 emissions from fossil fuels utilized by Canada's forest sector represented less than 5% of the emissions attributed to the nation as a whole (Figure 4.3d). Moreover, the proportion declined throughout the 1980s and early 1990s—from 4.8% to 3.8%. During this period, forest sector emissions were reduced by 15.1% (from 21.2 million tonnes to 18 million tonnes), while those of Canada as a whole increased by 6.6% (from 441 million tonnes to 470 million tonnes).

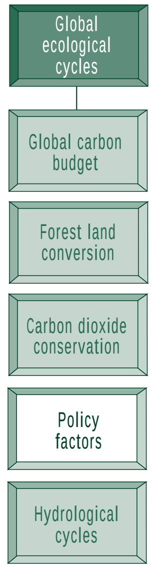
Summary

Total energy use by the forest sector has increased by roughly 13.5% since 1980, but the portion derived from fossil fuel sources has declined by 12.5%. This improvement was made possible by increasing the use of biofuels by 32% and hydro and nuclear energy sources by 38.2%.

Associated with the decline in fossil fuel use, total forest sector CO_2 emissions decreased by 15.1%. This decrease in emissions is linked to the replacement of fossil fuels by biofuels, the switching from more carbon-intensive fuels (e.g., coal, coke and heavy fuel oil) to less carbon-intensive fuels (e.g., natural gas), and the implementation of more energy efficient processes. Overall, the forest sector contributes less than 5% of the total CO_2 emissions from fossil fuel use in Canada, and this proportion is declining.

ELEMENT 4.4

FOREST SECTOR POLICY FACTORS



What are we measuring?

The appropriateness of Canada's policies can be gauged by how well its legal and regulatory framework influences the conservation and sustainable development of its forests, by the extent and quality of its forest inventories, and by its participation in the international climate change convention.

How do policy factors relate to the sustainability of Canada's forests?

Canada's legal and regulatory framework promotes the sound stewardship of its forest resources, provides for forest inventories to monitor the extent and condition of its forests, supports its participation in international climate change initiatives, and encourages its use of bioenergy. Canadians are custodians of 10% of the planet's forest area, and it is important that Canada conserve and manage its forests so that they continue to contribute to the orderly working of global ecological cycles.

What data are available?

Existence of laws and regulations on forest land management (4.4.5)

In addition to statutes and regulations, the legal framework for forest management in Canada comprises guidelines, standards, rules and manuals that provide direction to forest managers in their daily operations. The framework applies primarily to commercial Crown forests.

Most of Canada's public forest land is under provincial jurisdiction, and tenure arrangements, through which rights to public forest land are allocated to private companies, are a key forest management policy vehicle. The bulk of rights to forest land are held in the form of long-term tenure agreements. These agreements require forest companies to prepare detailed management plans (usually every five years) for approval by provincial governments. Most of the agreements contain provisions to ensure that areas are reforested soon after being harvested, as well as provisions aimed at achieving forest management objectives—to maintain a vigorous forest cover. *For a discussion on tenures, please see page 70.*

More recently, an increasing number of forest policies have been based on environmental and social, as well as economic considerations. Legislation to achieve sustainable development goals is beginning to reflect this change. New forest laws and stricter enforcement of previously informal policies and guidelines indicate the steps being taken by an increasing number of provinces in response to new imperatives.

The need to sustainably manage forest resources is acknowledged by all levels of government in Canada and is entrenched in the 1992 National Forest Strategy. New acts based on the principles of sustainability have already been passed by three provinces: British Columbia's 1994 Forest Practices Code Act, Ontario's 1994 Crown Forest Sustainability Act and Saskatchewan's 1996 Forest Resources Management Act. (In 1996, the Province of Quebec amended its Forest Act to reflect the same commitment.)

Tenure arrangements

In Canada, all timber cut on Crown lands is harvested under some form of tenure, which is defined as a right or interest granted by the Crown, subject to governing legislation and the terms and conditions of the document containing the grant. The rights conveyed under tenure vary greatly in comprehensiveness, duration and exclusiveness; and the obligations of the holders increase with the security and length of tenure.

Under tenure arrangements, the government and a forest company negotiate an agreement that allows the province to retain full ownership of the land, while conveying to the company exclusive rights to harvest the timber in a sustainable manner. (To obtain these rights, the company must submit detailed short- and long-term management plans for review and approval by the province on a regular basis.) The tenure also assigns responsibility for management costs. Long-term tenures (20–25 years) account for the majority of timber cutting rights (Figure 4.4a) and can be renewed, provided the company satisfies the terms of the agreement. Tenure arrangements for timber harvesting may overlap, with several tenure holders operating in the same area. Coordination and joint planning of forest activities by tenure holders are encouraged and sometimes mandated (e.g., in Quebec and New Brunswick).

Although timber production is the predominant use of forest land under tenure, in recent decades, tenure arrangements have also provided for access by other users in areas designated for integrated or multiple-use management. In cases of overlapping or conflicting uses of resources, integrated planning processes exist to establish priorities and provide a mechanism for departmental consultation.

Access to and use of non-timber forest resources (e.g., wildlife, water and minerals) are often granted by different government departments operating under various statutes. For instance, agricultural activities in forested areas may require leases, licences or permits for grazing and haying. Mineral exploration and development also are subject to a variety of permits and licences. Hunting, fishing, trapping, guide outfitting and water uses also are regulated and subject to a licence or permit system.

4.4a Proportion of timber allocated by province and form of long-term tenure, 1990

PROVINCE	FORM OF TENURE	TIMBER ALLOCATED %
British Columbia	Tree Farm Licences	25
	Forest Licences	56
Alberta	Forest Management Agreements	47
Saskatchewan	Forest Management Licence Agreements	93
Manitoba	Forest Management Licences	60
Ontario	Forest Management Agreements	70
Quebec	Timber Supply and Forest Management Agreements	100
New Brunswick	Crown Timber Licences	73
Nova Scotia	Licences and Management Agreements	86
Newfoundland	Leased and licenced land	65

Sources: Canadian Institute of Resources Law, Department of Alberta Environmental Protection

Forest lands are also subject to environmental protection legislation that applies regardless of ownership. For instance, water pollution and activities that may be harmful or destructive to fish habitat are prohibited under federal legislation (e.g., the Fisheries Act), as well as provincial statutes, and are subject to prosecution.

Existence of forest inventories (4.4.4)

Because forest resource management is largely a provincial and territorial responsibility, forest inventories in Canada have been developed in response to local or regional needs. Until fairly recently, a "forest inventory" was carried out to acquire information regarding area, condition, timber volume and tree species composition. Forest management agencies have since begun to broaden the scope of their inventories to encompass non-timber values, such as wildlife habitat and outdoor recreation. Inventory information is used for such purposes as planning, purchasing, evaluating, managing and harvesting.

Over the years, resource inventories have become more complete in their coverage, and most jurisdictions have programs for renewing inventories in areas under active forest management. The oldest resource inventories and the ones with the most data gaps tend to be those pertaining to remote areas. The extent of forest inventory coverage by data source class is shown in Figure 4.4b on page 72.

The national inventory compiles existing data from the inventory organizations of the provincial and territorial forest services, and aggregates it to the national level. Canada's Forest Inventory provides information on the distribution and structure of all of the major forested areas. Because it is a spatially referenced database, the national inventory can have other information overlaid on it for further analysis and to present forest characteristics in thematic maps. (The national inventory does not yield meaningful information on changes over time because much of the apparent change from previous inventories is due to improved coverage and procedures. Canada's forest inventories generally are not designed for monitoring forest conditions, but are usually one-time surveys.)

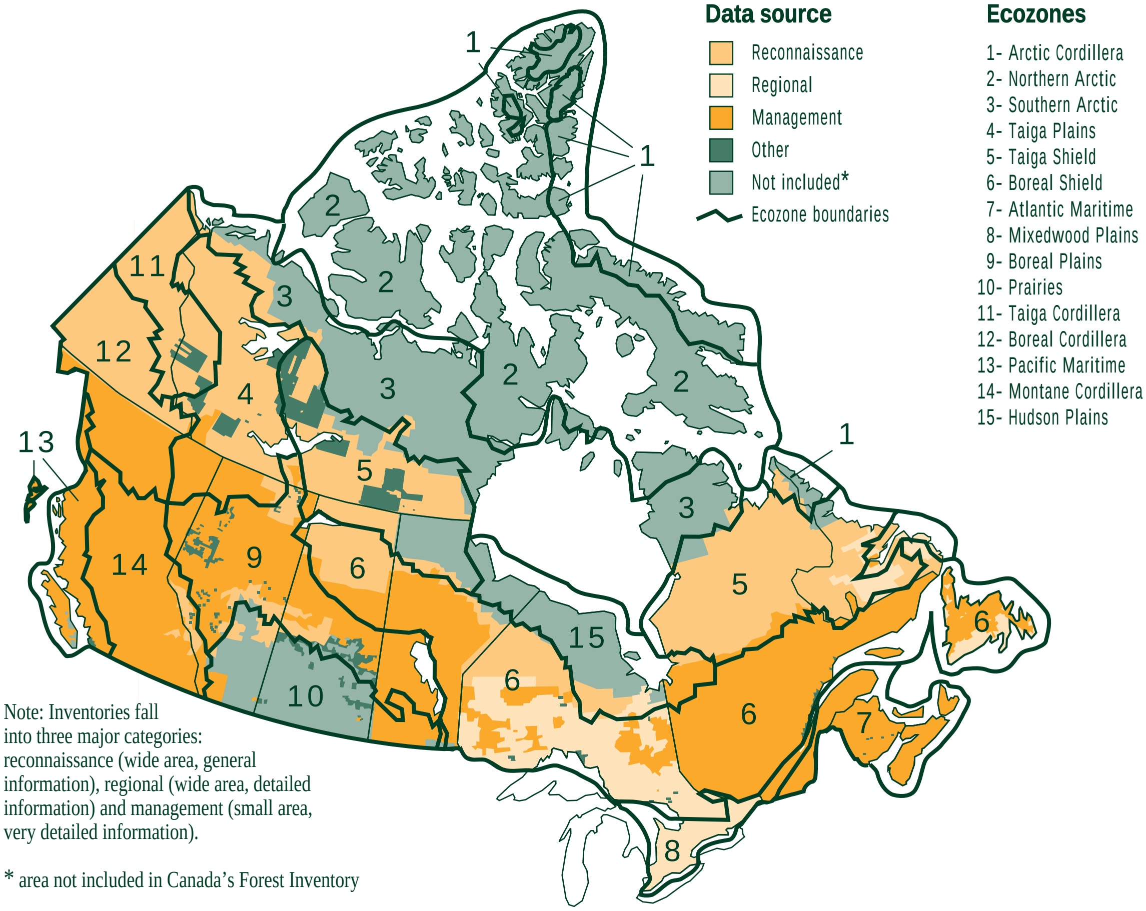
Statistics Canada collects time-series data on most economic indicators related to timber-based industrial activity. However, new data sets and monitoring systems will be required for most of the indicators related to cultural, social and spiritual needs and values, in terms of both resources and benefits. The Canadian Council of Forest Ministers (CCFM) has identified the information gaps and is developing an implementation plan to acquire the data needed to report on the full range of indicators of sustainable forest management. *Progress toward the establishment of multi-attribute forest inventories is described in Element 6.2 (Participation by Aboriginal communities in sustainable forest management) and Element 6.5 (Informed decision making).*

Participation in the climate change conventions (4.4.2)

Climate change is a key item on the international policy agenda. The important question for Canadians is how Canada, as a signatory to the United Nations (UN) Framework Convention on Climate Change, is responding to its commitments and obligations regarding greenhouse gas emissions.

As signatories to the Convention, Canada and other developed nations aim to stabilize the emissions of greenhouse gases (e.g., CO_2) at 1990 levels by 2000, thereby preventing the buildup of these gases from having a negative

4.4b Forest inventory coverage by data source



Note: Inventories fall into three major categories: reconnaissance (wide area, general information), regional (wide area, detailed information) and management (small area, very detailed information).

* area not included in Canada's Forest Inventory

Source: Natural Resources Canada–Canadian Forest Service

impact on climate. The intent of the Convention is to allow forests and other ecosystems to adapt naturally to climate change, while allowing economic development to proceed in a sustainable manner.

The Convention also encourages scientific research on climate change issues, through the UN Intergovernmental Panel on Climate Change. Forest scientists from Canada have participated in deliberations on biomass burning, the global carbon cycle, and the socioeconomic impacts of climate change on forestry. The Panel's 1995 assessment notes that the climate has changed in the past and will likely change in the future; it also points out, however, that a "discernable human influence" on global climate is evident. The next report is due in 2000.

In Canada, the federal, provincial and territorial governments have prepared the National Action Program on Climate Change (NAPCC). A key component of the NAPCC is to encourage voluntary action to offset and reduce greenhouse gas emissions through the national Voluntary Challenge and Registry Program. The Program, which was endorsed by energy and environment ministers at both levels of government in late 1994, encourages all sectors to explore cost-effective actions that may be taken to reduce greenhouse gas emissions. Major industry associations, individual corporations (including a number of forest companies) and municipalities are now participating in the Program.

As part of the NAPCC, the federal government is working with the provinces, territories and forest sector to assess the capacity of our forests to absorb and store carbon, the effects that climate change will have on this capacity, and the measures that the sector may take to mitigate and adapt to climate change. In addition, ways are being sought to preserve and enhance our forests' capacity to absorb and store carbon through recycling wood and paper waste, preventing the spread of wildfires, and planting trees in urban and rural communities and on marginal agricultural lands. Also, governments are working with the forest sector to reduce CO_2 emissions by improving energy-use efficiency within the sector and by developing the use of biomass as an alternative fuel.

Economic incentives for bioenergy use (4.4.3)

As mentioned above, the NAPCC includes measures to reduce greenhouse gas emissions by substituting bioenergy sources for fossil fuels. Currently, biomass provides approximately 7% of Canada's total energy use; almost all of that biomass originates from the forest. The forest sector itself uses the largest share of the bioenergy for space heating, steam and electricity, primarily in pulp and paper mills.

Most of the provincial and territorial governments offer programs that promote alternative energy sources, including forest biomass. The majority of these programs focus on information and public awareness, technology transfer, and the promotion of R & D. Approximately half the governments also offer financial incentives for the use of forest biomass.

The federal government allows companies to reduce their corporate income tax by claiming an accelerated capital cost allowance for investments in energy-producing equipment, providing that equipment is used in industrial processes fueled by renewable energy sources, including forest biomass. Also, the federal ENFOR (ENergy from the FORest) Program provides funding for R & D aimed at increasing the use of forest biomass as a source of bioenergy. Current work under the Program is focused on examining how to increase the supply of biomass for energy purposes, and determining how the increased production and removal of biomass will affect the environment. Other federal activities include technology transfer to increase biomass use, and the study of socioeconomic constraints to biomass use.

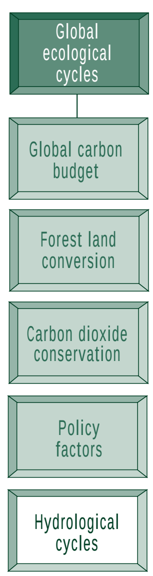
Summary

Although each level of government has its own responsibilities, there is a long tradition of cooperation between the federal and provincial/territorial governments in forestry matters. All provinces and territories have forest legislation governing the allocation of timber harvesting rights on all Crown lands and the requirements for forest planning and operations; private forests, too, are increasingly being regulated to ensure their sound management.

The CCFM has recognized that Canada's existing forest database systems should be broadened to include the additional information needed to manage forests for a full range of values. Most provinces and territories are examining the possibility of developing the new data sets and monitoring systems required for indicators related to non-timber values.

Over the past few years, Canada has strengthened its R & D on the impacts of climate change on forests; the role of forests in absorbing, releasing and storing atmospheric CO_2; and the technologies required to improve the use of forest biomass fuels as alternatives to fossil fuels. The federal government also funds R & D on forest bioenergy and provides tax incentives for greater industrial bioenergy use. In addition, most provincial and territorial governments have programs to encourage the use of forest biomass, although few of the programs provide economic incentives for bioenergy use.

ELEMENT 4.5
CONTRIBUTIONS TO HYDROLOGICAL CYCLES



What are we measuring?

Global ecological cycles are a series of processes that recycle the Earth's limited supply of water, carbon, nitrogen and other life-sustaining elements. The world's forests are critically dependent on these global processes, including the hydrological cycle, and make substantial contributions to them.

An estimate of the surface water in Canada is available from the *Canada Year Book*. *Canada's Forest Inventory 1991* also indicates the area covered by water, but only for forest lands—it does not include the prairie agricultural zone nor the areas north of the tree line, which both contain a considerable amount of surface water.

The numbers available from these two sources differ. Figures in the yearbook for the total area of surface water (60 million hectares) are lower than those in the inventory database (76 million hectares), despite the fact that the latter do not cover the entire country. The explanation for this discrepancy lies in the different methods that were used in compiling data for the yearbook and the inventory. The yearbook figures are derived from 1:250 000-scale maps; thus, they exclude rivers depicted as single lines and bodies of water measuring less than 6.25 hectares. Forest inventory data, however, are collected at scales of approximately 1:10 000 or 1:20 000, which allows the inclusion of a greater number of rivers, as well as bodies of water as small as 100–200 m^2.

This report outlines the estimated area of surface water in the various ecozones of Canada, based on *Canada's Forest Inventory 1991*.

How do hydrological cycles relate to the sustainability of Canada's forests?

Hydrological cycles are a vital component of ecological cycles. Forests require water to grow and remain healthy and vigorous, and in turn, they recycle some of the water to the atmosphere. Lakes and wetlands represent large reservoirs of fresh water within forested areas. In many cases, forests regulate the flow of water into these reservoirs, either directly or by influencing stream and river flows.

4.5a Surface area of fresh water by ecozone

ECOZONE	TOTAL AREA million hectares	FRESH WATER million hectares	FRESH WATER %
Arctic Cordillera	25.06	0.07	0.28
Northern Arctic	151.09	–	–
Southern Arctic	83.24	1.23	1.48
Taiga Plains	64.70	5.46	8.44
Taiga Shield	136.64	20.62	15.09
Boreal Shield	194.64	29.38	15.10
Atlantic Maritime	20.38	2.53	12.44
Mixedwood Plains	19.44	6.27	32.26
Boreal Plains	73.78	8.65	11.73
Prairies	47.81	0.84	1.75
Taiga Cordillera	26.48	0.23	0.88
Boreal Cordillera	46.46	0.97	2.09
Pacific Maritime	21.90	0.40	1.84
Montane Cordillera	49.21	1.49	3.03
Hudson Plains	36.24	0.68	1.86
CANADA	**997.06**	**78.83***	**7.91**

* table may not add due to rounding

Source: Canada's Forest Inventory

What data are available?

Surface area of water within forested areas (4.5.1)

Nearly 25% of the world's fresh water is found in Canada. Indeed, surface fresh water covers almost 8% of our total land area (Figure 4.5a).

Of the surface fresh water in Canada's forested area, approximately 83% is found in the Boreal and Taiga ecozones, combined. (Slightly more than half of Canada's forested area is located in these ecozones.) The least amount of surface water (1–3.5%) is in the Cordillera and Pacific Maritime ecozones.

Within the Boreal and Taiga ecozones, water covers 12.4% and 11.5%, respectively. This is not unexpected if one looks at the geology of these ecozones. The underlying bedrock is granite that has been heavily glaciated, causing many gouges in the hard rock and creating excellent places for water to collect.

Most of the ecozones—the majority of Canada, in fact—receive more precipitation annually than is lost by vegetation through evapotranspiration; and most of the forested area, especially in the Boreal Shield and Taiga Shield, registers at least twice as much annual precipitation as evapotranspiration. This indicates that the water supply is adequate to maintain the hydrological cycle of the forest.

Summary

Forests play an important role in the global hydrological cycle. One key component of this cycle is the storage of water in the form of lakes and other bodies of open water.

Canada is custodian of nearly a quarter of the world's fresh water. Lakes and other bodies of open water occupy some 79 million hectares—approximately 8% of of the nation's land area. Roughly 83% of the surface water area is contained within the Boreal Shield and Taiga Shield—the ecozones where more than half of Canada's forested area is located.

Canada's forest water balance is positive, with more precipitation falling annually in all of the ecozones than is lost through evapotranspiration.

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CRITERION 5.0

MULTIPLE BENEFITS OF FORESTS TO SOCIETY

INTRODUCTION

The first four criteria within the Criteria and Indicators (C & I) Framework are devoted to monitoring environmental processes and the impacts that human activities and natural disturbances have on those processes. Maintaining a flow of economic and other benefits also is an important dimension of sustainable development. The purpose of this criterion is to describe and, where possible, measure the economic and social benefits derived from Canada's forests. Criterion 5 also considers the capacity of the natural resource base and industrial base to continue to supply those benefits.

Forests provide us with a multitude of benefits. The production processes involved in the delivery of forest products contribute to the economy through the payment of wages, taxes, profits and other costs, such as stumpage fees. Non-timber and non-market benefits also are important.

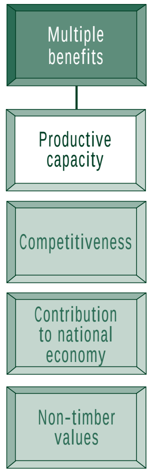
Forests are a finite resource. Therefore, choices must be made regarding how forests will be managed and utilized, how future consumption demands will be met, and which benefits (and in what proportion) will best satisfy the needs and desires of Canadians.

The mix of benefits provided by forests is determined by markets and governments. Canada has a high percentage of forest land under public ownership, and the flow of benefits from our forests reflects the commitment by governments to provide a broad range of public goods and services to current and future generations of Canadians.

Criterion 5 comprises four elements. The first element (Productive capacity) focuses on the capacity of the landbase to support a flow of both timber and non-timber benefits for current and future generations. The second element (Competitiveness of resource industries) considers the ability of the forest industries to maintain or expand the flow of economic benefits to the nation's economy. The next element (Contribution to the national economy) identifies the array of goods and services that forests provide and measures their contribution to our economy. Lastly, the fourth element (Non-timber values) considers goods, such as outdoor recreation, and the importance that Canadians place on some of the environmental values of forests, such as biodiversity, wilderness preservation and species preservation.

ELEMENT 5.1

PRODUCTIVE CAPACITY



What are we measuring?

Productive capacity is a measure of the ability of the forest landbase to provide a flow of benefits to society. It applies to both timber and non-timber resources and is a key factor in assessing our progress toward sustainable development.

Productive capacity can be measured by evaluating the magnitude and impact of harvesting, land-use changes and natural disturbances on the resource, versus the ability of the resource to sustain itself through a combination of natural processes (e.g., regeneration and growth) and management activities (e.g., silviculture and protection). Some information is available on changes in the commercial forest landbase, harvest rates for timber and wildlife, wildlife population levels and habitat availability, and forest management and development expenditures. All of this information provides some perspective regarding the productive capacity of the forest.

How does productive capacity relate to the sustainability of Canada's forests?

Forests and wildlife are renewable resources and generally are managed on a sustainable basis to maximize the productive capacity of the resource, protect conservation values, and maintain a perpetual flow of benefits. By measuring the productive capacity of the landbase, we can monitor the state of the forest and trace the effects of human intervention, while evaluating the forest's ability to provide society with a continuous stream of benefits.

What data are available?

Distribution of, and changes in, the landbase available for timber production (5.1.2)

Most of Canada's forest land is under public ownership (provincial, 71%; federal and territorial, 23%). Of the 417.6 million hectares of forests, 57% are considered "commercial"—capable of producing a range of both timber and non-timber benefits. However, only half of those forests are currently accessible and managed for timber production.

The provincial and territorial governments, which manage most (88%) of the commercial forest land, have enacted a range of policies and regulations to restrict the sale of forest land and its conversion to other uses. For example, Manitoba does not permit the sale of its designated public forest land—public lands with forest cover can only be sold if they are designated for agricultural purposes. In British Columbia, the 1994 Forest Land Reserve Act restricts the removal of designated land from forest production. In Alberta, the Green Area policy (established in 1948) states that public forest land will be managed primarily for forest production, watershed protection, recreation and other multiple uses.

In other provinces, privatization of public forest land is strictly controlled. For example, in Saskatchewan, disposal of public land requires an amendment to the Forest Act. In Ontario, the Public Lands Act enables the Ministry of Natural Resources to prohibit, regulate and control the sale of public land.

The amount of public forest land that is sold to private owners and subsequently converted to alternate uses (e.g., farmland) is minimal. The level of deforestation on public land from flooding, mining or the establishment of pipelines or right-of-ways also appears to be limited.

One factor affecting the availability of forest land for commercial harvesting is the steady and continuing increase in the amount of public forest land protected for other uses, such as parks, wilderness areas and reserves. Within areas that have not been protected as parks, governments have established policies and guidelines to regulate and control commercial timber harvests, thereby reducing the amount of public forest land available for that purpose. For example, logging is prohibited or restricted on buffer strips along waterways and on steep slopes. In many regions across Canada, forest cover must also be maintained for scenic values and wildlife habitat. In some areas, this has increased the flow of non-timber products and enhanced wilderness benefits. The combined effect of these policies has been, and will continue to be, some local reductions in the amount of public forest land available for timber production.

Annual removal of forest products relative to the volume of removals determined to be sustainable (5.1.1)

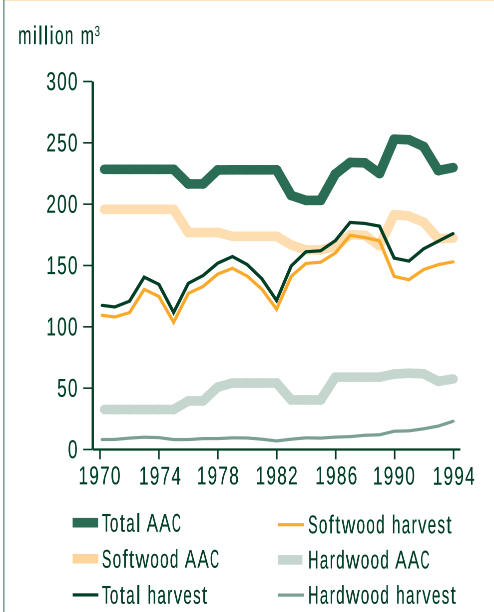
A wide variety of products are extracted from the forest annually, including timber, firewood and fuelwood, pelts, game, food (e.g., mushrooms and berries), and a range of botanical medicines and craft materials. At the national level, limited information is available on the harvest of these products.

The harvest rate for timber on provincial and territorial Crown lands is determined by annual allowable cuts (AACs), which dictate the maximum volume of timber that can be harvested annually from an area over a period of time. AACs do not include timber in parks, wilderness areas or other types of reserves.

The national AAC is arrived at by adding the total provincial and territorial AACs to the estimated harvest potential of federal and private lands. Over the past 20 years, Canada's AAC has remained relatively stable; however, it may decline in the coming years, due to such factors as fewer clearcuts and wider buffer strips. Furthermore, provinces regularly review their AACs, and since 1994, some have reduced them in certain regions to accommodate other land-use requirements, such as protected areas, wildlife habitat and Aboriginal land claims. In other regions, improved inventory information (e.g., growth and yield data) has enabled the provinces to increase local AACs.

Figure 5.1a shows that between 1970 and 1994, the national harvest of softwoods

5.1a AACs and harvests



Source: Natural Resources Canada–Canadian Forest Service

5.1b Number and value of pelts by species

SPECIES	1990–1991		1991–1992		1992–1993		1993–1994		1994–1995	
	Number	$ value	Number	$ value	Number	$ value	Number	$ value	Number	$ value
Badger	574	10 437	933	11 599	686	11 667	758	18 710	863	21 523
Bear	–	–	–	–	2 827	300 646	–	–	–	–
Black/brown bear	1 370	103 342	2 544	712 843	–	–	2 507	180 771	2 991	199 342
Grizzly bear	306	214 200	–	–	–	–	–	–	6	6 008
White bear	267	426 026	–	–	–	–	117	100 016	115	98 035
Beaver	167 519	2 207 143	219 737	3 651 009	85 965	2 776 341	244 561	7 335 439	326 550	8 908 501
Coyote/prairie wolf	24 324	443 445	43 682	1 507 453	48 696	1 890 970	48 752	1 937 164	51 059	1 328 219
Ermine (weasel)	18 675	65 344	30 388	104 862	23 442	106 904	28 460	149 955	51 804	201 981
Fisher	8 791	433 295	15 381	783 000	13 377	412 577	13 105	513 041	14 675	584 406
Blue fox	76	551	–	–	49 427	895 442	–	–	–	–
Cross/red fox	28 502	372 951	–	–	–	–	136	3 395	9 052	233 086
Silver/black fox	491	5 622	–	–	–	–	41 577	956 085	44 255	1 176 058
White fox	1 023	11 455	–	–	–	–	9 884	203 545	2 380	63 947
Lynx	7 579	572 325	11 542	999 170	7 180	511 333	4 713	487 855	4 875	419 235
Marten	157 733	7 979 946	184 222	10 371 796	117 879	4 463 088	109 356	6 067 000	139 552	6 450 572
Mink	41 037	1 052 597	46 512	1 634 104	33 618	802 629	34 450	926 048	39 318	760 548
Muskrat	195 659	321 496	204 112	444 297	218 890	436 133	326 353	875 134	401 372	1 010 933
Otter	8 489	245 647	12 026	601 486	12 575	727 348	15 383	1 500 216	21 132	1 663 749
Raccoon	12 499	75 516	23 493	246 055	26 927	291 093	56 390	957 690	122 660	1 884 386
Skunk	101	306	–	–	–	–	273	1 215	574	1 998
Squirrel	40 530	33 956	95 974	129 709	68 555	113 586	117 107	157 508	103 060	132 655
Wildcat	582	27 894	448	20 873	628	25 756	727	50 402	1 221	74 355
Wolf	2 566	502 267	3 155	559 816	3 770	593 329	3 721	573 024	3 372	387 106
Wolverine	414	78 040	686	147 696	637	106 485	485	85 500	559	105 667
Other	21	26	231	561	1 395	20 446	88	232	–	–
TOTAL	**719 128**	**15 183 827**	**951 876**	**22 919 937**	**816 474**	**14 485 773**	**1 060 662**	**23 115 771**	**1 344 263**	**25 781 387**

Source: Statistics Canada

and hardwoods (176.0 million m^3 in 1994) was consistently below the national AAC (229.8 million m^3 in 1994). The annual harvest of softwoods has increased since 1970, and by 1994, the harvest was close to—but still below—the national AAC. Some local shortages have been reported, however. The hardwood harvest, on the other hand, could be expanded in most areas.

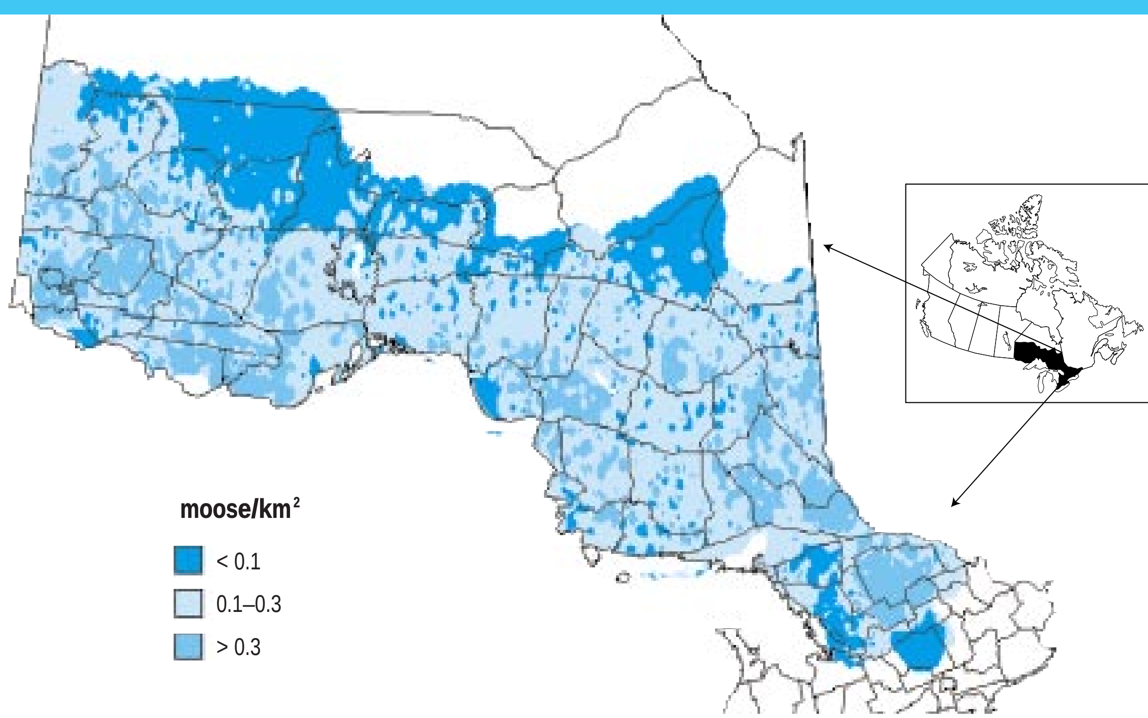
The productive capacity of important game and fur-bearing species is more difficult to measure at the national level. Statistics Canada collects data on the number of animal pelts sold by species (Figure 5.1b); however, information on annual quotas and harvest rates has never been sought from the provinces and territories. The current harvest of species that favour young forests (e.g., moose and deer) is sustainable, but there is concern regarding species that require large tracts of mature and overmature forests (e.g., grizzly bear and woodland caribou).

Animal population trends for selected species of economic importance (5.1.3)

The forest provides habitat for many species of birds, mammals, reptiles, amphibians and insects. Currently, there is no systematic method in place to track populations of commercially important wildlife species across Canada. However, some species are monitored by the provinces because of their importance for recreational hunting, trapping or subsistence use.

Since the 1970s, the Ontario Ministry of Natural Resources (OMNR) has been conducting aerial surveys in the winter to gauge moose populations throughout the north-central

5.1c Moose density estimates in the southern half of Ontario, 1990–1995



Source: McKenney, Rempell & Wong

portion of the province. In a collaborative effort between the OMNR and Natural Resources Canada–Canadian Forest Service, researchers in Sault Ste. Marie are using historical data to conduct spatial analysis to determine trends in moose population densities. The results are mapped using a Geographic Information System.

Figure 5.1c shows the moose population density (number of animals per km^2) for 1990–1995. Moose densities have increased substantially in parts of the province, particularly in the Algonquin Park area of southern Ontario and in northwestern Ontario.

Figure 5.1d shows the changes over time in moose population densities. Between 1975 and 1995, the portion of Ontario that was characterized by high-density populations increased from 3% to 21%.

This research provides valuable baseline information on population levels that is “spatially explicit,” and is helping to identify and quantify the key factors that affect moose population levels. Because fiscal constraints are making it difficult to undertake the same number of population surveys as in the past, results of the research are also being used to examine the implications of reducing the number of aerial surveys.

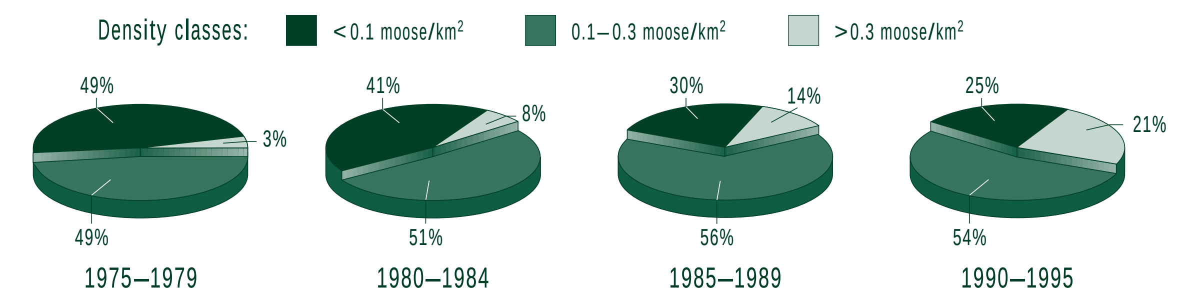
Figure 5.1e estimates the population levels of large forest-dwelling mammals. Populations of most ungulates, such as deer and elk, are stable or increasing. Barren ground caribou populations are not at risk; however, the Committee on the Status of Endangered Wildlife in Canada has listed the western population of the woodland caribou as “vulnerable” and the Gaspé population as “threatened.” Black bear populations are stable or increasing, while grizzly bear numbers appear to be stable or declining.

Availability of habitat for selected wildlife species of economic importance (5.1.5)

Human activity and natural factors can both significantly impact wildlife populations and habitat availability, and often it is difficult to separate their effects. For example, the mix of habitats in an area can be modified by such activities as high-impact, intensive logging or clearing forest land for agriculture or hydro right-of-ways. This may result in changes in the mix of species or in the population levels of individual species.

Wildlife populations are also sensitive to many natural stress factors, such as contagious diseases, predators, long and severe winters,

5.1d Moose populations by density class, 1975–1995



Source: Natural Resources Canada–Canadian Forest Service

5.1e Population estimates and trends for large forest-dwelling mammals by life zone, 1991

LIFE ZONE	MAMMAL SPECIES	POPULATION ESTIMATE	POPULATION TREND
Pacific/mountain	grizzly bear	16 000	stable/decreasing
	black bear	73 000–122 000	stable/increasing
	mule deer	135 000	increasing
	elk	35 000	increasing
	sheep[a]	17 000	stable/increasing
	woodland caribou[b]	13 500	stable
	barren ground caribou (porcupine herd)	178 000	increasing
Boreal	grizzly bear	4 000	stable/decreasing
	black bear	207 000–217 000	stable/increasing

[a] includes Rocky Mountain bighorn sheep, California bighorn sheep, Dall's sheep and Stone's sheep
[b] a regional population of 2 500 mountain caribou (a subspecies of woodland caribou) in the Pacific/Mountain life zone is being threatened by economic development

Source: State of the Environment Report, 1991

drought, and competition for food and cover. A national scientific assessment of habitat status for major forest-dwelling game and fur-bearing species would complement research and information on population status.

Management and development expenditures (5.1.4)

Management and development expenditures have the potential to increase the productive capacity of the landbase. Data for silviculture, resource access (e.g., road construction), protection and general stewardship (e.g., inventory development, research, timber management, integrated resource management and public information) are available at the national level through the National Forestry Database Program (NFDP). Trend data for wildlife management, recreation management, parks programs and costs of protected areas either are not available or are aggregated with general stewardship data. The NFDP could be expanded to include this information.

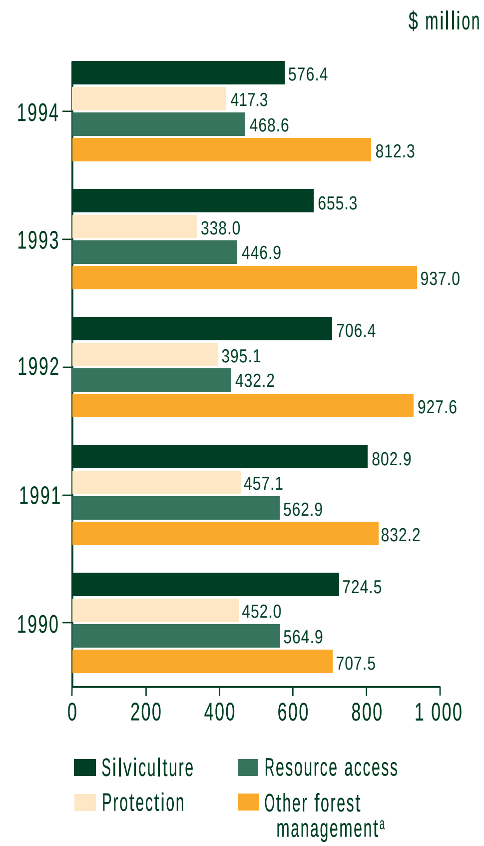
Figure 5.1f shows the trends in forest management spending by governments and industry over the period 1990–1994. Expenditures on silviculture, protection and resource access decreased, while those for other management activities (e.g., research and timber management) increased slightly. These trends may reflect the shift toward ecosystem-based management regimes, which are information intensive and emphasize natural regeneration of harvested lands, rather than costly planting and seeding.

Summary

Measuring productive capacity and comparing those measures to levels of utilization is one way to determine if our forest and wildlife management practices are biologically sustainable.

At the national level, timber harvesting remains within the limits of sustainability. The annual harvest of softwoods and hardwoods has consistently been below the national AAC.

5.1f Forest management expenditures by activity



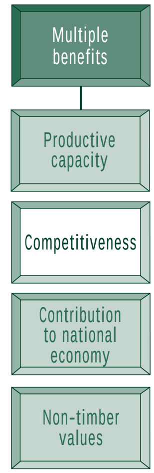
[a] includes research, timber management, administration and other activities

Sources: Canadian Pulp & Paper Association, Natural Resources Canada–Canadian Forest Service, National Forestry Database

Similarly, hunting and trapping are closely regulated to ensure that local wildlife populations do not decline to unsustainable levels. However, to improve our ability to monitor the status of wildlife species, more information is required regarding the types of wildlife, their population levels, location and habitat needs.

ELEMENT 5.2

COMPETITIVENESS OF RESOURCE INDUSTRIES



What are we measuring?

Competitiveness is a measure of the ability of an industry to efficiently combine inputs (e.g., labour, capital and raw material) in producing and selling goods and services. Competitiveness is also influenced by institutional, social, cultural and regulatory regimes. For example, tax laws, trade policies, social policies (e.g., manpower training, education and health) and environmental regulations all have an impact on the competitiveness and performance of industries.

The competitiveness of Canada's forest sector can be assessed by providing information on changes over time in profitability. The industries' ability to compete with foreign suppliers in the global marketplace will be measured by examining trend data on Canada's share of trade in various forest commodities. Technological change and investment in industry-oriented research and development (R & D) also are important for remaining competitive, and expenditures in this area will be assessed as well.

How does competitiveness relate to the sustainability of Canada's forests?

Measures of competitiveness are an important element of sustainability for two basic reasons. First, the ability of forest industries to continue to provide jobs and incomes and pay corporate taxes to governments is dependent on their ability to continue to access foreign markets, earn profits, and attract new investment. Secondly, the relative efficiency and competitiveness of firms determines their ability to absorb the higher costs that may be associated with more environmentally sensitive resource development and industrial production.

What data are available?

Net profitability (5.2.1)

Monitoring the profitability of the forest sector enables us to assess the structural changes that may be taking place. Canadian firms compete with foreign firms in export markets. In some cases, new low-cost producers may enter traditional markets and reduce prices. However, declining profitability in a particular sub-sector should not automatically be equated with unsustainability. The decline may simply be a symptom of structural changes occurring in the marketplace.

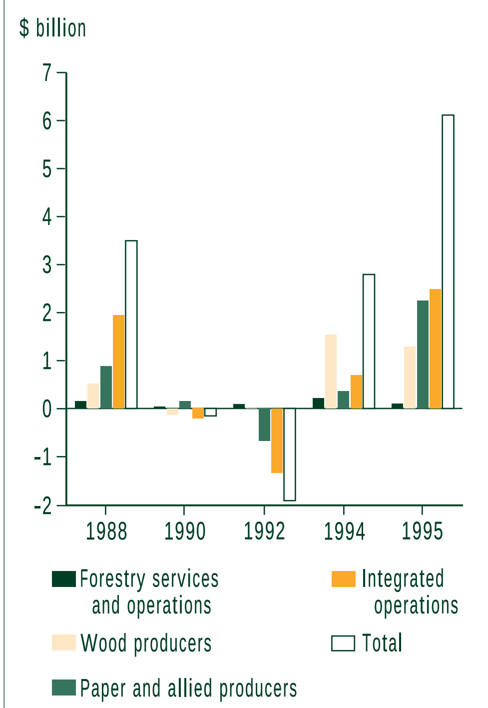
Figure 5.2a shows the profit performance of Canada's forest sector from 1988 to 1995. The graph demonstrates the high levels of profit variability that may be experienced over short periods of time. Canada's forest industries are traditionally cyclical. Reduced profits and financial losses are normal in the forest sector during the down portion of business cycles, as experienced in the early 1990s. Profits rose again in 1995.

Trends in global market share (5.2.2)

Canada is the world's major forest products exporter, accounting for almost 20% of the total value of global forest products trade. Our export success stems from the consistently high quality of our products, delivered at competitive prices.

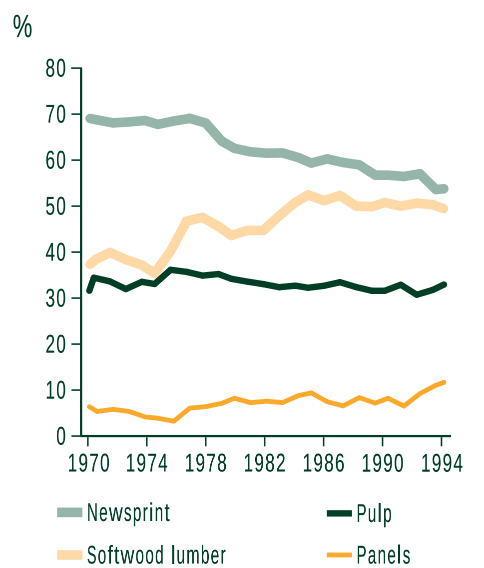
Figure 5.2b shows Canada's share of world exports for various forest products. Canada accounts

5.2a Profits in Canada's forest sector



Source: Statistics Canada

5.2b Canada's share of global trade in forest products



Source: Food & Agriculture Organization

for almost 50% of global trade in softwood lumber. The majority of our exports are destined for the U.S. market, although the Japanese market is becoming increasingly important.

Our share of sales in panel products rose from 6% in 1970, to 12% in 1994. This trend can be attributed to the increasing acceptance of new products manufactured from chips and other wood residues.

Canada's share of the global pulp market remained at roughly 33% between 1970 and 1994. Traditionally, our advantage in this market was attributed to the high quality of our bleached kraft softwood pulp. However, recent technological advances have increased the quality of hardwood pulp and have enabled countries without coniferous species to enter the global pulp market. Nevertheless, the introduction of other new technologies, such as chemi-thermo-mechanical pulp, has enabled Canada to keep its global market share relatively constant over the past 25 years.

Canada's share of newsprint trade declined from 69% in 1970, to 54% in 1994. The majority of our newsprint exports are destined for the USA; however, our share of that market has declined steadily since 1966, mostly because our mills are older and smaller than those of our competitors. Recently, a few state-of-the-art mills have been built, particularly in western Canada, and some older mills have upgraded their paper machines to increase their production levels and expand their product line to include more value-added papers.

Trends in R & D expenditures in forest products and processing technologies (5.2.3)

The ability of forest products producers to compete in domestic and international markets is determined by their ability to minimize production costs and develop value-added products for specialty markets. Technological progress is important for achieving both of these objectives.

Trends in R & D expenditures provide a useful preliminary indication of the ability of firms to innovate and thus maintain their competitiveness. Several studies on the expected net social benefits of R & D in the forest sector indicate that increased investment is desirable and that private returns are high enough for firms to increase their R & D investments, even in the absence of government incentives.

Historically, research efforts in the forest sector focused on developing the knowledge and technology required to produce a quality product while minimizing production costs. Recently, the emphasis has changed. The sector is continuing its research into efficient processing, but is now focusing its efforts on new and value-added products and on environmental protection activities. It is also responding to changing consumer preferences and placing a higher emphasis on research into more environmentally benign products, as well as products made from recycled materials.

Figures 5.2c and 5.2d provide information on industry-oriented R & D expenditures by performers and funders, respectively. Data from Canada's three principal industrial forest research institutes are included in the figures. FERIC, Forintek and PAPRICAN conduct R & D in forest engineering, forest product development, and pulp and paper technology, respectively. *Resource-oriented R & D expenditures will be discussed in Indicator 6.5.2 (Investments in forest-based R & D and information).*

5.2c Performers of industrial intramural forestry R & D

PERFORMER	1988	1989	1990	1991	1992	1993	1994[a]	1995[b]
	$ million							
Logging industry and forestry services	7	8	8	11	8	9	9	9
Wood industries	20	18	42	19	20	23	24	24
Paper and allied industries	145	151	115	98	94	102	102	110
TOTAL	**172**	**177**	**165**	**128**	**122**	**134**	**135**	**143**

[a] preliminary
[b] projections

Note: Also includes the following research institutes: FERIC, Forintek and PAPRICAN.
Sources: Statistics Canada, Natural Resources Canada–Canadian Forest Service

The definition of what constitutes R & D spending varies from country to country. Furthermore, spending levels may not fully reflect the technological advancement of a country, as firms may choose to purchase new technology through licencing arrangements or obtain it from parent firms in other countries, rather than develop it on their own through R & D.

Summary

Canada has a proven track record in producing and delivering high-quality products at a competitive price. However, our overall dominant position in the global marketplace has diminished somewhat in recent years. The profit performance of Canada's forest products sector has been affected by low product prices and increasing production costs. To maintain our export position and compete in the growing Pacific Rim market, Canadian producers may be required to develop niche markets in higher value-added commodity grades.

Canada's forest industries must continue to innovate to remain competitive. Examination of trends in R & D investment suggests that expenditures are not keeping pace with growth in the sector and that more technological innovation is required.

5.2d Funders of three industrial forest research institutes

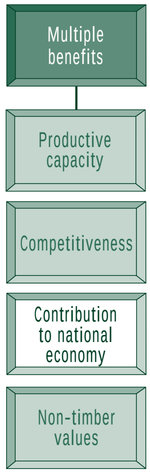
FUNDER	FERIC		FORINTEK		PAPRICAN		TOTAL	
	1993	1994	1993	1994	1993	1994	1993	1994
	$ million							
Industry	2.6	2.7	3.9	4.0	26.5	27.0	33.0	33.7
Federal govt.	2.2	2.1	6.6	6.3	3.4	2.5	12.2	10.9
Provincial govt.	0.7	0.7	4.1	4.2	–	–	4.8	4.9
Others[a]	2.2	1.9	–	–	2.6	2.8	4.8	4.7
TOTAL	**7.7**	**7.4**	**14.6**	**14.5**	**32.5**	**32.3**	**54.8**	**54.2**

[a] includes resources that could not be allocated by funders

Sources: Statistics Canada, Natural Resources Canada–Canadian Forest Service

ELEMENT 5.3

CONTRIBUTION TO THE NATIONAL ECONOMY



What are we measuring?

A wide range of goods are manufactured from forest resources, creating opportunities for the establishment of industrial enterprises. In addition to the traditional forest products industries, the forest landbase supports a number of smaller industries, including outfitters, maple products producers and Christmas tree growers, as well as the increasing number of industries that cater to tourists.

The combination of all salaries, wages, profits, taxes and royalties for the sale of natural resources represents the contribution of the forest sector to the national Gross Domestic Product (GDP). A complete picture of the contribution of the forest landbase to Canada's economy also includes the many products, such as firewood and subsistence food and craft materials, that are obtained directly from the forest without money being exchanged.

How does the forest sector's contribution to the national economy relate to the sustainability of Canada's forests?

An important dimension of sustainable development is the performance of various industry sectors in creating jobs, generating personal incomes and corporate profits, and contributing to the national income through the GDP. The forest sector also provides a stable economic base for rural communities, which is consistent with the principles of sustainable development.

In rural areas, the production and sale of goods and services derived from forests creates jobs and incomes for many residents for whom alternative economic activities may be limited. In small, resource-dependent economies where other employment opportunities are rare, mill closures can lead to high and sustained levels of unemployment, with significant potential for social disruptions to workers, their families and other members of the community.

What data are available?

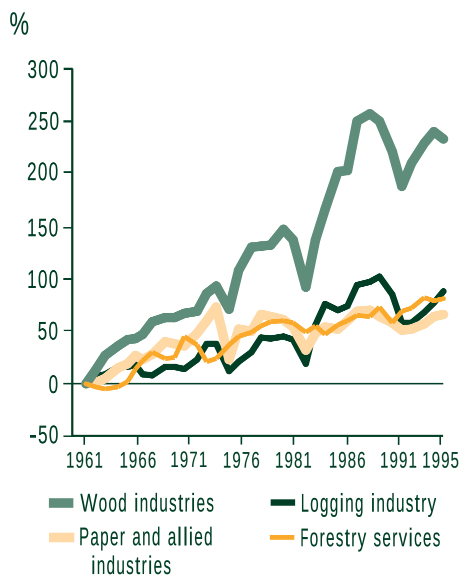
Contribution of timber and non-timber sectors to the gross domestic product (GDP) (5.3.1)

Canada's forest sector makes a significant contribution ($20.38 billion in 1995) to the national GDP ($776 billion in 1995). In 1995, the pulp and allied industries made the largest contribution to the national income—$9.86 billion. Wood industries contributed $6.37 billion; the logging industry, $3.65 billion; and forestry services, $500 million.

Figure 5.3a shows the trends in the forest sector GDP since 1961. The contribution of the paper and allied industries increased by approximately 66% between 1961 and 1994, while the contribution of the wood industries showed much more significant gains—a 233% increase.

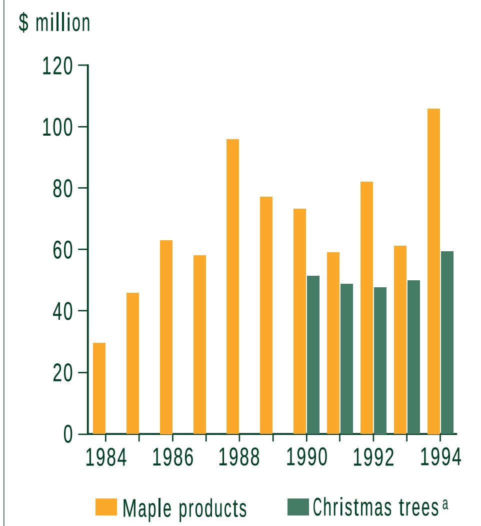
Figure 5.3b shows that after peak sales of almost $100 million in 1988, the wholesale value of maple products declined overall until

5.3a Changes in the forest sector's real GDP



Source: Statistics Canada

5.3b Wholesale value of maple products and Christmas trees



[a] data not available before 1990

Sources: National Forestry Database, Statistics Canada

1993, but improved dramatically in 1994—to $106 million. The Christmas tree industry averaged $52 million in sales between 1990 and 1994.

Figure 5.3c reveals that revenues of private campgrounds, outfitting operations, and recreation and vacation camps increased steadily between 1986 and 1993.

Total employment in all forest-related sectors (5.3.2)

Figure 5.3d shows that between 1975 and 1995, total direct employment in the forest products industries was fairly constant overall, at approximately 340 000. (Employment numbers for non-timber industries are not available.) Between 1992 and 1995, however, employment

5.3c Establishments and revenues for campgrounds, outfitting operations and camps

YEAR	CAMPGROUNDS AND TRAVEL TRAILER PARKS		OUTFITTING OPERATIONS AND OTHER RECREATION AND VACATION CAMPS	
	Number of establishments	Total revenue $ million	Number of establishments	Total revenue $ million
1986	2 003	229.9	1 439	232.0
1987	2 198	256.3	1 337	277.6
1988	2 387	279.1	1 618	299.9
1989	2 405	291.4	1 764	329.8
1990	2 454	310.1	1 826	347.1
1991	2 478	316.3	1 862	339.7
1992	2 514	325.3	1 847	331.3
1993	2 507	340.4	1 826	346.2

Source: Statistics Canada

actually increased by more than 59 000. Logging and wood industries (particularly sawmills, oriented strand board [OSB] mills and particle-board mills) accounted for most of this increase.

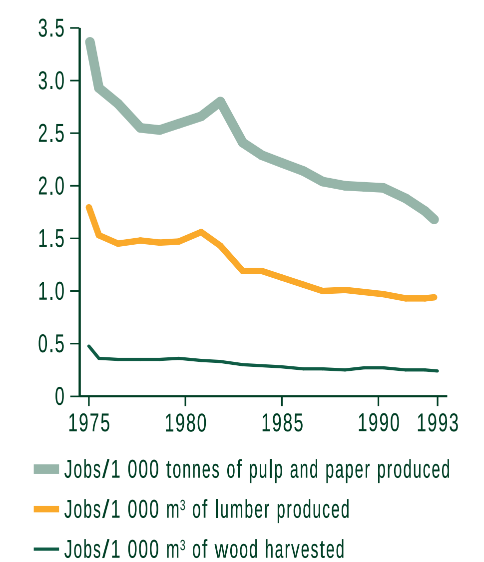
A wide range of labour-saving technologies were adopted by the forest industries between 1975 and 1995. The new technologies have reduced the number of jobs required per unit of production for certain products, particularly in the pulp and paper sector (Figure 5.3e), and have enabled the forest sector to increase its output and remain competitive.

All of these factors have led to increased wages in the forest sector, where salary increments have now exceeded those in the manufacturing sector (Figure 5.3f). In 1993, the average annual income of workers in the paper and allied industries was $45 327. Employees in the logging and wood industries earned $40 645 and $33 694, respectively, while the average income of employees in the manufacturing industries was $35 800.

5.3d Direct employment in Canada's forest sector

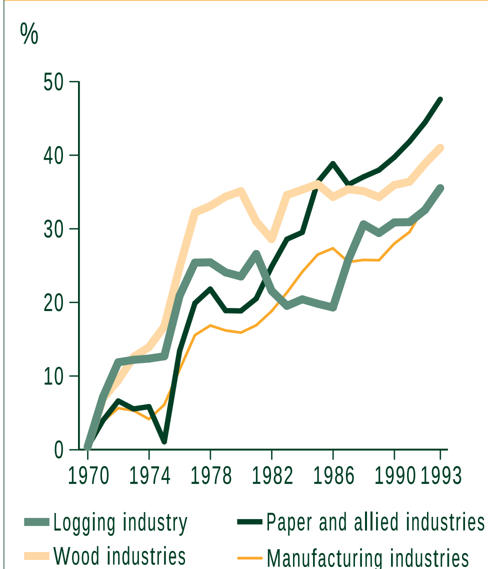
Source: Statistics Canada

5.3e Jobs per unit of production



Sources: Canadian Pulp & Paper Association, Statistics Canada, Natural Resources Canada–Canadian Forest Service

5.3f Changes in real wages



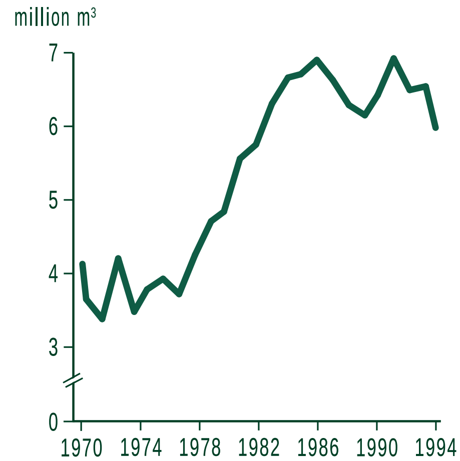
Source: Statistics Canada

Utilization of forests for non-market goods and services, including forest land use for subsistence purposes (5.3.3)

Non-market consumptive forest uses range from subsistence hunting to berry picking. One such use for which data are available at the national level is the harvesting of trees for firewood and fuelwood. (It should be noted, however, that a significant volume of these goods are in fact traded on the market.) Figure 5.3g shows the long-term trend in this activity.

According to Statistics Canada, in 1995, wood was the principal heating fuel in 3.8% of Canada's 11 million households, down from 4.5% in 1990. The use of wood for this purpose tends to be concentrated in small remote areas, Aboriginal communities and isolated cottage areas. Also, there are significant regional differences in the percentage of households using wood as a fuel source (Newfoundland, 16%; Prince Edward Island, 10%; British Columbia, 3.4%; and Alberta, 0.4%). On a global scale, the use of wood for cooking and heating accounts for approximately 55% of all wood harvested.

5.3g Harvest of firewood and fuelwood



Source: Natural Resources Canada–Canadian Forest Service

Data on other non-market consumptive forest uses in Canada are not available at the national level and are only sporadically available at local levels. For this reason, a case study of

Case study: Subsistence use of wildlife and fisheries resources by native bands in Manitoba

In 1985, a survey was conducted on the subsistence use of wildlife resources by 26 of Manitoba's 60 native bands. A total of 17 100 individuals (20% of Manitoba's native population) were polled.

Figure 5.3h shows the number of species harvested per capita and the amount of fish and meat consumed. Based on these results, the subsistence use of fish and wildlife by Manitoba's native population was estimated to be in the order of 2.5 million kilograms in 1985.

5.3h Subsistence use of wildlife by 26 native bands in Manitoba, 1985

SPECIES	NUMBER HARVESTED PER CAPITA	kg CONSUMED PER CAPITA
Moose	0.08	8.40
Elk	0.00	0.27
Deer	0.11	2.00
Caribou	0.01	0.20
Bear	0.01	0.30
Lynx	0.01	0.03
Fish	–	12.62
Waterfowl	2.93	1.61
Grouse/ptarmigan	0.19	0.06
Beaver	0.55	3.49
Muskrat	4.48	1.04
Hare	0.59	0.29
TOTAL	**–**	**30.06**

Source: Wagner

the subsistence benefits of forests for Manitoba's native community is provided above.

Economic value of non-market goods and services (5.3.4)

Products obtained by subsistence hunting and gathering activities are not sold in the traditional market economy, and national data are not readily available on their economic value and contribution to local economies. The products are, however, of considerable value to the individuals who collect them.

The purpose of this indicator is to examine the inherent economic value of non-market consumptive forest goods by determining the replacement value of those goods—the cost to an individual of purchasing similar goods from a retail outlet. Because national information is not available, a case study is presented below to demonstrate the value of non-market consumptive

Case study: Economic value of subsistence forest products for residents of the Lower Liard Valley

In 1993–1994, the Canadian Forest Service and the University of Alberta conducted a comprehensive study of subsistence forest use in two communities in the Lower Liard Valley: Fort Liard and Nahanni Butte. The study provided a detailed assessment of the relationship of residents with their surrounding environment and included an analysis of the replacement value of subsistence products. The study authors caution, however, that there are limitations to using replacement values that assume consumers are indifferent regarding the choice of using their time to hunt and fish or to work in the wage economy and purchase food. By ignoring the integral value of hunting and fishing to the spiritual and cultural fabric of Aboriginal societies, this assumption may underestimate the inherent value of subsistence products.

Figure 5.3i provides a summary of the study results. Meat products dominate the range of subsistence forest products, and non-animal products (e.g., firewood, berries and birchbark crafts) comprise the second most important category.

5.3i Total replacement value of selected subsistence forest products for residents of the Lower Liard Valley, 1993–1994

PRODUCT	FORT LIARD $	NAHANNI BUTTE $
Meat	366 380	101 821
Furs	106 133	14 858
Non-animal products	252 096	69 670
Moosehide crafts	40 000	5 000
Total for households sampled[a]	764 609	191 349
Estimated total for all households	1 470 402	265 763
Average per household	10 892	10 630

[a] of the 135 households in Fort Liard, 71 were surveyed; in Nahanni Butte, 18 of 25 households were surveyed

Source: Beckley & Hirsch

goods to the residents of two communities in the Lower Liard Valley.

Summary

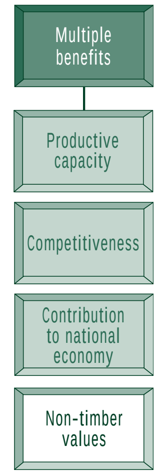
The contribution of Canada's traditional forest industries (e.g., paper and allied industries and wood industries) to the GDP has increased since 1961. Between 1986 and 1993, the revenues of campgrounds, outfitting operations, and recreation and vacation camps also increased steadily. In addition, the sale of maple products increased dramatically in 1994 (after declining from 1988 to 1993), while that of Christmas trees has remained stable in recent years.

Direct employment in the forest industries has increased since 1992, reaching 369 000 in 1995, with an average of 340 000 since 1975. Historically, the forest sector has provided well-paying jobs. The number and type of positions, however, has been affected by the adoption of new labour-saving technologies, which have enabled the forest sector to increase its production levels.

No national data exist on the utilization of forests for non-market goods and subsistence purposes, although case studies may be used to provide information on a particular community or region.

ELEMENT 5.4

NON-TIMBER VALUES



What are we measuring?

Our forests provide a number of non-timber values that are difficult to measure because of the absence of information regarding their cost and use. This general lack of information on the social benefits of non-timber values is a challenge for policy-makers, planners and foresters, who must make difficult choices regarding the mix of benefits to provide.

Describing the range of non-timber benefits provided by forests is a multi-dimensional problem. Indicators must, therefore, be selected that incorporate not only the importance of the forest values (worth per individual), but also the intensity of utilization (total participation levels).

For non-timber values that involve forest use, proxies such as visits to national parks and trends in expenditures provide a partial indication of preferences. One of the most comprehensive databases on Canadians' expenditure and activity patterns for outdoor recreation is the National Survey on the Importance of Wildlife to Canadians, conducted by Environment Canada and Statistics Canada.

People also place importance on forests even though they may never actually visit or use them. They just want to know that forests continue to exist and will be available for future generations. These values fall into a class termed "non-use" or "passive-use" values. The proxies used to measure these values are trends in the total area of natural landscape protected from economic development, as well as memberships in and donations to conservation and outdoor organizations.

How do non-timber values relate to the sustainability of Canada's forests?

Canada's forests provide a number of non-timber benefits, including considerable opportunities for outdoor recreation. As the world population grows, demand for outdoor experiences in natural settings is expected to increase. This demand will be further affected by increases in per capita income. Therefore, indicators of the value of forest recreation and the level of participation are important aspects of reporting on sustainable development.

In addition, recreation and conservation organizations can be significant players in the development of forest and land-use policies. The level of memberships in these groups could be a barometer of preferences for such initiatives as forest preservation, conservation and sustainable use.

Lastly, protected areas serve as a vehicle for preserving ecosystems, endangered species and special landscape attributes that might otherwise be at risk from economic development. Trends in the amount of land set aside are an indicator of the importance placed on ensuring the continued existence of unique forest ecosystems and habitats and maintaining options for future generations.

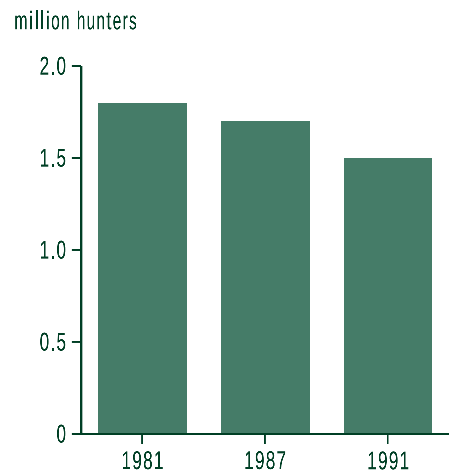
What data are available?

Availability and use of recreational opportunities (5.4.1)

Changes in public preferences and in the availability of forests for outdoor recreation are illustrated by the levels of participation in a small set of forest-based recreation activities.

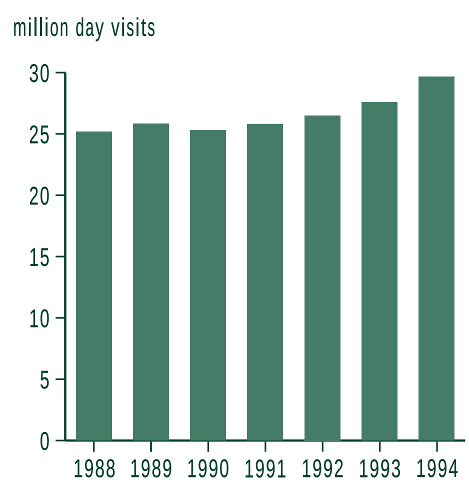
Trends in the number of days that Canadians spent hunting and in the number of visitors (Canadians and foreigners) to Canada's national parks are illustrated in Figure 5.4a and Figure 5.4b, respectively. As wildlife populations are not declining, the decrease in hunting over the period 1981–1991 would appear to reflect reduced interest

5.4a Hunting by Canadians



Source: National Survey on the Importance of Wildlife to Canadians

5.4b Visits to national parks in Canada's forests



Source: Canadian Heritage

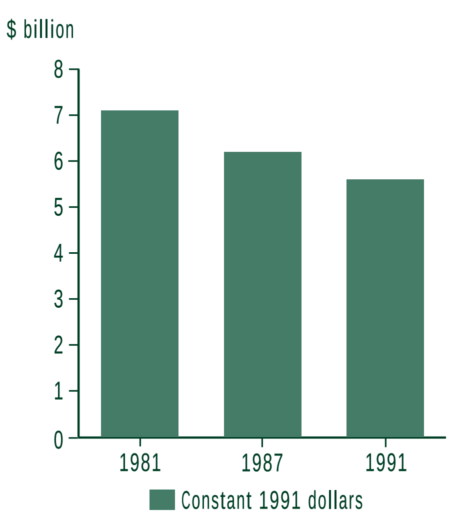
on the part of Canadians. Visits to national parks, on the other hand, rose over the period 1988–1994, suggesting increased demand for the kinds of forest-related goods and services offered by parks (e.g., natural beauty, wildlife-viewing opportunities and resorts).

Total expenditures by individuals on activities related to non-timber use (5.4.2)

Expenditures incurred by people consuming non-timber goods and services provide a partial proxy for the value of outdoor recreation. It is important to emphasize, however, that these are not direct measures of the value of non-timber use, because the true value of the experience may considerably exceed the cost. A 1995 study in British Columbia, for example, showed that the direct benefits of big game hunting are valued at approximately $45–105 per day over the expenditures incurred.

Figure 5.4c shows the trend in wildlife-related expenditures in constant 1991 dollars. In 1981, Canadians spent a total of $7 billion on wildlife-related activities, including accommodation, transportation, food, equipment, habitat improvements, donations, etc. In 1991, the expenditures totalled $5.6 billion. A range of factors may be used to explain this drop of more than 20%, including the economic recession that began in 1990, a declining interest in hunting, and a shift to other outdoor recreation activities that are not directly related to wildlife.

5.4c Wildlife-related expenditures by Canadians



Source: National Survey on the Importance of Wildlife to Canadians

Memberships and expenditures in forest recreation-oriented organizations and clubs (5.4.3)

Memberships in forestry-related organizations may be a barometer of the interest in various initiatives, such as the preservation, conservation and sustainable use of forests, as well as in forest recreation activities, such as hunting, fishing, snowmobiling and skiing. Comprehensive national summaries of membership levels and expenditures, however, are not available.

In the spring of 1996, the Canadian Institute of Forestry sent a survey to 145 national and provincial organizations representing forest recreation and conservation interests. Information was requested on the number of members and the level of contributions. (The organizations will be surveyed annually to identify trends in rates of participation by Canadians.) Seventy-three organizations responded to the survey—a response rate of 55%. More than 1.3 million individuals and 1 451 corporations were members of at least one of the outdoor and environmental organizations that responded. Most membership fees were under $100. The annual expenditures of these organizations totalled approximately $45 million.

Another important source of information is the National Survey on the Importance of

5.4d Memberships in and financial contributions to wildlife organizations

SURVEY YEAR	MEMBERSHIPS million	PORTION OF POPULATION %	CONTRIBUTIONS $ million
1981	1.1	6.0	119.4
1987	1.4	6.9	73.5
1991	1.9	9.0	151.2

Source: National Survey on the Importance of Wildlife to Canadians

Wildlife to Canadians. This survey was conducted in 1981, 1987 and 1991, and planning is now underway for another survey in 1997. Between 1981 and 1991, there was a 73% increase in the number of Canadians who were members of, or contributed to, a wildlife organization. And between 1987 and 1991, fees and donations to such groups more than doubled (Figure 5.4d).

Area and percentage of protected forest by degree of protection (5.4.4)

The data and information relating to this indicator are found under Indicator 1.1.3 (Area, percentage and representativeness of forest types in protected areas).

Summary

The study of non-market forest values is not well developed in Canada. However, the Canadian Forest Service has identified non-market valuation methodologies as a priority research area. The proxy values used to measure Canadian participation rates and expenditures on forest-related activities suggest a general increase in the value of nature to Canadians.

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CRITERION 6.0

Information related to 6.5.1 is found under 4.4.4; information for 6.5.4 is found under 6.4.1-6.4.3

ACCEPTING SOCIETY'S RESPONSIBILITY FOR SUSTAINABLE DEVELOPMENT

INTRODUCTION

The sustainable development of forest resources has as much to do with people as it does with trees, soil, water and other ecological components of forest ecosystems. Criterion 6 comprises indicators that assess the social dimensions of sustainable development.

Canadians are demanding more direct involvement in forest management, planning and policy making. Specific stakeholders and interest groups that have traditionally been outside these processes are gaining legitimacy and are participating more frequently and directly in forest issues. However, the rights to use forest resources and participate in forest policy making, planning and management are accompanied by certain responsibilities. That is why Criterion 6 bears the title "Accepting Society's Responsibility for Sustainable Development." Creating a sustainable future is not solely the responsibility of government or industry; rather, it is a responsibility that must be shared by all members of society.

The relationship between Canadians and their forest resources is evolving, as are the values placed on forests and the goals set for forest management. The very notion of sustainable development is quite new. As society's relationship with the natural world changes, different priorities emerge, and institutions are created to address these new objectives. This criterion measures the degree to which changing values and priorities are being incorporated into forest practices, programs and policies.

Criterion 6 encompasses such elements as the respect for Aboriginal and treaty rights and the role of Aboriginal communities in sustainable forestry. It also deals with forest community sustainability, fairness in decision making, and the degree to which informed decisions are made. Aboriginal and forest communities are both key elements to consider because each has a vested interest in maintaining the sustainability of our forests. Informed public participation also is an important aspect of sustainability, as it ensures that the various demands placed on forests can be mediated and accommodated.

Little information is available for many of the indicators in Criterion 6, because the social dimensions of sustainable forestry have only recently become a priority for government and university researchers. Further conceptual work and definitional clarity will be required for some of the indicators before reliable data may be collected. Much of the existing data and information are case-specific, and one of the principal challenges facing forest science researchers is aggregating this data at the national level in a meaningful and scientifically sound manner.

ELEMENT 6.1

ABORIGINAL AND TREATY RIGHTS

What are we measuring?

This element measures the extent to which forest planning and management processes consider and meet legal obligations with respect to Aboriginal and treaty rights.

The Royal Proclamation of 1763 required the consent of Aboriginal peoples before their land was occupied and gave the Crown sole authority to negotiate such land settlements. From the Proclamation flowed treaties that outlined the Crown's responsibility to protect Aboriginal peoples' way of life, including hunting, trapping, fishing and gathering.

The Constitution Act of 1867 gave the federal government jurisdiction over all matters concerning "Indians" and "Indian lands." In 1982, the Act was updated to further affirm and protect Aboriginal and treaty rights. Specifically, Section 35 states, in part, that the "existing Aboriginal and treaty rights of the Aboriginal peoples of Canada are hereby recognized and confirmed." In 1992, Strategic Direction Seven of the National Forest Strategy recognized the importance of these rights in forest management and reflected the commitment made by Canada at the 1992 United Nations Conference on the Environment and Development—to recognize the role of Aboriginal peoples in forests, traditional use, knowledge and ways of life.

How do Aboriginal and treaty rights relate to the sustainability of Canada's forests?

There is growing awareness of the need for sustainable forest management to recognize Aboriginal peoples' rights and protect their traditional way of life. Aboriginal use of forest land—be it subsistence or commercial fishing, hunting, trapping or gathering—affects forest management and thus, forest management planning.

What data are available?

Extent to which forest planning and management processes consider and meet legal obligations with respect to duly established Aboriginal and treaty rights (6.1.1)

Aboriginal and treaty rights are in part defined by law, and in some regions of Canada, they are evolving as a result of land claims negotiations. However, differences still exist between Aboriginal peoples and the provinces regarding the intent of the treaties. The National Aboriginal Forestry Association (NAFA) addressed this issue in a submission to the Royal Commission on Aboriginal Peoples, entitled *Forest Lands and Resources for Aboriginal People*, and in its position paper *Aboriginal Participation in Forest Management: Not Just Another "Stakeholder."*

Some provinces have amended their forest legislation, regulations and practices to address Aboriginal rights. For example, as part of its policies on Crown land, British Columbia has instituted the Protection of Aboriginal Rights Policy, which requires consultation with Aboriginal communities impacted by resource activities. This regularly affects logging plans and other Ministry of Forests and licencee development plans. A total of 614 000 hectares of operable commercial forests (2.4% of the province's operable landbase) are currently in deferred (log-around) status due to outstanding Aboriginal issues. Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Nova Scotia all recognize the Aboriginal right to fish, trap and hunt for food year-round. The right to log commercial forests generally is not recognized, although a New Brunswick court recently ruled that Micmacs have a treaty right to harvest timber on Crown land for commercial purposes.

Recent land-claim settlements and modern treaties have addressed Aboriginal rights to lands and resources. For example, the Agreement in Principle between the Nisga'a and the Province of British Columbia includes rights to access natural resources within the claim area. Land claim agreements in the Northwest Territories and the Yukon Territory also have incorporated Aboriginal access to renewable resources.

Summary

Measuring the extent to which forest planning and management processes consider and meet legal obligations with respect to Aboriginal and treaty rights is difficult because of the changing interpretations of those rights and the evolving forms of co-management between Aboriginal peoples and provincial governments. At this point, measurement entails an overview of provincial legislation and regulations and a best-practices or case-study approach.

ELEMENT 6.2
PARTICIPATION BY ABORIGINAL COMMUNITIES IN SUSTAINABLE FOREST MANAGEMENT

What are we measuring?

This element measures the extent of Aboriginal participation in sustainable forest management by examining Aboriginal peoples' share in forest-based economic opportunities; the protection of their social, cultural and spiritual sites; the number of Aboriginal communities with a significant forestry component in their economic base; the diversity of forest use at the community level; the area of forest land available for subsistence purposes; and the area of reserve lands under integrated forest management plans. Various federal, provincial and Aboriginal sources provide some insight into these indicators, but comprehensive national data are not yet available.

How does participation by Aboriginal communities relate to the sustainability of Canada's forests?

More than 80% of Aboriginal communities lie in the productive forest zones of Canada. The Aboriginal people living in some of these areas have unique cultural and spiritual connections with the land and an intimate knowledge of forest ecosystems. This traditional knowledge can enhance forest management, demonstrating that Aboriginal participation is a valuable component of sustainable forest management.

What data are available?

Extent of Aboriginal participation in forest-based economic opportunities (6.2.1)

This indicator assesses Aboriginal participation in forest industry-related activities. Some data on industry-based economic opportunities are available through Statistics Canada in the Standard Industrial Classification Codes. Through the Indian Lands Forestry Program, Natural Resources Canada–Canadian Forest Service (CFS) provides estimates of roundwood production, as well as some information on the revenues generated from forestry activities on reserve lands between 1984 and 1992. Although no comprehensive national data are available, several studies have looked at Aboriginal economic involvement in the forest industry. These studies include the *Aboriginal Forestry Training and Employment Review*, the *Class Environmental Assessment for Timber Management on Crown Lands in Ontario* and the *Lands, Revenues and Trusts Forestry Review*. In addition, some provinces record the forest licences awarded to Aboriginal communities.

Extent to which forest management planning takes into account the protection of unique or significant Aboriginal social, cultural or spiritual sites (6.2.2)

Several provinces have passed heritage legislation to protect Aboriginal sites, while others rely on forest management legislation. In British Columbia, for example, provincial forest legislation requires the cataloguing of Aboriginal sites—work that is being done as part of the Traditional-Use Study Program. Archaeological sites in the province are protected under the British Columbia Heritage Conservation Act. Ontario has a guidelines identification system in place entitled *Timber Management Guidelines for the Protection of Cultural Heritage Resources*, while in the Yukon Territory and the Northwest Territories, land claim agreements include provisions for the protection of culturally significant Aboriginal sites.

Many Aboriginal communities have conducted land-use studies to map social, cultural and spiritual sites. Monitoring the integration of these sites into forest management planning would provide an indication of the extent to which such sites are protected.

Number of Aboriginal communities with a significant forestry component in the economic base and diversity of forest use at the community level (6.2.3)

NAFA's 1995 report, entitled *An Assessment of the Potential for Aboriginal Business Development in the Ontario Forest Sector,* surveyed 17 communities and described on- and off-reserve forestry activities; forest sector impacts; human resources development; and barriers and opportunities relative to the population, reserve landbase and forest area.

NAFA has also begun to develop a database on Aboriginal forest businesses. Other business directories have already been compiled for specific regions (e.g., the 1996 Quebec Native Business Directory and the directory of Grand Council Treaty N° 3).

The information described in Indicator 6.2.1 (Extent of Aboriginal participation in forest-based economic opportunities)—particularly the data available through the former Indian Lands Forestry Program—also can be used to establish baseline information for this element.

Area of forest land available for subsistence purposes (6.2.4)

For Aboriginal communities in forested areas, subsistence use involves hunting, fishing, trapping and gathering. The data currently available on these activities are insufficient to determine the amount of forest land required for subsistence purposes.

One source of information on subsistence use is Indian and Northern Affairs Canada, which maintains a database on Aboriginal trappers. In addition, many Aboriginal communities have carried out traditional land-use studies to define their areas of subsistence use. Among these peoples are the Innu of Labrador, the Gitxsan and Wet'suweten of northern British Columbia, and the Dene of the Northwest Territories. In Alberta, Alberta-Pacific Forest Industries (Al-Pac), worked with Aboriginal communities to map their traditional areas and incorporate this information into the company's forest management plans.

Historical reviews of land-use patterns may give an indication of the area that is currently available for subsistence use, as well as the changes that have occurred over time. Also, an extensive and growing body of academic literature on traditional knowledge and practices can provide case-study background. For example, in 1996, NAFA completed a report entitled *Aboriginal Forest-Based Ecological Knowledge in Canada*, which described six cases involving Aboriginal subsistence and traditional use of forests in management planning processes.

Some provincial legislation recognizes the Aboriginal use of forest resources. Saskatchewan's new Forest Resources Management Act, for example, allows Aboriginal people to gather such items as medicinal plants and fallen wood for personal or family use without requiring a licence.

Area of Indian reserve forest lands under integrated management plans (6.2.5)

The federal government has responsibility for land areas referred to as "Indian reserves." The forests on these reserves make up only a small percentage of the total forest land in Canada (roughly 0.3%). Some reserves, however, are large enough to provide a base for sustainable forest management and to enable Aboriginal people to participate in sustainable management off-reserve. The total area of reserve lands is nearly 1.4 million hectares, with a total volume of merchantable timber of almost 140 million m^3 and an annual allowable cut estimated at just under 3 million m^3.

Of the total reserve land area, 807 845 hectares (58%) are currently under management. Earlier management plans were for timber harvesting rather than integrated management, and existing records catalogue the total area, total forested area, softwood and hardwood volume, total volume, annual allowable cut, and the year the management plan was prepared. Further research is required to determine the extent to which non-timber data have been included in more recent management plans.

Summary

The CFS has collected data regarding on-reserve forestry activities for the past 10 years, but with the exception of British Columbia, the provinces have collected such information only sporadically. Since the creation of NAFA in 1991, several studies have highlighted Aboriginal participation in these activities, while a number of other Aboriginal organizations have surveyed their membership for information on business and economic opportunities. Coordination among federal and provincial governments and Aboriginal organizations is needed for the collection and assessment of this type of data.

ELEMENT 6.3

SUSTAINABILITY OF FOREST COMMUNITIES

What are we measuring?

Canada is highly dependent on its forest resources for the provision of domestic goods and services, as well as exports. That dependence, however, is not distributed equally across the country. Within or adjacent to forested regions are hundreds of communities that rely on the forest sector. Ideally, to determine how many such communities exist in Canada, we would create a yardstick that could be used to measure all of the varied human uses of forests, including psychological and cultural benefits, timber and non-timber economic benefits, and subsistence activities. *Measurements for some of these values are provided in Criterion 5 (Multiple benefits of forests to society).* Unfortunately, the national data that are currently available can only be used to determine timber dependence.

How do forest communities relate to the sustainability of Canada's forests?

Forest communities, by definition, depend on local forests for their livelihood. Indicators related to community sustainability contribute to our overall understanding of the sustainable management of our forests. For example, if forest communities continue to be economically, culturally and spiritually sustained by their local forests, the forests are likely being managed on a sustainable basis. However, if the health and productivity of their forests decline due to natural events (e.g., fires or insect damage) or human actions (e.g., pollution or unsustainable harvest rates), the viability of the communities may be compromised. It is important to know how many forest-dependent communities exist and determine, to the extent possible, how vulnerable they are to ecological, economic and political change.

Another important dimension pertaining to the sustainability of forest communities is their ability to control their own future. However, there are too few community-based tenures to determine the impact of local involvement on resource management and community stability. Local stakeholders have the most to gain from responsible forest management and the most to lose from unsustainable practices. Therefore, their involvement in forest management and stewardship also are considered indicators of sustainability.

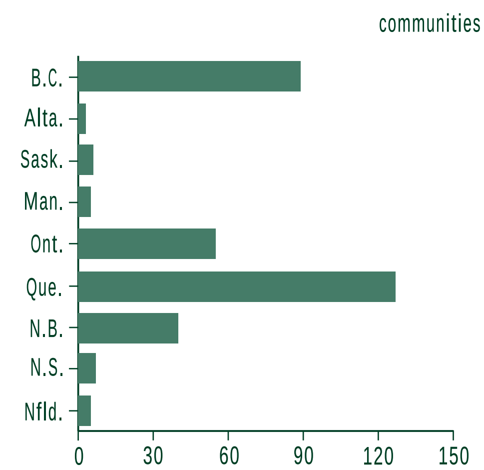
What data are available?

There is no national research program that examines the psychological and cultural benefits of forests, nor are data available to assign a monetary value to community dependence on non-timber forest products or subsistence activities.

Number of communities with a significant forestry component in the economic base (6.3.1)

In Canada, 337 communities are classified as heavily forest dependent—forest industries account for more than 50% of their economic base employment (Figure 6.3a). An additional 1 294 communities are moderately forest

6.3a Heavily forest-dependent communities by province



Source: Natural Resources Canada–Canadian Forest Service

dependent, relying on the forest sector for 10–50% of their economic base (Figure 6.3b).

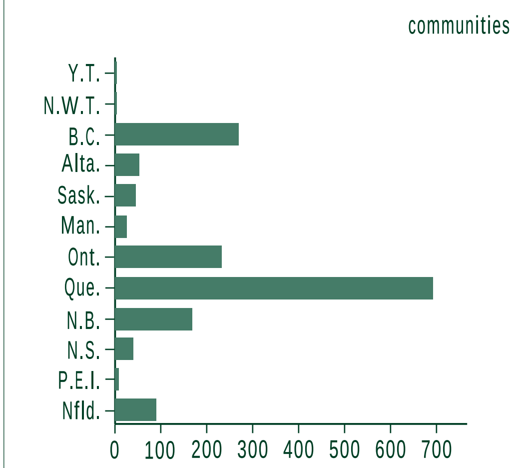
Index of the diversity of the local industrial base (6.3.2)

Forest-dependent communities often possess, or are located in proximity to, resources that provide other economic opportunities, such as mining, agriculture or energy. Currently, data are available on the diversity of the industrial base with respect to natural resources for Prairie communities with populations exceeding 250. Communities in which one other sector accounts for more than 10% of employment are classified as dual-sector dependent; those with two or more additional sectors are considered diversified (Figure 6.3c).

Diversity of forest use at the community level (6.3.3)

Currently, there are no data available at the national level to measure this indicator.

6.3b Moderately forest-dependent communities by province/territory

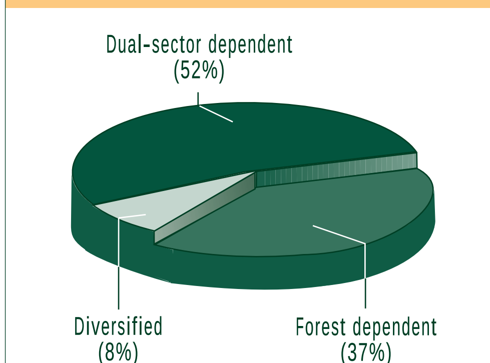


Source: Natural Resources Canada–Canadian Forest Service

Number of communities with stewardship or co-management responsibilities (6.3.4)

Public involvement in forest stewardship and management is on the increase, particularly with respect to Crown forest lands. However, it is difficult to measure the number of communities having stewardship or co-management responsibilities, because definitions of these terms vary considerably. Further research and more

6.3c Diversity of the economic base of moderately forest-dependent communities in the Prairies



Source: Natural Resources Canada–Canadian Forest Service

practical examples may enable us to better assess this dimension of forest community sustainability.

Summary

This element report has focused on measurable dimensions of forest dependence, namely the number, distribution and degree of dependence of communities that rely on the forest sector for their economic well-being. Further research is required to develop measures of non-timber dependence and to determine the number of forest communities that still rely on subsistence activities for a significant portion of their livelihood. It is likely that some aspects of human reliance on forests, such as psychological benefits or ecological services, never will be measurable, but they must be acknowledged as society considers its responsibility for sustainable development.

ELEMENT 6.4
FAIR AND EFFECTIVE DECISION MAKING

What are we measuring?

Measuring public participation for the purposes of reporting on sustainable development is difficult. Quantitative assessments, such as person days of participation, the number of forest products companies with citizen advisory boards, and the number of government-sponsored public meetings, fail to reflect the real spirit behind this element—the fairness and effectiveness of decision-making processes. In this context, "fairness" is defined in terms of inclusiveness, while an "effective" decision is one that incorporates and mediates the broad spectrum of concerns on a given issue. Qualitative assessments of decision-making processes likely will prove more useful in determining progress toward sustainable development. These two types of assessments are difficult to compare, however, and no one formula can work in all situations.

Indicators of fair and effective decision making include the degree of public participation in designing decision-making processes, making and implementing decisions, and monitoring progress toward sustainable forest management.

How does fair and effective decision making relate to the sustainability of Canada's forests?

Public involvement is assumed to be linked to sustainable development because of the breadth of goods and services that Canadians demand from their forests. *Diversity of forest use was discussed in Element 6.3 (Sustainability of forest communities).* If all of the stakeholders advocating varying uses of forests are included in the decision-making process, it is more likely that forest management will be carried out on a sustainable basis to maintain the flow of these goods and services.

What data are available?

Public participation in decision making (6.4.1–6.4.3)

For the purposes of this report, Indicator 6.4.1 (Degree of public participation in the design of decision-making processes), Indicator 6.4.2 (Degree of public participation in decision-making processes) and Indicator 6.4.3 (Degree of public participation in the implementation of decisions and the monitoring of progress toward sustainable forest management) are discussed together.

Provincial governments are responsible for the design of forest decision-making processes and the development of forest-management policies and strategies. Public participation in these areas currently occurs through a variety of processes, including round tables, public meetings, advisory bodies, written submissions and the distribution of discussion papers. It is rare for the public to be invited to participate in creating decision-making processes or monitoring the activities of public- or private-sector forest managers. When that occurs, it is done as a matter of tradition or policy—not as a legislative requirement.

Although difficult to measure, public participation appears to be on the increase, with experiments and innovation beginning to take place all across Canada. For example, public involvement in land-use planning, including forest planning, has increased dramatically in British Columbia through the province's land- and resource-management planning process. In northern Alberta and Saskatchewan, the integration of Aboriginal involvement in forest planning, decision making and monitoring has been a focus in recent years. Manitoba's new Forest Plan explicitly states that greater public involvement will be required in future forestry activities. The Province of Ontario has developed citizens committees under its Crown Forest Sustainability Act. And Quebec developed its "inhabited forest" policy in response to a grassroots attempt to accept more local responsibility for forest management. The Nova Scotia Department of Natural Resources has taken steps to involve the public in the development of policies and in decision making. And Newfoundland is experimenting with consensus-based decision making by involving planning teams in the management of forest ecosystems.

Summary

In the forest sector, there is more experimentation in the areas of co-management, community forestry, public advisory boards and consensus-based processes than is reflected in the existing literature. Qualitative assessments of decision-making processes are difficult to compile and compare. To advance our knowledge in this area and make progress toward sustainable development, it is critical that information be shared and that we draw on existing professional networks to do so. To date, very little analytical work has been done to determine which models have worked and why.

ELEMENT 6.5
INFORMED DECISION MAKING

What are we measuring?

Forest management and planning are complex tasks that require knowledge of such diverse disciplines as engineering, sociology, hydrology, ecology and economics. To make the right choices, and to maximize the societal benefits of forests without compromising their ability to continue to provide these benefits, all of society must work in partnership and employ the best and most current information available. This element relates to the quality of that information, and to mechanisms for its incorporation into forest policies and planning. Investments in research and expenditures in public forest education, international forestry and mutual learning are all indicators of informed decision making. There is a direct connection between this element and Element 6.4 (Fair and effective decision making), because for the public to participate effectively in forest management, it must be well-informed.

How does informed decision making relate to the sustainability of Canada's forests?

Continued excellence in forest-based research is critical because it helps define sustainable forestry and monitor and evaluate sustainable forest practices. Ecosystems and social systems are both in a constant state of flux, and research is necessary so that the latest findings on everything from society's attitudes and preferences to developments in environmentally sound technologies may be integrated into forest management planning and decision making.

People can make better decisions if they know more about ecological processes, and professional foresters and policy makers can make better management decisions if they know more about the public's concerns. Therefore, mutual learning—a rational and reasonable exchange of information in the spirit of partnership—is another indicator of sustainable forestry.

Canadians' responsibility for sustainable forest management does not end in Canada, however. Given our significant forest educational and institutional infrastructures, and our political will to practice sustainable forest management, we have much leadership and direction to offer the world. Expenditures in international forestry are, therefore, another indicator of informed decision making and of society's support for sustainable development.

What data are available?

Investments in forest-based R & D and information (6.5.2)

Each year, significant resources are allocated to forest research in Canada. In 1993–1994, the Model Forest Program spent $1.8 million on forest research, and that figure rose to $2.9 million in 1994–1995. The forest research expenditures of the Sustainable Forest Management–Network of Centres of Excellence (SFM–NCE) Program totalled $2.4 million in 1995–1996 and $4.0 million in 1996–1997.

Figure 6.5a shows the amount of money that was spent annually on other forest-based research between 1990 and 1994. This includes the budget of the CFS and provincial forest agencies, as well as research supported by the federal–provincial agreements in forestry, but not research conducted in universities.

Most provincial funding goes to applied forest research. Expenditures range from zero in jurisdictions with low forest dependence (e.g., Prince Edward Island and the Yukon Territory), to tens of millions of dollars in jurisdictions heavily dependent on forests (e.g., British Columbia spent $18.7 million in 1995–1996, and Quebec has averaged $13.5 million per year over the past few years).

6.5a Government expenditures on other forest-based research

1990	1991	1992	1993	1994
		$ million		
112.8	126.1	137.0	137.0	151.2

Source: National Forestry Database

In recent decades, federal–provincial agreements provided millions of dollars for forest research, but they have not been renewed. Other forms of federal–provincial partnership are now emerging, such as the $3 million that Alberta contributed to the SFM–NCE. Some new provincial initiatives, including the Forest Renewal British Columbia Program, also may provide research funds in the area of sustainable forest management.

Total effective expenditures on public forestry education (6.5.3)

Expenditures on public education are another critical component of sustainable forestry. The Model Forest Program places a high priority on public awareness and technology transfer. Its expenditures in those areas are outlined in Figure 6.5b.

The Canadian Forestry Association has documented more than 200 forest education programs in local school systems. Public forest education is difficult to measure, in part because it is impossible to objectively distinguish between programs and materials designed to educate and those designed to affect public opinion. Interest group and industry brochures and promotional materials, as well as peer-reviewed science and university extension efforts, are all considered educational because they tell us how different segments of society conceptualize forest issues and processes. All such expenditures on public information should, therefore, be included in future reporting on this indicator.

6.5b Model Forest Program expenditures on technology transfer and public awareness activities

ACTIVITY	1993–1994	1994–1995
	$ thousand	
Technology transfer	625.4	1 281.0
Public awareness	1 102.5	1 514.0

Source: Canadian Model Forest Network

Mutual learning mechanisms and processes (6.5.6)

Some attempts have been made recently to bring together a broad range of forest stakeholders to discuss forest and environmental issues. The WildFor and EnviroFor conferences, for example, were structured so that interest groups, who often conduct their dialogue indirectly (via letters, protests or the media), could meet face to face to discuss their perspectives and concerns.

The Model Forest Program also focuses on partnership building. For example, the management and partnership committees of most model forests include representatives from a broad range of interest groups.

Mutual learning has also occurred through industry-sponsored initiatives, such as the public involvement process and the co-management of the NorSask forest in northwestern Saskatchewan.

Expenditures on international forestry (6.5.5)

Canadians' acceptance of responsibility for global sustainable development may be measured by expenditures on international forestry. In 1995, the Canadian International Development Agency (CIDA) reported expenditures of nearly $70 million on forest programs. This compares with the previous level of nearly $100 million per year. The CIDA funds are spent on managing existing forests, creating new forests, and developing commercial forest ventures.

More than 150 projects are ongoing in at least 60 countries. In 1995, the International Development Research Centre (IDRC) spent approximately $1 million on the International Model Forest Program. IDRC spent additional millions on sustainable human development, land rehabilitation and property rights, but is unable to determine what percentage of those projects had implications for forestry.

Summary

As our society evolves and we learn more about social, economic and ecological processes, the values that we associate with "sustainable development" will change. For this reason, it is important to have up-to-date information. "Informed" decision making refers to the quality of information that goes into forest management and planning. If sustainable forestry can be considered a final product, accurate information is the raw material. A strong commitment to research, public education and mutual learning, combined with an understanding of Canada's role and responsibilities in international forestry, will move us closer to sustainable forest management. More attention to these specific issues in a research context will also allow us to better assess them for future reports.

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Glossary

Abiotic: Concerning the non-living component of the environment (e.g. climate, ice, soil and water).

Aboriginal: As defined by the Constitution Act, 1982, Section 35(2), "Aboriginal peoples of Canada" includes the "Indian, Inuit and Metis" peoples of Canada.

Annual allowable cut (AAC): The amount of timber that is permitted to be cut annually from a particular area; AAC is used as the basis for regulating harvest levels to ensure a sustainable supply of timber.

Aquatic: Pertains to both marine and freshwater ecosystems.

Bequest values: Values obtained by the current members of society in knowing that forests are being protected, conserved and sustainably managed, and will be available for future generations.

Biodiversity: The total variability of life on Earth, including the diversity of genes, species and ecosystems.

Bioenergy: The kinetic energy released from biomass when it is eaten, burned or converted into fuel; the potential energy embodied in biomass.

Biological productivity: The capacity to produce biomass; the production of biomass.

Biomass: The dry weight of all organic material (i.e., animals, plants and microorganisms) living or dead and above or below the soil surface.

Biosphere: Regions of the planet where life is found, ranging from the oceans to the lower atmosphere.

Biosystematics: The field of science dealing with the diversity of life and the relationships of life's component organisms, including taxonomy (recognition), phylogenetics (evolutionary relationships), classification (patterns in evolution) and taxagenetics (processes responsible for origin and adaptation).

Biota: All of the living organisms in a given ecosystem, including bacteria and other microorganisms, plants and animals.

Bogs: Peatlands that are generally unaffected by nutrient-rich groundwater. They are acidic and are often dominated by shrubs and mosses; they may also include open-growing, stunted trees.

Buffer: A strip of land where disturbances are not allowed, or are closely monitored, to preserve aesthetic and other qualities adjacent to roads, trails, waterways and recreation sites.

Carbon cycle: The cycle of carbon in living things in which carbon dioxide is fixed by photosynthesis to form organic nutrients and is ultimately restored to the inorganic state by respiration and proto-plasmic decay.

Carbon sink: An area where the rate of carbon uptake by living organisms exceeds the rate of carbon release, so that carbon is actively sequestered in organic or inorganic forms.

Catchment area: The area tributary to or draining to a lake, stream, reservoir or other body of water.

Chemi-thermomechanical pulp: Pulp that has undergone the process by which wood chips are separated into fibres using heat, pressure and chemicals.

Climate change: An alteration to measured quantities (e.g., precipitation, temperature, radiation, wind and cloudiness) within the climate system that departs significantly from previous average conditions and is seen to endure, bringing about corresponding changes to ecosystems and socioeconomic activity.

Co-management: Forms of shared natural resource management between local representatives and provincial governments, with local participants having a varying degree of decision-making power—from advisory to shared jurisdiction.

Commercial forest: Forest land that is able to grow commercial timber within an acceptable time frame.

Commodity: A general term referring to primary-level manufactured products (e.g., dimension lumber, plywood and market pulp) that are sold in bulk volumes. These products are often used to produce higher value-added products (e.g., structures, furniture and fine papers).

Compaction: A reduction in soil volume (usually caused by repeated passes of heavy equipment) leading to poor soil aeration, impeded drainage and root deformation.

Connectedness: The ease with which individuals of a given species move from one habitat patch to another.

Crown transparency: The amount of skylight visible through the foliated portion of a tree crown.

Cutover: An area of forest from which some or all of the timber has recently been cut.

Decomposition: The breakdown or decay of organic materials by the action of bacteria, fungi and other minute organisms.

Deferred area: An area in which a restriction-of-activity order is put into effect for a specific period of time.

Defoliator: An agent that causes plants to lose their leaves.

Deforestation: Clearing an area of forest for another long-term use.

Detritus: Loose material covering the soil surface that consists of decomposing plant matter that results directly from disintegration

Dieback: A condition in woody plants in which peripheral parts are killed, usually beginning at the terminal portion.

Displacement: The removal of soil, including the forest floor, from one location to another, causing a change in the natural microtopography.

Dual-sector dependent communities: Forest-dependent communities in which one other sector (e.g., mining, agriculture or hydro) accounts for more than 10% of employment.

Ecosystem: A dynamic system of plants, animals and other organisms, together with the non-living components of the environment, functioning as an interdependent unit.

Ecosystem resilience: The ability of an ecosystem to recover from disturbances caused by natural and human-induced means.

Ecosystem-based management: The development of management systems that attempt to simulate ecological processes with the goal of maintaining a satisfactory level of diversity in natural landscapes and their pattern of distribution in order to ensure the sustainability of forest ecosystems and forest ecosystem processes.

Ecozone: A broad-scale ecological unit that is based on patterns that include climate, geography and ecological diversity.

Edge habitat: A loosely defined type of habitat that occurs at the boundary between two different habitat types (e.g., where forests border on non-forest land). Typically, edge habitats have transitional characteristics that benefit certain species, but exclude others.

Environmental service values: Values related to the ability of forest ecosystems to assimilate waste and respond to human disturbances while continuing to provide environmental goods and services, such as clean air, water, soil retention and wildlife habitat. These functions include ground water recharge, filtration, flood control, erosion protection, migratory bird habitat, pest control, nutrient recycling, climate regulation and carbon fixing.

Erosion: To wear away by the action of water, wind or glacial ice.

Eutrophication: The process by which a body of water becomes—either naturally or by pollution—rich in dissolved nutrients (e.g., phosphates), often with a seasonal deficiency in dissolved oxygen.

Evapotranspiration: Loss of water from soil and vegetation, both by evaporation and by transpiration from plants.

Ex situ approach: A method of conservation in which components of biodiversity are conserved outside their natural habitats.

Existence value: A value placed on the knowledge that a particular forest ecosystem exists and is being protected. It is not necessary to actually experience the forest to obtain value from it.

Exotic species: Any organism that enters an ecosystem beyond its normal range through deliberate or inadvertent introduction by humans.

Fire behaviour: Ignition, flame development, spread and intensity of a forest or wildland fire.

Fire environment: Weather, fuels and topography that affect forest or wildland fires.

Fire severity: Negative impacts of a forest or wildland fire on other ecosystems.

Firewood: Trees that will yield logs suitable in size and quantity for the production of firewood; also the logs of such trees.

Forest-dependent community: A community that is dependent on forests for its survival; due to data availability, dependence is usually measured with timber sector data.

Fossil fuel: Oil, gas, coal and other fuels that were formed under the Earth's surface from the fossilized remains of plants and tiny animals that lived millions of years ago.

Fragmentation: The division of a continuous block of forest or other wildlife habitat into disconnected units as a result of human or natural disturbances.

Fuelwood: Trees that will yield logs suitable in size and quality for the production of firewood logs or other wood fuel; also the logs of such trees.

Full suppression fire: A forest or wildland fire that is controlled as quickly as is reasonably possible.

Geographic information system (GIS): An information system that uses a spatial database to provide answers to queries of a geographical nature through a variety of manipulations, such as sorting, selective retrieval, calculation, spatial analysis and modeling.

Geosystem(s): Existing soil and water processes affected by fire.

Greenhouse effect: The preservation of warmth in the Earth-atmosphere system caused by the presence in the atmosphere of certain trace gases (e.g., water vapour and carbon dioxide) that transmit shortwave energy (visible and ultraviolet radiation) from the sun to the Earth's surface, and the absorption of long wave radiation emitted from the Earth's surface resulting in a greater atmospheric temperature. Without the "greenhouse" effect, the Earth's temperature would be 33ºC lower than present values, and life on Earth as we know it would not exist.

Gross domestic product (GDP): A measure of national income—the amount paid to Canadians, including governments, in terms of salaries, wages, profits, taxes and royalties.

Habitat (wildlife): The environment in which a population or individual lives; includes not only the place where a species is found, but also the particular characteristics of the place (e.g., climate or availability of suitable food and shelter) that make it especially well suited to meet the life-cycle needs of that species.

Hardwood(s): Broad-leaved trees; also refers to the wood produced by these trees. Hardwoods belong to the botanical group angiospermae and are the dominant type of tree in the deciduous forest.

Heavily forest-dependent community: A forest-dependent community that relies on the forest sector for more than 50% of its economic base.

Heritage legislation: Legislation addressing the protection of sites that have cultural, historical or spiritual significance deemed important for present and future generations.

Humus: A brown or black complex material resulting from the partial decomposition of plant or animal matter and forming the organic portion of the soil.

Hydrological cycle: The global cycle that describes the movement of water through terrestrial and aquatic ecosystems and back into the atmosphere.

Hydrology: A science dealing with the properties, distribution and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

In situ approach: The conservation of ecosystems and natural habitats, and the maintenance and recovery of viable populations of species in their natural surroundings.

Integrated forest management: Forest management that incorporates timber and non-timber values.

Kraft pulp: Pulp made by boiling wood chips in a sodium sulfate solution; typically used for corrugated paper or grocery bags.

Landfill site: Low-lying land that has been built up by the disposal of waste buried between layers of earth.

Life zone: Widely used in the study of birds and mammals in North America: generally refers to a series of temperature zones.

Litter: The uppermost slightly decayed layer of organic matter on the forest floor.

Mean annual increment (MAI): Average net annual increase in yield (expressed in terms of volume per unit area) of living trees to a given age; measure of the net biomass production of the forest.

Moderately forest-dependent community: A forest-dependent community that relies on the forest sector for 10–50% of its economic base.

Modified fire response: Response to a forest or wildland fire at less than full suppression; normally employed in low-value areas.

Mulch: Any loose covering on the surface of the soil, whether naturally occurring (e.g., litter) or deliberately applied (e.g., gravel); used to reduce competing vegetation, retain humidity, and protect against frost and heavy rain.

Mutual learning: A rational and reasonable exchange of information in the spirit of partnership.

Non-commercial tree species: A tree species for which there is currently no market.

Non-market consumptive goods: Products (e.g., berries, mushrooms, craft products, firewood, fiddleheads, Christmas trees and ornamental trees) that individuals obtain from forest lands free of charge.

Non-timber values: Includes all forest-related values that are not derived from timber harvesting and the subsequent production of forest products.

Non-use values/passive-use values: Values where it is not necessary for the individual to be in the forest or directly experience the forest in any way. For example, many individuals in Canada obtain psychological satisfaction and place a value on knowing that a particular forest ecosystem exists and is being protected.

Old-growth forest: A forest dominated by mature trees that has not been significantly influenced by human activity. The stand may contain trees of different ages and various species of vegetation.

Oriented strand board (OSB): Panels made from narrow strands of fibre oriented lengthwise and crosswise in layers, with a resin binder. Depending on the resin used, OSB can be suitable for interior or exterior applications.

Outfitter(s): Small commercial operations where the owner or operator provides the necessary equipment and supplies to individuals or groups so that they can obtain an outdoor experience in a particular area. In some cases, the outfitter guides or accompanies the individual or group to provide his knowledge, of local sites, conditions, trails, outdoor skills, and wildlife or fishing locations.

Overmature forests: Trees or stands past the mature stage of development.

Ozone: A form of oxygen (O_3) formed naturally in the upper atmosphere by a photochemical reaction with solar ultraviolet radiation and a major agent in the formation of smogs.

Panel products: A class of forest products sold in the form of sheets or panels of various dimensions and thicknesses. Products include softwood and hardwood plywood, particleboard, oriented strand board, medium density fibreboard and hardboard.

Particulate: Of or relating to minute separate particles.

Passerine birds: The largest order of birds, which includes more than half of all living birds and consists chiefly of songbirds that have perching habits.

Peatland: Terrain that is covered by an accumulation of partially decomposed plant matter due to excessive moisture.

Photosynthesis: Formation of carbohydrates in the chlorophyll-containing tissues of plants exposed to light.

Phytotoxic: Poisonous to plants.

Protected area: An area protected by legislation, regulation or land-use policy to control the level of human occupancy or activities. Categories of protected areas include protected landscapes, national parks, multiple-use management areas, and nature or wildlife reserves.

Puddling: The development of very small pools of water, usually as a result of compacting heavy, textured soils.

Pulp: Wood chips that have been ground mechanically into fibres and are used for the production of inexpensive paper, such as newsprint, or that have been chemically treated to remove the lignin and are used to manufacture higher quality papers.

Recycling: The set of processes for reclaiming– as a material input to a product or service system– material that would otherwise be disposed of as waste.

Reforestation: The reestablishment of trees on denuded forest land by natural means or by planting or seeding.

Regeneration: The renewal of a forest stand following disturbance. Natural regeneration occurs from roots, stems or seeds that are already present or are brought in by wind or animals. Other forms of regeneration involve direct seeding or planting.

Renewable resource: A natural resource that is capable of regeneration. Renewable resources can essentially never be exhausted, usually because they are continuously produced (e.g., tree biomass, fresh water and fish).

Reserve: A tract of land in which the Aboriginal interest is permanently preserved for a particular group of Aboriginal people. Defined under the Indian Act as a "tract of land, the legal title to which is vested in her Majesty, that has been set apart by Her Majesty for the use and benefit of a band."

Resource industry: An industry based on the primary resources obtained from agriculture, fisheries, forestry or mining, including wheat, cod, timber or iron ore.

Respiration: The physical and chemical processes by which an organism supplies its cells and tissues with the oxygen needed for metabolism and relieves them of the carbon dioxide formed in energy-producing reactions. Any of various energy-yielding oxidative reactions in living matter.

Riparian: Relating to, or living or located on, the bank of a natural body of fresh water.

Rutting: The development of artificial drainage channels in compacted, displaced soil.

Sedimentation: The action or process by which matter settles to the bottom of a body of water.

Siltation: Loose sedimentary material with rock particles.

Silviculture: The theory and practice of controlling the establishment, composition, growth and quality of forest stands; can include basic silviculture (e.g., planting and seeding) and intensive silviculture (e.g., site rehabilitation, spacing and fertilization).

Slash burning: Burning the residue on the forest floor that is left after stand tending or harvesting, or after accumulating from natural causes.

Sludge: A soft, thick mixture, deposit or sediment. Often a by-product of sewage treatment processes.

Softwood(s): Cone-bearing trees with needles or scale-like leaves; also refers to the wood produced by these trees. Softwoods belong to the botanical group gymnospermae and are the predominant tree type in coniferous forests.

Species at risk: A wildlife species that is facing extirpation or extinction if nothing is done to reverse the factors causing its decline, or that is of special concern because it is particularly sensitive to human activities or natural events.

Standing biomass: The amount of biomass that occurs on a given site at a particular time without reference to the rate of accumulation (i.e., kg/ha).

Stewardship: The science, art and skill of responsible and accountable management of resources.

Stocking: A qualitative expression of the adequacy of tree cover on an area in terms of crown closure, number of trees, basal area or volume in relation to a pre-established norm.

Subsistence: The minimum food and shelter necessary to support life.

Subsistence activities: Harvesting or growing products directly for personal or family livelihood.

Succession (successional trends): Changes in the species composition of an ecosystem over time, often in a predictable order.

Sustainable forest development: The development of forests to meet current needs without prejudice to their future productivity, ecological diversity or capacity for regeneration.

Trophic (web/status): Of or relating to nutritional relationships.

Troposphere: The portion of the atmosphere that extends outward approximately 11–16 km from the Earth's surface.

Turbidity: Reduced clarity or purity.

Ungulates: Any group of the hoofed mammals, of which most are herbivorous and many are horned.

Unspecified broadleaves: A group of hardwood trees not identified to the genus or species level.

Use values: Activities (e.g., subsistence food gathering, outdoor recreation, and hunting and trapping) where the individual directly uses or consumes a good or service from the forest.

Value-added production: Manufacturing that adds value to a primary product as it passes through various processing stages.

Variable-retention silvicultural system(s): Harvesting method by which some forest cover is retained.

Vitality: Capacity for ecosystems to maintain energy flow and endurance.

Vulnerable species: A species that is particularly at risk because of low or declining numbers, a small range, or for some other reason, but is not threatened.

Watershed: An area of land that is drained by underground or surface streams into another stream or waterway.

Wetland: Land that is seasonally or permanently covered by shallow water, or land where the water table is close to or at the surface. In either case, the presence of abundant water has caused the formation of hydrolic soils and has favoured the dominance of either hydrophytic or water-tolerant plants.

Wilderness: A part of our natural landscape that is sufficiently large and varied to constitute a more or less self-regulatory ecological unit, where human interference with the land, plants and animals is minimal, and where the beauty and character of the landscape has aesthetic, cultural or scientific significance.

SUBJECT INDEX

An "f" is used to indicate information that appears in a figure.

SUBJECT INDEX

SUBJECT INDEX

SUBJECT INDEX

SUBJECT INDEX

G

H

I

J

K

L

SUBJECT INDEX

SUBJECT INDEX

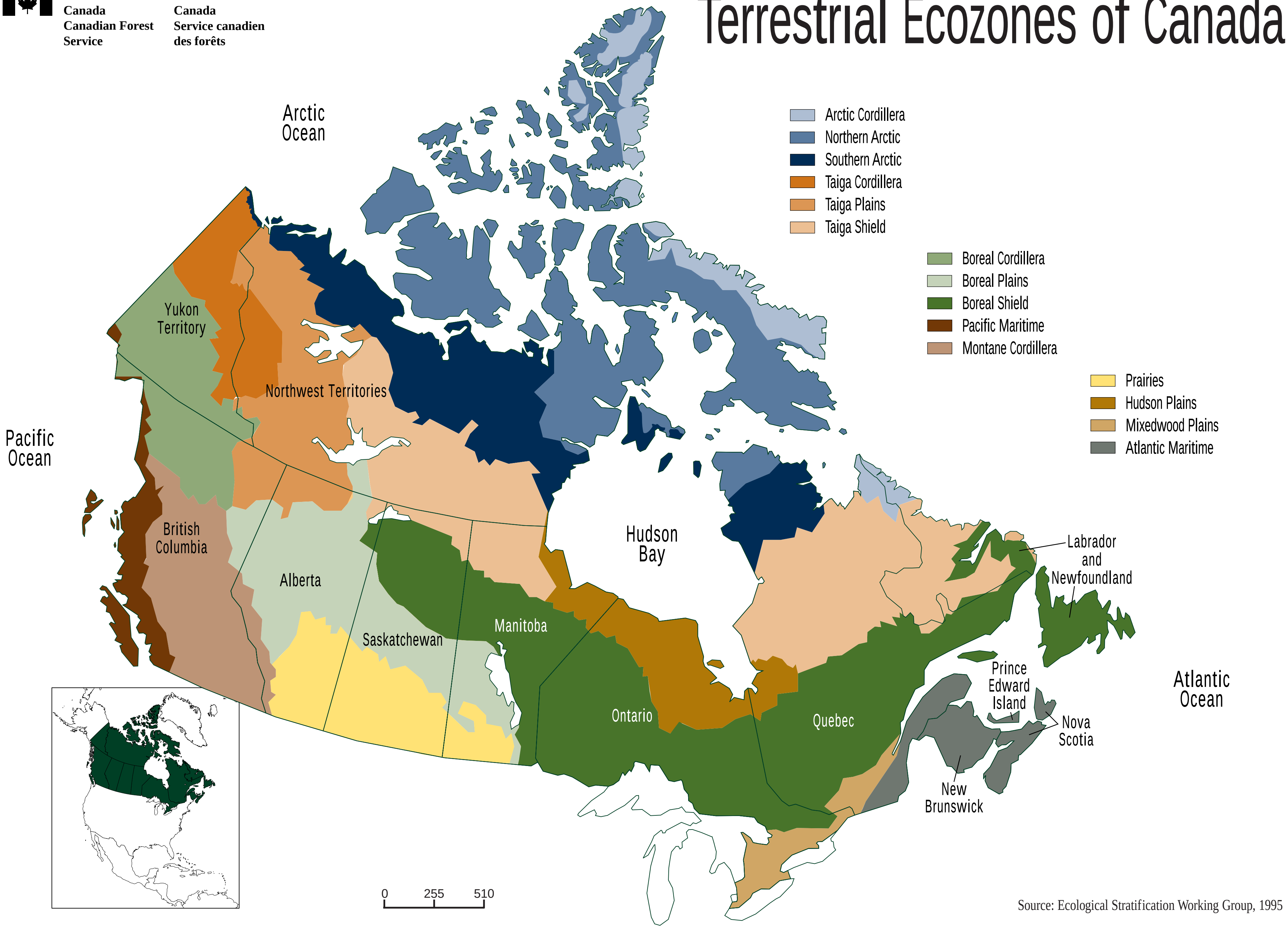
SUBJECT INDEX

SUBJECT INDEX

SUBJECT INDEX

Natural Resources Canada
Canadian Forest Service
Ressources naturelles Canada
Service canadien des forêts

Terrestrial Ecozones of Canada



Source: Ecological Stratification Working Group, 1995

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