


CANADA's LARGE INTACT FOREST LANDSCAPES

Edmonton, Alberta 2003

Global Forest Watch

Global Forest Watch is an international network that provides timely, accurate, and balanced information and analysis on forests and forest use to promote public understanding, informed decision-making, support for practical management solutions, and enhanced accountability. The World Resources Institute launched Global Forest Watch in 1997.

Global Forest Watch Canada

Global Forest Watch Canada is a partner in the Global Forest Watch network, and was formed to provide access to more complete information about development activities in Canada's forests and their environmental impacts. We are convinced that providing greater information about Canada's forests will lead to better decision-making on forest management and use, which ultimately will result in forest management regimes that provide a full range of benefits for both present and future generations.

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A report by Global Forest Watch Canada

By:
Peter Lee (Global Forest Watch Canada)
Dmitry Aksenov (Socio-Ecological Union International)
Lars Laestadius (World Resources Institute)
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Executive Summary

Canada's forests provide critically important benefits to the nation — ranging from their economic contributions via the forest products industry to recreational opportunities to life-sustaining ecosystem services, such as soil erosion control and watershed protection. The vast extent of Canadian forests represents one tenth of the world's forested area, one quarter of the world's temperate rainforests, and more than one third of the world's boreal (i.e., northern, conifer-dominated) forests.

Despite the importance and diversity of benefits derived from Canada's forests, until very recently Canadians had little access to information about forests other than timber production statistics. This is now beginning to change, with various national and provincial government agencies and other groups documenting and reporting on a wider range of forest values.

This report presents the results of a multiyear project to map Canada's large, intact forest landscapes and analyze their distribution and level of protection. Intact forest landscapes contain no visible signs of large-scale human activities such as agriculture, logging, mining, roads, pipelines, or powerlines. Mapping these landscapes is important for several reasons.

Intact forest landscapes are becoming increasingly rare at the global level, due in large part to their vulnerability to the effects of large-scale human interventions — effects that are not easily or quickly reversed. The remaining global tracts of intact forest landscapes have intrinsic value as part of the Earth's natural endowment. They are also growing in importance as benchmarks or reference points for understanding managed forest landscapes and designing management schemes that preserve or restore significant aspects of the natural forest landscape. Indeed, intact forest landscapes are areas of opportunity and responsibility, where all land use options — from development to conservation — are still open. They are areas in which the best available knowledge and technology can be applied to inform effective and responsible decision-making.

This project to map Canada's intact forest landscapes aims to increase knowledge about their extent and location, and to enable better decision-making by providing data in accessible forms for use by government, industry, and the public. It is the result of a unique collaboration among members of the international Global Forest Watch network and was carried out by Global Forest Watch Canada, partner organizations of Global Forest Watch Russia, and the World Resources Institute. The project builds on and extends previous work assessing forest intactness in Canada and is part of a larger effort by the Global Forest Watch network to map intact forest landscapes in important forest countries around the world. The methodology was initially developed by Global Forest Watch to map Russia's intact forest landscapes, and analysts from Global Forest Watch Russia have been key partners in this Canadian study.

For the purposes of this study, we define an intact forest landscape as a contiguous mosaic of natural ecosystems in a forest ecozone, essentially undisturbed by human influence, including both treed and naturally treeless areas. An intact forest landscape must be large enough to contain and support natural biodiversity and ecological processes, and to provide a buffer against human disturbance from surrounding areas. Hence, in this study, we decided to examine forest tracts of 50,000 hectares or larger that are at least 10 kilometres wide, and to refer to them as large, intact forest landscapes. Other forest areas may possess high conservation value, but mapping them was beyond the scope of this study.

This collaboration uses a modified version of the Russian methodology, tailored to suit Canadian circumstances. Compared with previous work on forest intactness in Canada, this study represents the most detailed national assessment undertaken, looking at a wider range of human disturbances and using satellite images and better ancillary information. The methodology involves identifying intact forest landscapes using high-resolution satellite imagery (Landsat data at a resolution of 30 metres on the ground and ASTER data at a resolution of 15 metres) as well as some medium-resolution Landsat data and ground and aerial photography verification.

The method presumes all forest landscapes to be intact at the outset of the study, and disturbed areas are systematically eliminated through successive efforts to detect positive evidence of human influence on the landscape. Thus, the search is for signs of human disturbance, not for signs of intactness, as the former are much easier to detect. This simple methodology and decision model enables mapping of intact forest landscape areas that is replicable, cost-effective, feasible at the continental level, at a scale of 1:1.5 million, sufficiently detailed to support practical decision making.

Numerous data contributors, advisors, and collaborators provided input throughout the course of the project, and reviews by stakeholders and experts improved the result. It is important to bear in mind, however, that this methodology likely overestimates the area of intact forest landscapes, as signs of disturbance are more likely to remain undetected than to be mistakenly identified.

Key findings arising from our mapping of Canada's large, intact forest landscapes are:

- **Canada retains extensive, globally significant areas of large, intact forest landscape.** More than half of Canada's forest area (and more than one third of the country's total land area) consists of large intact landscapes. More than one third of the area of these intact landscapes is naturally treeless, such as bogs and areas above the tree line in high elevation mountainous areas.

- **Large, intact forest landscapes are unevenly distributed across the country, with most found in northern Canada and at higher elevations in western Canada.** The most biodiversity-rich and productive forests, which are located in southern Canada, have been the most extensively influenced by human activity.

- **Northern boreal forest regions remain largely intact, but southern boreal regions have been broadly affected by modern land use.** More than half of the Boreal Shield, Canada's largest ecozone, is made up of large, intact forest landscapes. The northernmost boreal ecozones are least affected by human disturbance, with intact landscapes making up 89 percent or more of the study area in each of four northern boreal ecozones (Taiga Cordillera, Boreal Cordillera, Hudson Plains, Taiga Shield) and 61 percent in the Taiga Plains. The southernmost boreal regions have been considerably affected by industrial activity; for instance, the Boreal Plains ecozone retains less than one fifth (17 percent) of its area in large, intact forest landscapes.

- **Less than one third of temperate forest areas remains as large, intact forest landscapes.** Over 90 percent of this area is located in British Columbia, with the remainder in Alberta. Of these intact landscapes, more than half are naturally treeless, including high-elevation alpine tundra, ice, and rock in the western mountains. No large, intact forest landscapes remain in the Mixedwood Plains and Atlantic Maritime ecozones.

- **Québec and the Northwest Territories together account for more than one third of Canada's large, intact forest landscapes; combined with Ontario and British Columbia, they account for nearly two thirds of these landscapes.** Three provinces — New Brunswick, Nova Scotia, and Prince Edward Island — have no remaining large, intact forest landscapes.

- **Only a small portion of Canada's large, intact forest landscape occurs in protected areas.** Although national parks make up one third of Canada's protected areas, only 2 percent of large, intact forest landscapes are located in national parks. Boreal regions account for most of the area in protected, large, intact forest landscapes — about 21 million hectares versus 8 million hectares in temperate zones. However, a greater percentage of large, intact temperate forest landscape is subject to protection — about 27 percent, versus less than 10 percent for boreal landscapes. The majority of these protected temperate forest landscapes are naturally treeless.

- **First Nation historic treaty areas contain more than half (55 percent) of Canada's large, intact forest landscapes.** About one quarter of large, intact forest landscapes are contained in modern land claim settlements.

Global Forest Watch is committed to providing the best possible information for decisions on forest land use. Thus, we plan to work to refine and expand this analysis to include more detailed data, map smaller (between 5,000 and 50,000 hectares) undisturbed areas of forest landscape, analyze the location of social, economic, and conservation values in the forest landscape, and conduct studies tracking past and future forest change. We encourage the Canadian government, industry, and public to join us in these efforts.

Chapter 1. Introduction

Human activities have an impact on the world's forest ecosystems. Much of the original forest cover has been cleared for agriculture or otherwise impacted by various resource extraction activities, such as logging and mining.[1] Over the last several decades, the rate of forest change has increased substantially.[2] Various studies continue to document the ongoing loss of forest ecosystems.[3] As a result, undisturbed — or even intact — forest ecosystems are becoming increasingly rare and unevenly distributed across the world.[4]

A few countries, including Canada, still retain globally significant areas of forest ecosystems. Canada, with over 400 million hectares of forest,[5] contains one tenth of the world's forests, over one third of the world's boreal forest, one fifth of the world's temperate rainforest[6] and one quarter of the world's frontier forests.[7] Ninety-four percent of Canada's forests are on public land[8] and they are valued by Canadians for both their ecological and economic benefits.[9] Canada's forest ecosystems contain a wealth of biodiversity,[10] provide numerous opportunities for recreation,[11] and fulfill a number of important ecosystem needs including the protection of soils, the preservation of watershed functions, the moderation of climate and the sequestration of carbon.[12] Box 1 outlines the importance of forests to the Canadian economy.[13]

In the past, Canadians have had little access to forest information other than on timber production.[14] This is beginning to change. Government agencies and other groups are increasingly documenting and reporting on a greater range of forest ecosystem values. For example, Natural Resources Canada (Canadian Forest Service), in collaboration with Canada's provinces and territories, is developing a flexible forest monitoring system that addresses multiple conservation attributes. The British Columbia government has mapped intact watersheds, forest recreation resources and forest conservation themes,[15] and the Ontario government has mapped the state of Ontario's wilderness.[16] The Canadian Forest Service has mapped un-accessed forests using existing datasets of roads.[17] Global Forest Watch Canada and the World Resources Institute have mapped un-accessed forest areas in Canada[18] and North America[19] at a coarse scale, using existing datasets of roads and other access routes, and in some cases, expert advice.

Box 1. Importance of the Canadian forest economy.

The forest industry is worth $74 billion,[1] contributing more than $29 billion (2.9 percent) to the national GDP, and $34 billion (8.4 percent) toward the trade surplus in 2001.[2] The use of forest resources create direct employment for close to 353,000 Canadians, equal to 2.3 percent of total employment in Canada. Forests also provide a backdrop for a tourism industry worth several billion dollars.[3] Canada is the world's largest forest products exporter, accounting for 20.5 percent of all world forest product exports. In 2001, it ranked first in the world production of newsprint (24 percent) and second in both softwood lumber (21 percent) and wood pulp (16 percent).[4]

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This study is an additional contribution to the efforts of further data collection by mapping the extent and location of remaining intact forest landscapes in Canada that are at least 50,000 hectares. The objectives of the study are twofold:

1. To increase knowledge about the extent and location of intact forest landscapes in Canada.
2. To enable better decision making about intact forest landscapes by providing this data in accessible forms for use by government, industry and the public.

The purpose of this study is not to identify all forest areas in Canada with high conservation value, nor is it to set conservation priorities.[20] Rather, the intent is to complement existing studies and stimulate further study, as discussed in more detail below. The questions we set out to answer were: How much is left? Where are they located? How much is protected?

As noted, this work is part of a larger effort by the Global Forest Watch to map intact forest landscapes in important forested countries around the world.[21] To this end, and using Russia as a pilot country, Global Forest Watch has established a definition for intact forest landscapes, and developed a mapping methodology that uses a combination of satellite imagery, ancillary data sources and ground verification.[22] Combining the results of this study with preliminary results from mapping Canada, Alaska and Fennoscandia, Global Forest Watch has also produced a draft map of intact forest landscapes for the entire boreal zone of the northern hemisphere.[23] Resources permitting, this work will be extended into temperate and tropical areas in the future.

For the purposes of this study, we have mapped intact forest landscapes that are at least 10 kilometres wide and a minimum of 50,000 hectares. Further work on smaller areas of intact forest landscape is a high priority.

The intact forest landscape definition, concepts and criteria are discussed in greater detail in Chapter 2. However, key concepts and definitions are outlined below.

1.1 What Is Intactness?

Ecologists and conservation biologists use the terms *natural* or *naturalness*, and *ecological integrity* far more frequently than intact, but they essentially refer to the same basic concept. The term *intact* in relation to forests has been defined to mean that all the critical ecosystem components are present and structured in such a way that processes function within normal limits, and that component populations and functions will be maintained over time.[24] A number of major themes emerge in the scientific literature regarding these similar terms, including:

- ecosystems are said to be intact when ecosystem structure and (or) processes stay at a predefined baseline level;
- intactness is preserved when a system is permitted to change unaffected by human influence; and
- an ecosystem's ability to stay organized or self-correcting in the face of disturbance ensures the preservation of intactness.

An intact landscape is one that is able to maintain its biodiversity and ecosystem functionality over time as a dynamic property, rather than in any fixed, quantitative sense.[25] There is no place on Earth that has not been influenced by humans in some way, but some places have been more directly impacted and to a larger degree than others.[26] We know that intact forest landscapes begin losing components and natural functions as the impacts from human use grow and continue over time. Some ecosystem changes can be gradual (for example, loss of interior forest habitat over time), while others are rapid (for example, loss of a keystone species).

Intactness is not a binary quality but one of degree. One can envision a continuum ranging from least-impacted nature on one end to an urban development on the other. Quantifiable and replicable indices and scales of measurement are needed to help assign ecosystems as being intact on such a continuum. Although some progress is being made,[27] this area of applied research is still new.

If one desires to maintain the composition, structure and function of natural forest landscapes, size matters. It is not clear, however, how large a forest landscape must be to be considered intact. Two important size criteria are (1) the area needed to sustain a forest's natural disturbance regime, and (2) the full complement of large home ranges required by sensitive species. Operationally, the larger of the two should dictate any minimum size threshold. Key challenges, however, are that both criteria are difficult to rely on for determining absolute ecological thresholds for mapping intactness, and both vary greatly between forest types. Criteria on size are discussed further in Chapter 2.

1.2 How Do *We* Define an Intact Forest Landscape?

For the purposes of this work, an intact forest landscape is defined as a contiguous mosaic of naturally occurring ecosystems in a forest ecozone, essentially undisturbed by significant human influence. An intact forest landscape is a mosaic of various natural ecosystems including forest, bog, water, tundra and rock outcrops.

An intact forest landscape does not necessarily consist of old trees and may not even be entirely forested. In some cases, such as the bog-dominated landscapes of Canada's taiga ecozones and mountainous landscapes of western Canada, only 20 to 30 percent of the total area may consist of trees.

An intact forest landscape has the following characteristics:

- It is free from substantial anthropogenic fragmentation (settlements, roads, clearcuts, pipelines, power lines, mines, etc.);
- It is free from detectable human influence for periods that are long enough to ensure that it is formed by naturally occurring ecological processes (including fires, wind and pest species);
- It is large enough to be resilient to edge effects and to survive most natural disturbance events;
- It contains only naturally seeded indigenous plant species, and supports viable populations of most native species associated with the ecosystem.

By virtue of their size, intact areas allow all strata of biological diversity to co-exist in natural patterns, including large mammal species that are sensitive to human impact such as caribou, grizzly bear and wolves. The large size also allows natural disturbance factors, such as fire and wind, to play out in natural regimes. These natural disturbances are responsible for much of the structure and, ultimately, biodiversity of forest regions.[28] Smaller blocks of undisturbed forest landscape may have outstanding biological diversity value, but they lack the special features of intact forest landscapes.

Our definition of intact forest landscapes differs from other definitions and concepts in use (Table 1), as ours builds on the definitions of frontier forests.[29] It also builds on the un-accessed forests concept, as it is sensitive not only to access (roads) but also to other forms of human disturbance, such as logging. The use of new terminology reflects an effort to find a neutral term that is meaningful in many languages.

Table 1. Overview of forest intactness and conservation value concepts.

Intact Forest Landscape	A contiguous mosaic of natural ecosystems in the forest landscape, essentially undisturbed by human influence.
Frontier Forest	Relatively intact primary forests large enough to support viable populations of dominant indigenous species and to face catastrophic events. Natural events determine the structure and composition of these forests.[1]
Ancient Forest	Relatively undisturbed forests containing abundant and diverse wildlife and maintaining natural disturbance regimes. Human impact is limited to low-level hunting, fishing, harvesting of forest products, and shifting agriculture.[2, 3]
Endangered Forest	A forest that is naturally or anthropogenically rare, intact, otherwise ecologically important, or the site of human or indigenous rights violations or of illegal logging or trade.[4]
High Conservation Value Forest (HCVF)	A forest containing significant concentrations of biodiversity values as well as rare, threatened or endangered ecosystems; they encompass large landscape level forests, and forests providing basic ecosystem services in critical situations. HCVFs are essential to meet basic needs of local communities and communities' traditional cultural identity.[5]
Natural Forest	Stands of native trees unaffected by any type of exploitation or management, sustaining most of the key elements of a native ecosystem; however, they may lack abundance of mature trees and be subject to human disturbances.[6,7,8] Naturalized exotic species may exist if they do not significantly modify the original forest.[9]
Old Growth Forest[10,11]	A forest that has originated through natural succession and maintains significant portions of dead wood and old trees.[12] A multi-layered structure is often present. The forest may be at a climax stage.[13, 14]
Primary Forest	A forest of any age that has never been logged or converted and still maintains its natural disturbance regimes and processes. Slight use by indigenous and local communities may occur.[15, 16]
Pristine Forest	A forest that has never been disturbed, spoiled, corrupted or polluted by humans.[17]
Semi Natural Forest	Stands of native trees grown naturally or accidentally on sites not suited for development, exploitation or management.[18]
Virgin Forest	Original, natural mature forest of any age that has never been significantly influenced by humans.[19]

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1.3 Why Is It Important to Map Intact Forest Landscapes?

Locating and mapping intact forest landscapes is important for a number of reasons. Large, undisturbed forest ecosystems and landscapes are becoming increasingly rare at the global level (Table 2). Intact forest landscapes provide a reference against which managed forest landscapes can be compared and understood. Some would argue that intact forests have intrinsic value as part of the Earth's natural endowment and need to be considered along with other values in decision-making. They are landscapes for which a full range of management options — from protection to development — are possible. As intactness cannot easily be artificially restored nor can biodiversity be easily maintained within a managed forest landscape,[30] using a precautionary, decision-making approach is desirable (see Box 2).

Several companies have adopted policies that relate to intact forest ecosystems and which require maps for their implementation. For example, the purchasing policy of IKEA demands that wood in solid wood products "does not originate from intact natural forests, unless they are certified according to a standard recognized by IKEA."[31] Other retailers, such as Home Depot, Staples and Lowe's have adopted purchasing policies that relate to "endangered forests," a concept in which elements of intact forest landscapes could be included.[32]

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11. The United States Forest Service (USFS) has adopted a generic definition for old-growth although it has also developed definitions for each of the major forest types in the United States. U.S. Department of Agriculture, Forest Service, U.S. Department of the Interior, Bureau of Land Management. 2000. Definitions for Old Forests. Interior Columbia Basin Ecosystem Management Project. Supplemental Draft Environmental Impact Statement. Volume II, Appendix 17a. (Available online at http://www.icbemp.gov/pdfs/sdeis/Volume2/Appendix17a.pdf) (6/9/03)
12. StoraEnso (*op cit.*)
13. [FSC-US] Forest Stewardship Council—United States. (Available online at http://www.fscus.org/about_fsc/who_we_are/glossary_of_terms.html#o) (6/9/03)
14. Silva Ecosystem Consultants. 1992. Old Growth Literature Review. (Available online at http://www.silvafor.org/publications/library/docs/Old%20Growth%20Ecology.pdf) (6/9/03)
15. Convention of Biological Diversity: Indicative definitions taken from the Report of the ad hoc technical expert group on forest biological diversity (http://www.biodiv.org/programmes/areas/forest/definitions.asp) (5/28/03)
16. StoraEnso (*op cit.*)
17. *Ibid.*
18. Ministry of Agriculture and Forestry, Finland.1998 (last updated online). European List of Criteria and Most Suitable Quantitive Indicators. Ministerial Conference on the Protection of Forests in Europe. June 16-17 1993 in Helsinki. (Available online at http://www.mmm.fi/english/forestry/policy/minkonf/criteria.htm) (6/9/03)
19. StoraEnso (*op cit.*)

The forest certification standard of the Forest Stewardship Council assigns high conservation value to "large landscape level forests" in which "viable populations of most, if not all naturally occurring species exist in natural patterns of distribution and abundance."[33] Several Canadian governments — British Columbia, Ontario and Nova Scotia — have also adopted policies that address the maintenance of large, un-fragmented forest landscapes.[34]

1.4 Other New Datasets

Several new spatial datasets (besides intact forest landscapes) were compiled as part of this work. A national protected areas dataset was compiled from a wide variety of sources in order to begin developing an understanding of their distribution and extent in relation to intact and non-intact forest landscapes. Based on satellite imagery, a northern forest line was established to determine the northern study area boundary. And finally, a draft national dataset of forest fire burn areas for approximately the last 50 years was compiled to assist in the identification of intact forest landscapes. Further details are provided in Chapter 2.

1.5 Structure of the Report

The remainder of this report presents an overview of the methods, results of the analysis, and a series of maps. Chapter 2 describes how the study area was determined and the criteria that were used to define intact forest landscapes. Chapter 3 describes how satellite images and other information were used to map intact forest landscapes. Chapter 4 presents and discusses the results. Chapter 5 summarizes key conclusions and suggests priorities for further research. The Annex provides a summary of the review process used by Global Forest Watch Canada and Global Forest Watch during the course of this study.

Table 2. Change in frontier forest cover.[1]

	Remaining forest cover as % of forest cover 8000 years ago	*Remaining frontier forests*		
		As % of current forest cover	As % of original forest cover	% under threat
South America	70	65	46	54
Canada and US	78	44	34	26
Russia	69	43	29	19
Oceania	65	34	22	76
Central America	55	18	10	87
Africa	34	23	8	77
Asia	28	20	6	60
Europe	32	1	0.3	100

Source:

1. Bryant, D., Nielsen, D., and Tangley, L., 1997. *The Last Frontier Forests: Ecosystems and Economies on the Edge.* World Resources Institute, Washington, D.C., 42 pp. Available for purchase at: http://forests.wri.org//pubs_description.cfm?PubID=2619 (5/7/03).

Box 2. The precautionary approach.

With the full support of the provinces and territories, Canada was the first industrialized country to ratify the United Nations Convention on Biological Diversity, which came into force on December 29, 1993, following the United Nations Conference on Environment and Development, Rio de Janeiro, June 3 –14, 1992 ("Earth Summit").[1] By ratifying the Convention on Biological Diversity, Canada entered into specific obligations to the international community with respect to conservation of biodiversity, including:

- To manage a protected areas system for conservation of biodiversity (Art. 8 [b]), and to manage areas adjacent to protected areas to conserve biodiversity (Art. 8 [e]);
- To protect terrestrial ecosystems, natural habitats and species throughout their natural ranges (Art. 8 [d]) and to manage biological resources important for the conservation of biological diversity (Art. 8 [c]); and,
- To integrate considerations of the conservation and sustainable use of biological diversity and resources into policies and decision-making (Art. 6 [b] and 10 [a]), and to adopt measures relating to the use of biological resources to avoid or minimize adverse impacts on biological diversity (Art. 10 [b]).

To meet these obligations, the Convention on Biological Diversity notes the precautionary approach is relevant: "where there is a threat of significant reduction or loss of biodiversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat."[2] Further, the Rio Declaration on Environment and Development, the report of the "Earth Summit," stated that "in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities."[3] The precautionary principle was re-affirmed at the World Summit on Sustainable Development, Johannesburg, August 26 – September 4, 2002,[4] and has been recognized in Canadian law.[5]

1. Convention on Biological Diversity. Concluded at Rio de Janeiro, 5 June 1992. Entered into force, 29 December 1993. 31 I.L.M. 818(1992), (the "Convention on Biological Diversity") available on-line at http://www.biodiv.org/convention/articles.asp (July 2, 2003) and Canada, Canadian Biodiversity Strategy – Canada's Response to the Convention on Biological Diversity (Hull: Supply and Services Canada, 1995) p. 9.
2. Convention on Biological Diversity, preamble, para. 9.
3. United Nations Environment and Development. 1992. Rio Declaration on Environment and Development. Principle 15. Available at: http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm. (6/19/03).
4. United Nations Division for Sustainable Development. 2002. Johannesburg Plan of Implementation. Section X, Subsection 109(f). Available at: http://www.un.org/esa/sustdev/documents/docs.htm. (6/19/03).
5. The Supreme Court of Canada has recently recognized the precautionary principle: "where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation." 114957 Canada Ltee (Spraytech, Societe d'arrosage) v. Hudson (Town), 2001 SCC 40, para. 31, available on-line at http://www.lexum.umontreal.ca/csc-scc/en/pub/2001/vol2/html/2001scr2_0241.html (May 17, 2003).

Chapter 2. Intact Forest Landscapes: Study Area, Definitions and Criteria

This chapter describes the criteria that were used to delineate the study area and within it, the intact forest landscapes. Chapter 3 describes how these criteria were applied to delineate Canada's large intact forest landscapes.

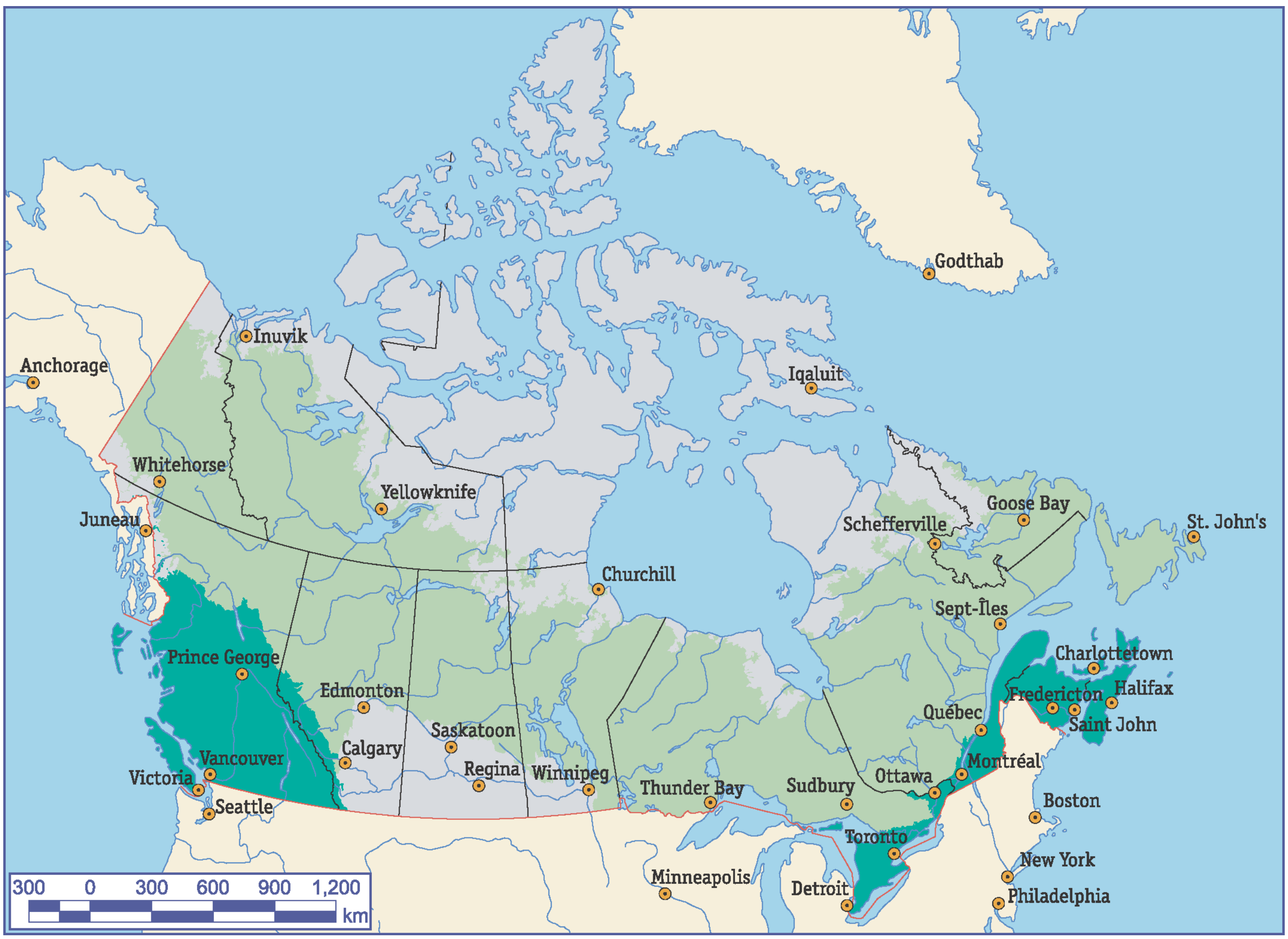


Figure 1. Study area

Study area:

Boreal forest landscapes	Area outside the study area
Temperate forest landscapes	Provincial and territorial boundaries

2.1 Study Area

The study area for this project covers 601 million hectares of Canada's 998 million hectares of overall land area[1] (Figure 1). We defined the study area using a number of criteria, including Canadian ecozones, forest boundaries and national boundaries. The rationale is described below, while more technical notes are given in section 3.1.

2.1.1 Ecozones

There are 15 ecozones within the National Ecological Framework for Canada (see Figure 2). Of these, 11 are forest ecozones: the Pacific Maritime, Montane Cordillera, Boreal Plains, Boreal Shield, Mixed Wood Plains, Atlantic Maritime, Boreal Cordillera, Taiga Cordillera, Hudson Plains, Taiga Plains, and Taiga Shield. There are also five predominantly non-forested ecozones: the Prairies, Hudson Plains, Southern Arctic, Northern Arctic and Arctic Cordillera.

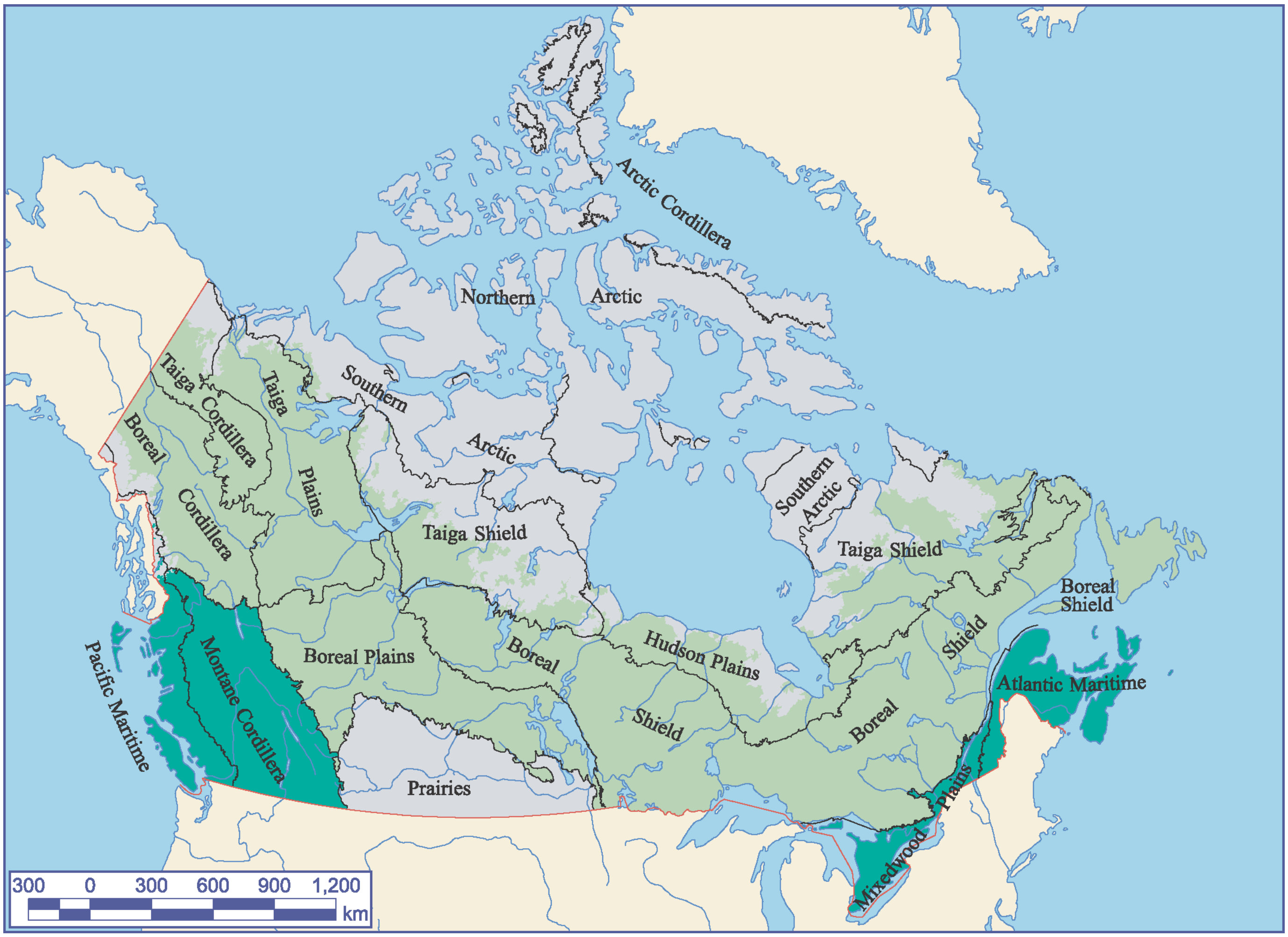


Figure 2. Terrestrial ecozones of Canada and northern forest boundary

Study area:

Boreal forest landscapes

Temperate forest landscapes

Area outside the study area

Terrestrial ecozones' boundaries

For the purposes of our study, we eliminated some ecozones at the outset. The Prairies ecozone, which is naturally predominantly treeless, was excluded. Additionally, we excluded the Arctic Cordillera and Northern Arctic ecozones, as both are far beyond the limits of the treeline. We then defined a northern forest boundary (see Figure 2 and description in section 2.1.2). This step eliminated most of the Southern Arctic ecozone and portions of the Taiga Cordillera, Taiga Shield and Hudson Plains ecozones. Seven ecozones are fully contained within the study area (Pacific Maritime, Montane Cordillera, Boreal Plains, Boreal Shield, Boreal Cordillera, Mixed Wood Plains, and Atlantic Maritimes). It is important to note the total areas used in our study do not always match the exact land area of ecozones given in national statistics.

2.1.2 Northern Boundary

As trees get successively smaller and sparser at northern latitudes and high altitudes, the northern edge of the forest can be diffuse. Since an intact forest landscape often changes gradually into an equally intact tundra landscape, drawing the northern boundary of a forest landscape is a difficult task. The outcome depends on the definition used for forest and does not reflect any change in the degree of intactness.

The boundary of forests given on topographical maps and existing digital datasets could not be used to represent the northern boundary of closed forests, or the northern forest boundary. While it corresponds to the previous internationally agreed definition for closed forest (canopy density more than 20 percent canopy, tree height more than 5 to 7 metres), an analysis of Landsat satellite images suggests that the existing maps and digital datasets are partly out of date and show areas of southern tundra shrubs and sparse woodlands as being forests.

The northern forest boundary for this study was drawn based on medium resolution images (Landsat preview images with a resolution of 300 metres). All tree-covered areas exceeding 20 percent canopy density and more than 2 kilometres in width were classified as forest. Narrow strips of forest occurring along the boundary — such as denser forests typically found along river valleys — were classified as part of the treeless tundra zone outside of the study area, as were areas of trees with less than 20 percent canopy density. Natural fragments of forest north of the boundary were not assessed for intactness due to insufficient information. The boundaries of such areas are shown on the maps as a separate category without any division into classes of intactness.

2.1.3 Southern Boundary

The southern boundary of the study area is defined by the Prairie ecozone boundary and by the national border between Canada and the United States. Intact forest landscapes were mapped only within the political boundary of Canada and adjacent areas in the United States of America were not considered. Thus, some blocks of trans-boundary intact forest landscapes may have been excluded.

2.2 Criteria for Intactness

Intactness is based on a number of criteria, as discussed briefly in the introduction. This is discussed in greater detail in the following sections.

2.2.1. Smallest Viable Area of an Intact Forest Landscape

The size of a natural landscape is of considerable importance to its ecological viability. If a block is too small, it does not allow all essential components of the intact landscape to be conserved in their natural state. For example, considerable space is required for viable populations of large predatory vertebrates to coexist with the full range of natural ecological functions (including disturbance regimes such as resulting from fires and insects). Upwards of tens of thousands of hectares, sometimes as much as hundreds of thousands of hectares, are needed to support these populations.[2]

Forest blocks that are not large enough may also fail to provide sufficient protection against edge effects due to anthropogenic influence,[3] or to the influence from disturbed and transformed areas outside the boundary of the intact forest landscape. Disturbances to neighbouring fragmented areas have greater impacts on the perimeter rather than the interiors of intact forest landscapes. Typical examples of edge effects include biological contamination (such as invasion by non-native species), and hydrological changes caused by the draining or water-logging of fragmented areas. People rarely visit the central parts of large, non-fragmented natural areas, making these central areas less likely to be as affected by human activity.

Different species and processes clearly occur at differing spatial scales, but the size of the space required by the combination of processes and species is difficult to establish with great certainty. The risk of an area being too small decreases as the threshold size increases, but the desire to have a next-to-zero risk for the most area-demanding species (such as wolf-caribou interactions) and processes (such as large natural fires) would require a very large threshold size of at least several hundred thousand hectares.

Nature reserve design principles help explain the importance of large size for natural landscapes in maintaining ecological integrity. Based originally on island biogeography theory,[4] size was proposed as an important consideration in planning mainland nature reserves[5]. There are some problems associated with projecting island theory onto mainland system reserves; for example, attributes of, and processes in, mainland systems are usually far more directly influenced by the adjacent landscape (sometimes referred to as the matrix) than in true island systems.[6] However, the importance of large reserves is widely accepted because they:

1. generally contain more species;
2. generally support larger populations of certain species with greater genetic variability leading to greater population viability;
3. have a better chance of incorporating natural disturbances than smaller ones; and
4. contain a greater area of interior habitats buffered from the negative effects of edges.[7]

There are two approaches to the question of how large an area would have to be to maintain the natural composition, structure, and function of a natural forest landscape in a forest landscape unit. One approach involves multiplying the mean patch size of disturbance by 50 to determine the minimum dynamic area.[8] Based on the available data on fires for one study area in northwest Alberta from 1961 and 1995, the minimum dynamic area using this technique would be approximately 12,500 hectares.[9]

The second involves a minimum size of about four times the size of the largest and most severe disturbance event.[10] For Canada's boreal region, where some individual fires reach 200,000 hectares in size (and have even been recorded at over 1 million hectares)[11], the minimum dynamic area would be at least 800,000 hectares. There is obviously a huge difference between 12,500 and 800,000 hectares, but these figures give a sense of the magnitude of the size required.

In trembling aspen forest stands of western Canada, phase gap dynamics (the loss of individual trees or small clusters of trees due to aging, wind or ice) are an important natural disturbance regime, which impacts 4 to 17 percent of all forest stand areas. The mean gap area is 52.3 square metres.[12] In boreal and subalpine conifer forests, studies have documented mean gap areas ranging from 41 to 200 square metres.[13]

If the minimum dynamic area was calculated from this disturbance agent, a single area could be quite small. However, in this forest ecosystem, the area requirements for some important forest species exceed the minimum dynamic area based on the dominant disturbance agent. For example, black bears are mammals with large territories. Home ranges differ considerably based on various environmental factors such as food productivity, den site availability, and abundance of escape habitat. In one study, home range needs for female black bears without young ranged between 750 and 930 hectares.[14] Maintaining bear populations would require tens of thousands of hectares.

It may not be practical or necessarily ecologically desirable, however, to think in terms of how large a single forest landscape unit must be to be considered intact. We already know that wild nature needs to occupy large areas to be sustained — the larger the building blocks the better. In light of continuing human pressures on our forests, however, it might be wiser to ask how much natural forest area remains, in what configuration (including size and spatial arrangement), and is it protected and to what degree.

The most pragmatic and ecologically meaningful objective is to identify and map the best remaining examples of relatively intact forest landscapes rather than choosing a single size *a priori* that likely meets all criteria. This should be done on an ecoregional basis since ecoregions are widely believed to be the most ecologically useful organizing unit for conservation purposes.[15]

Starting with the largest remaining forest landscape units and working down to smaller units, intact forest mapping should be carried out. Science should single out potential starting points for criteria such as landscape unit size and level of fragmentation, and identify where more detailed mapping has little value at the ecoregional scale. For example, forest landscape units smaller than 5,000 hectares in a boreal ecoregion where the landscape is largely intact makes little sense. However, in coastal temperate rainforests, such as those in British Columbia that are characterized by many forest islands and mountain watersheds, a minimum size below 5,000 hectares may be useful and warranted.

As a first step in mapping intact forest landscapes in Canada, we chose to map only the largest remaining areas due to resource limitations. The size criteria for these large intact forest landscapes were set at:

- A minimum area of 50,000 hectares;
- A minimum internal width of 10 kilometres (i.e., the diameter of the smallest circle that can be placed inside the contours of an area); and
- A minimum 2 kilometres width of protrusions along an intact boundary (i.e., the edges were "smoothed" to eliminate narrow peninsulas).

Further mapping of smaller-sized areas is desirable and is a priority for future efforts. Work undertaken appropriate to the type of forest ecosystem is especially needed.

This approach of mapping large intact forest landscapes does not imply that smaller areas possess lower conservation values. The complex issue of conservation values and priorities in smaller blocks of forest landscape fall outside the scope of this study.[16]

Wildlife avoidance of developed and fragmented areas occurs over a much larger area than that of the physically altered footprint of development.[17] The extents of the zones within which wildlife will become affected by infrastructure vary according to species, season, type of disturbance, habitat, and other environmental factors, and the effect of human development is species-specific. While some studies have suggested that wildlife and industrial development are highly compatible, most studies that include both specialist and generalist species, conclude that total species diversity declines with increasing human development.

2.2.2. Important Types of Human Influence

Every place on Earth has been exposed to human influence at some time, and has been modified, inhabited or managed in some way.[18] In this sense, humans are part of forest ecosystems. Human disturbance of the forest landscape has changed over time, however, and there are degrees to which activities modify these forest landscape systems.[19] In order to be meaningful, any application of the definition of intact forest landscapes must reflect the fact that intact forest landscapes are not "wild" in a true sense, but are the best well-preserved remaining examples of naturally functioning forest ecosystems.

It is both interesting and useful to delineate the intact portion of the forest landscape. This involves distinguishing between areas that are more or less disturbed; that is, between areas shaped by "substantial" human influence and those affected by "non-substantial" or "background" influences. Intact areas should show no signs of having been substantially modified by human activity or subject to industrial land use for the last six to seven decades (see Figure 3).

Many human disturbances that occurred during the past 60 to 70 years were identified in the satellite imagery used in this study. Types of disturbance that are visible in high-resolution satellite imagery (i.e., 15 and 30 metre resolution) include agricultural clearings, urbanization, logging sites (especially clearcuts), linear features such as roads, and industrial infrastructure. Further details are given in Chapter 3.

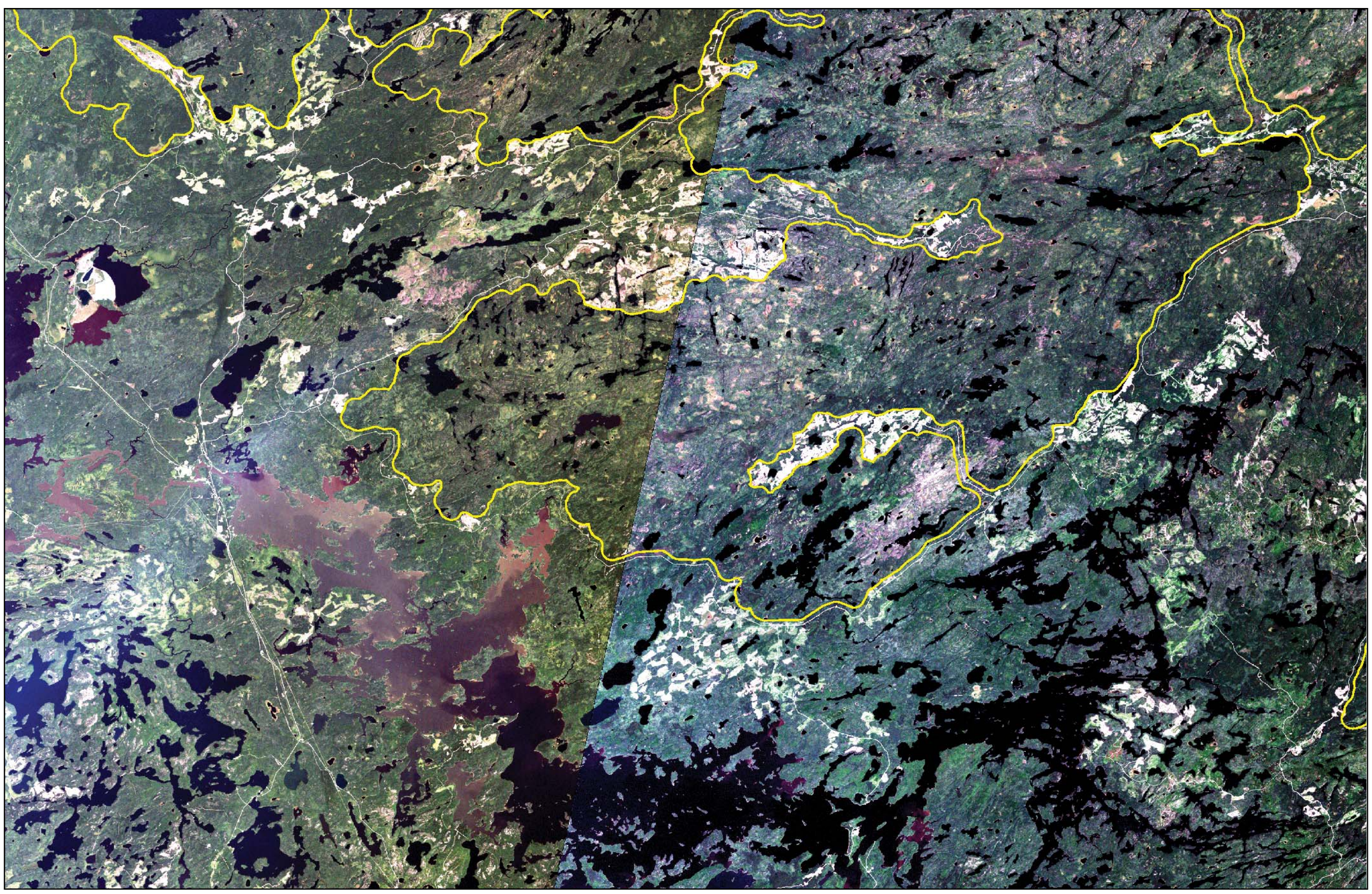


Figure 3. Significant kinds of human-caused disturbance

The yellow line placed over Landsat-7 satellite images indicates the boundary of an intact forest landscape. Significant kinds of human-caused disturbance shown in this picture include a small settlement, roads and clearcuts. The fire scar in the lower right side of the images (pink colour) is considered part of the intact forest landscape.

Two groups of human activities were classified as background influences:

1. Non-industrial, historic forms of human activity and more recent analogous activities were either not detectable using satellite imagery, or were treated as evolutionary factors in today's forest landscapes rather than disturbances:
   - hunting, fishing, mushrooms and berry picking (including construction of seasonal cabins);
   - grazing, excluding cases of overgrazing with grass cover degradation;
   - swathing, baling and stacking small hayfields remote from the large areas of agricultural lands (for example, floodplains of small forest rivers),
   - selective logging for local, small-scale industrial needs, and high-grading for certain species such as White Pine (*Pinus strobus*) in eastern Canada and other species throughout southern Canada, unless the effect of logging was detectable in satellite images;[20]

2. Human-induced forest fires (see section 2.3).

Additionally, two groups of activities were very difficult to map using remote satellite imagery. These were:
1. Industrial types of human activities that occurred more than 40 to 70 years ago. Influences such as these cannot be detected or confirmed by remote sensing using Landsat imagery (see section 2.2.3).
2. Effects of global or regional-scale human influence. Impacts from these activities, such as air pollution and climate change, could not properly be assessed at this time although they may have had, or are currently having, impacts.

All other types of human influence were, in principle, considered significant. An intact forest landscape, by definition, is one that has not been substantially affected by human influences. For the purposes of the study, however, positive evidence of any disturbance was required before an area was classified as non-intact. Consequently, the resulting intact forest landscape areas are likely an over-estimation. Higher resolution imagery would be needed to increase the accuracy of the intact forest landscape areas.

2.2.3. Minimum Time Since Disturbance

Human activity has shaped Canada's forests for millennia. Either directly or indirectly, people have been a cause of forest fires since European colonization, and even before that in some regions.[21] In many cases, it is impossible to tell to what extent a feature in the forest landscape, such as fire disturbance, is the result of natural processes such as lightning, or of human influence. The landscape has evolved through interaction with this human influence. Only the detectable traces of recent human activities are therefore considered as substantial signs of disturbance (as noted in the previous section).

Much of the disturbance of Canada's forests by industrial land use is recent, at least on a forest time scale. Several centuries of European colonization have modified the landscape substantially in Newfoundland, and in the southern areas of other provinces in eastern and western Canada. This modification includes changes in dominant tree species, or even a conversion (from forest) to heathlands over large areas. The forestry sector only began to cut large amounts of trees, however, at the end of the 19th century.[22]

In many parts of Canada, including Alberta, the expansion of the petroleum and forest industrial sectors did not occur until after the Second World War and the 1980s, respectively.[23] Logging in Canada increased substantially in the latter half of the 20th century. The total area logged annually has increased by 51 percent in just a 25-year period, from 680,000 hectares in 1975 to over 1 million hectares in 2000.[24] The petroleum industry has contributed to disturbances since the mid-1900s, with a rapid increase beginning in the early 1970s.[25]

The earliest forest cutting that can still be detected in high-resolution (Landsat) images generally occurred from the 1930s to 1940s. In some highly productive sites, such as the western temperate forests, only logging that occurred after the 1960s can be detected. All logging before this time was considered to be a non-substantial disturbance for the purposes of this study, unless it was evident in recent Landsat imagery or supported by reliable, spatially explicit ancillary information. Many of these sites are likely undergoing spontaneous restoration and will return to a natural forest condition if left undisturbed. Other sites may remain permanently changed due to early human disturbances.[26]

It is conceivable that areas significantly impacted by past human activities have been classified as intact forest landscapes. Such areas may be different in forest structure and composition and have not yet recovered, yet specific human disturbance is not evident in recent satellite imagery.

2.3 Natural Disturbances

The forest landscapes of Canada are subject to several types of large- and small-scale natural disturbance, such as fire, insects, wind, flooding, and mortality and falling of individual trees.

The most important of these disturbances is probably fire. Forest fires occur naturally in most forest landscapes in Canada, and are a significant dynamic factor where it occurs. Areas not significantly affected by fire include portions of the temperate forest ecozones, some areas in the boreal and taiga ecozones (including large regions of moist forest), and some portions with specialized characteristics, such as riparian forests. Government records show that lightning strikes are responsible for most of the area burned by forest fires.[27] The area burned varies greatly from one year to another. Large fires are generally associated with so-called fire years in which extreme weather conditions, including extended periods of hot, dry weather, make the forest highly susceptible to burning.[28] The vast majority of all managed and unmanaged fires are less than 5 hectares in size but in extreme fire years, individual fires can cover 100,000 to 200,000 hectares, and have been recorded at 1 million hectares and 1.4 million hectares.[29]

Over a long period of time, a natural fire regime will produce a certain structure in the forest landscape. Consequently, modifications in the fire regime will also affect the landscape. The increase in fire frequency due to modern settlement and land use in some areas will increase the area of forest that is in young successional stages, decrease the number of fire refuges, and change the water balance along with the soil permafrost horizon and the intensity of erosion. The decrease in fire frequency owing to recent increases in fire suppression efforts in other areas will increase the area of forest in older successional stages, as well as increase the number of fire refuges, and also affect the water balance.

Although the effect of an individual fire does not depend on its origin, the combined effect on the landscape of all human-caused, human-suppressed, and natural fires is different from that of a strictly natural fire regime. To credibly identify and spatially separate human-caused, human-suppressed and natural fires post-facto is very difficult, and was beyond the means and expertise of this study. Therefore, a simple decision rule had to be adopted. All fires were considered natural, that is, as part of a natural fire regime. As a consequence, burned areas were consistently treated as a sign of natural disturbance and therefore as a legitimate part of the intact forest landscape.

It could be argued that fire suppression has altered the ecological processes of many forest ecosystems in Canada. It would be difficult, if not impossible, to separate landscapes into intact and non-intact based on either types of change to the natural fire cycle.

This approach to fire represents an important modification to the mapping approach used in Russia.[30] In that work, an attempt was made to separate natural and human-caused fires. A schematic decision rule was constructed, according to which fire scars adjacent to infrastructure were treated as human-caused. This decision rule reflects the increased probability that a fire in the vicinity of infrastructure would either have been caused by humans and/or that human influence would affect the post-fire succession and/or lessor investments in fire suppression efforts.

Other natural disturbances have a strong impact on the forest landscape. Tree mortality caused by insects is estimated to be 1.5 times that due to fire, although this is widely variable in space, time and severity of effects.[31]

Wind and flooding are other significant natural landscape-level disturbance factors. A widespread agent of small-scale disturbance of mature forest canopies is the falling of individual trees. The resulting canopy gaps play a significant role in the ecological dynamics of coastal rainforests and an important role in many boreal and taiga forests.[32]

In this study, all the above-mentioned disturbances were considered to be entirely natural, that is, not human-caused. Consequently, they did not affect the delineation of intact forest landscapes. The next chapter outlines the technical specifications of the methodology used to delineate the intact forest landscapes.

Chapter 3. Methods

This study maps large, intact forest landscapes in Canada using a modified version of a methodology developed by Global Forest Watch Russia to map intact forest landscapes in Russia.[1] This chapter describes the overall method, key differences in analysis from the Russian approach, data used for analysis, and the key technical decision-making processes.

3.1 General Mapping Approach

All forest landscapes were presumed intact at the outset of the study. Forest landscapes were then systematically eliminated through the mapping methodology, which employed a stratified approach that used increasingly detailed datasets. Initially we used inexpensive, accessible and previously purchased datasets of roads, pipelines and populated areas, to eliminate disturbed areas. As the study area was reduced, more detailed data in the form of remote sensing imagery, well site data and pipeline data, were acquired to assist in detecting additional industrial activities, including logging, mining, and oil and gas facilities, for which comprehensive publicly available digital datasets do not necessarily exist. The approach is described in more detail in section 3.3

This approach was adopted owing to information constraints associated with both cost and availability of data. A two-step approach made it possible to exclude large areas from further analysis on the basis of readily available and affordable information, which led to substantial savings in work time and data costs.

Analysis was conducted in a Geographic Information System (GIS) environment using ESRI's ArcView v. 3 series and Leica Geosystems' Geographic Imaging software (formerly ERDAS). Most vector layers used were in decimal degrees projection, and all vector and raster layers were interactively projected in the Lambert Conformal Conic projection.[2] This projection is extensively used in ellipsoidal form for large-scale mapping of regions of predominantly east–west extent, including many maps in the International Map of the World (1:1,000,000 scale) series, and topographic mapping in many nations.[3] The GIS environment allowed interpreters to identify signs of human disturbance, measure and delineate the area of the territory, and prepare the final maps for publication.

3.2 Data

As noted in section 3.1, a range of data was used to undertake this study. This chapter describes the different types of data, sources, and key technical issues and challenges.

3.2.1 Satellite Imagery

Satellite images were the main source of data for step 2 (section 3.3). A number of different satellite imagery types were used (see Figures 4 and 5), as follow:

- Landsat 7 ETM+: approximately 700 images, mostly from the summer season for the period 1998 to 2002.[4] These images have a resolution of 28.5 metres.
- Terra ASTER: approximately 200 images, mostly from the summer season from the period 1999 to 2000.[5] These images have a resolution of 15 metres.

- Landsat 5 TM: approximately 300 images from the late 1980s to early 1990s.[6] These images have 30 metres ground resolution.
- Landsat 5 TM Outlooks: approximately 200 images from the late 1980s to early 1990s. These images consist of three channels and are compressed, and thus only have a resolution of 300 metres.

Landsat 7 ETM+ was the preferred imagery type because of its resolution. Owing to cost constraints and availability limitations, however, we used Landsat 5 TM scenes to fill in gaps in coverage. These gaps were mostly in remote areas. Most of the Landsat 5 scenes were available only as merged individual images in compressed format (resulting in some loss of the information), with only three spectral channels. We used ASTER to help fill in gaps in Landsat coverage and to identify additional disturbances related to energy developments in the Western Canada Sedimentary Basin, as this imagery's 15 metre resolution is able to detect some seismic activity.

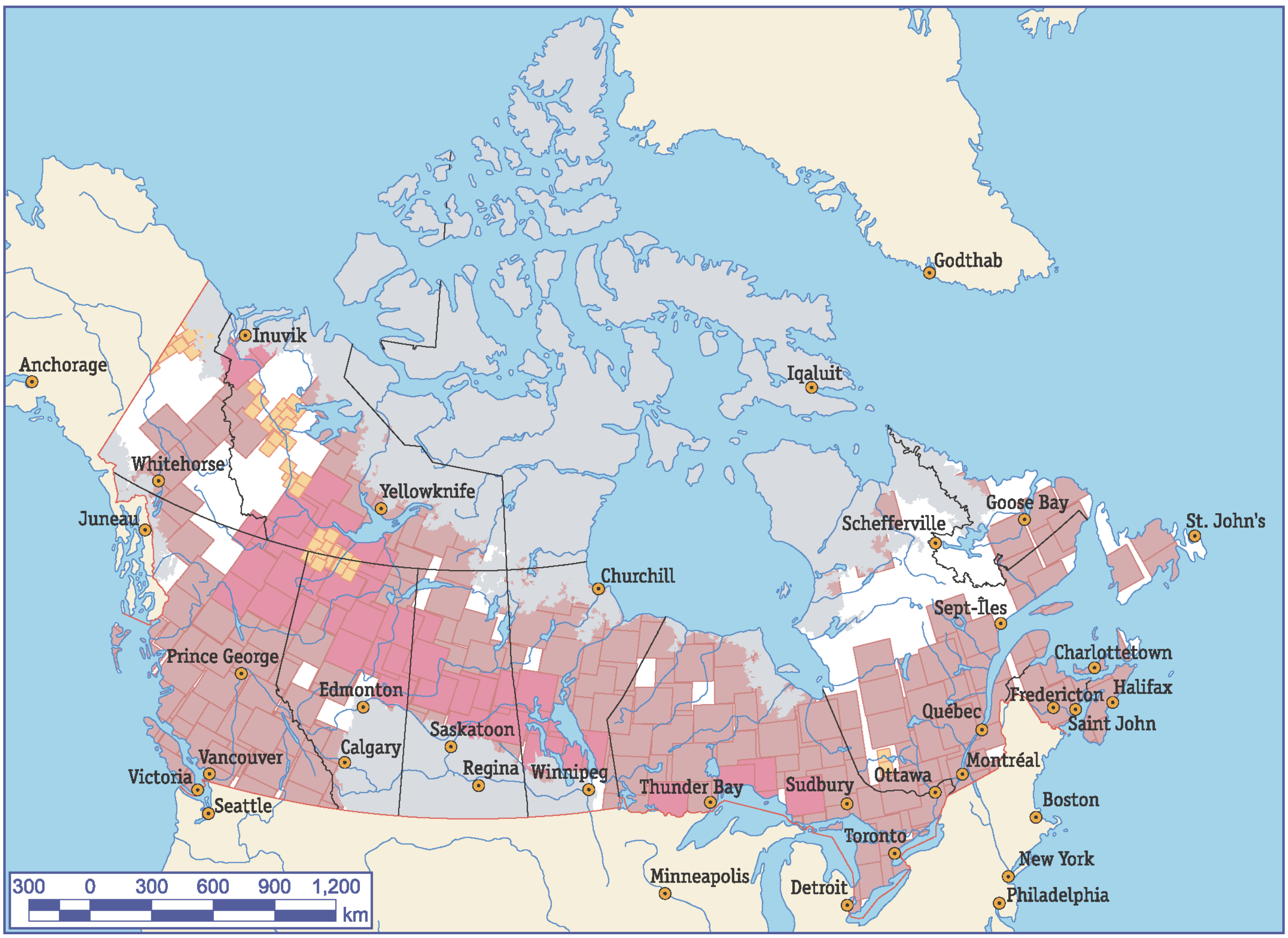


Figure 4. Landsat 7 and ASTER imagery used in this study

- Landsat 7 UTM+, spectral 30 m resolution channels only used
- Landsat 7 UTM+, spectral channels used along with panchromatic (8th) 15 m resolution channel
- Terra ASTER used
- Area outside the study area

All Landsat 7 ETM+, and Landsat 5 TM images had less than 20 percent cloud cover. Some ASTER images may have had cloud cover in the 20% range. Various band combinations were selected to enhance visibility. All images were geo-registered and many were orthorectified, using multiple points and Leica Geosystems' Geographic Imaging software (formerly ERDAS). Approximately 110 of the Landsat 7 ETM+ images were obtained through the Global Land Cover Facility (GLCF), which obtains Level 0R data and processes it to Level 1G data. Most of these images were co-registered successfully with Earth Satellite Corporations's orthorectified Landsat TM data from the late 1980s-early 1990s.[7]

In areas of high relief, such as British Columbia, the ETM+ data were sent to Earth Satellite Corporation for orthorectification. Further details on the processing of Landsat 7 ETM+ by Natural Resources Canada is available at the Geogratis website.[8] Merged and compressed Landsat 5 imagery were prepared by, and available from GeoGratis of Natural Resources Canada.[9]

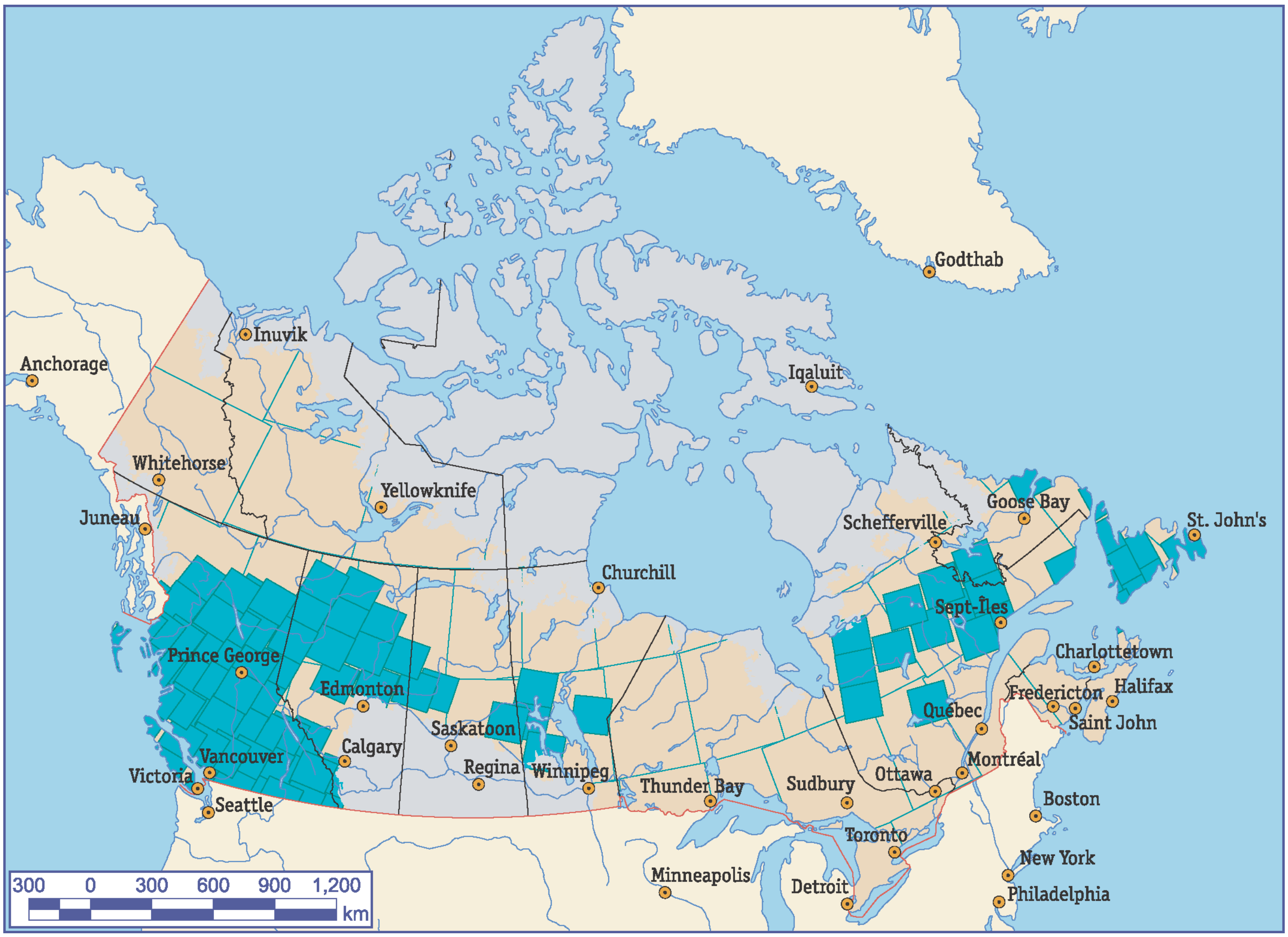


Figure 5. Landsat 5 imagery used in this study

Landsat 5 TM, regular scenes used

Landsat 5 TM, compressed three-channels merged coverage used

Area outside the study area

Details on enhancement and analysis of imagery for identifying intact areas is provided in section 3.3.

3.2.2 Infrastructure and Settlements Data

The VMap0 (Vector Map Level 0), developed by the United States National Imagery and Mapping Agency Natural Resources and subsequently updated and distributed by Canada's Centre for Topographic Information, was used for mines, populated places, railroads, pipelines and bodies of water. This vector product is the equivalent to the Digital Chart of the World, and presents features at a 1:1,000,000 scale.[10]

3.2.3 Roads

We used Desktop Mapping Technologies Incorporated (DMTI Spatial) roads dataset of Canada, which includes streets, roads, highways, expressways, local roads and railways, as well as water and utility features at a scale of 1:100,000.[11] The Terrain Resources Information Management (TRIM)[12] roads dataset for portions of British Columbia at a scale of 1:20,000, and the Updated Road Network of Canada (URN)[13] that comprises road coverage at 1:50,000, were also used. The latter includes data on hydrographic and man-made features.

3.2.4 Land Cover

Land Cover of Canada 1995 Database Version 1.1 by the Canada Centre for Remote Sensing and the Canadian Forest Service, Natural Resources Canada[14] was used as the land cover base because there is no better national forest cover data currently available.[15] The dataset is based on the multi-temporal satellite data of 1 kilometre resolution obtained in 1995 by the Advanced Very High Resolution Radiometer (AVHRR) on NOAA-14 satellite, operated by the U.S. National Oceanic and Atmospheric Administration. The dataset contains 31 land cover classes, including 12 forest (including two burn classes), three shrubland, seven cropland, grassland and mosaic; and nine non-vegetated classes.

3.2.5 Administrative Units

Administrative units were taken from the 1:1 million scale VMap0 dataset by the United States National Imagery and Mapping Agency.

3.2.6 Ecozones

We used the terrestrial ecozones, ecoregions, ecodistricts and ecoprovinces of Canada by Agriculture and Agri-Food Canada from February 2003.[16] This dataset displays ecozones at the 1:1 million scale.

3.2.7 Protected Areas

We initially used the Conservation Biology Institute — World Wildlife Fund's Protected Areas Database from 1999 as a base spatial data layer.[17] Our dataset builds on available compiled datasets, maps and images and includes boundaries of all federally, provincially and territorially owned protected areas in Canada that meet the Endangered Spaces criteria of World Wildlife Fund Canada.[18] Most of the data are at 1:100,000 and include many different types of protected areas. As management regimes of protected areas vary among jurisdictions, we make no distinction between the different management systems, except we highlighted national parks in our analysis.

3.2.8 Historic Treaty Areas, Modern Land Claim Settlements, First Nations Communities

Historic treaty areas and modern land claim settlements were initially compiled by Global Forest Watch and World Resources Institute in 2000.[19] Treaty outlines and locations were obtained from National Atlas Map 4162, Geogratis, Natural Resources Canada. Updates were provided by Legal Services Division, Natural Resources Canada. Data on Aboriginal/First Nations communities were obtained from Statistics Canada and included Indian Reserves, Metis Settlements and communities with populations of Aboriginal peoples as defined by Indian and Northern Affairs Canada (INAC).[20]

3.2.9 Fire

The fire scars and post-fire successions layer were compiled from three different sources:

1. The main source was the official large fire database from provincial and territorial governments (compiled and obtained from Canadian Forestry Service, Natural Resources Canada, by special request). Most of the data contains references to the year of fire occurrence. We filtered the data by year selecting only fire areas since the year 1950. When the references to the year were absent (one of two data sets for Manitoba) or unclear (Saskatchewan), we checked those data sets with satellite imagery. If the fire scars from the data set were clearly visible, we assumed they were younger than 1950. For some jurisdictions, only the fire areas of later years were available. Thus, for example, for Northwest Territories the data set includes only fires since 1965. In these cases, we included all available polygons into the final layer.
2. Land Cover of Canada data set by Canada Center for Remote Sensing of 1995, Version 1.1. Classes 11 and 12 (Burns) were filtered from the data set and added to the fire scars layer. All represent comparatively recent fires.
3. Our own data. We applied our own interpretation of the available Landsat 7 ETM+ satellite images for two provinces — Newfoundland and Labrador, and British Columbia. The reason for this approach was because the data sets available for those two provinces were incomplete, and provided data only 1980s–1990s. For these two provinces, we digitized additional large fire scars (over 1000 hectares) using satellite imagery. Only clearly visible and evident fire scars were digitized.

The final data set was produced by combining filtered records from all data sets, as described above, into a single layer and dissolving the boundaries of overlapping polygons (Figure 6).

3.3 Analysis

As noted earlier, we identified large, intact forest landscapes using a stratified approach. Our analysis included four basic steps: (1) setting study area boundaries, (2) eliminating disturbed areas using existing datasets, (3) elimination of further disturbed areas using satellite imagery and more detailed, regional datasets, and (4) a verification process using site visits, aerial photography, and a widespread review. These steps are described below (also see Figure 7 and Figure 8).

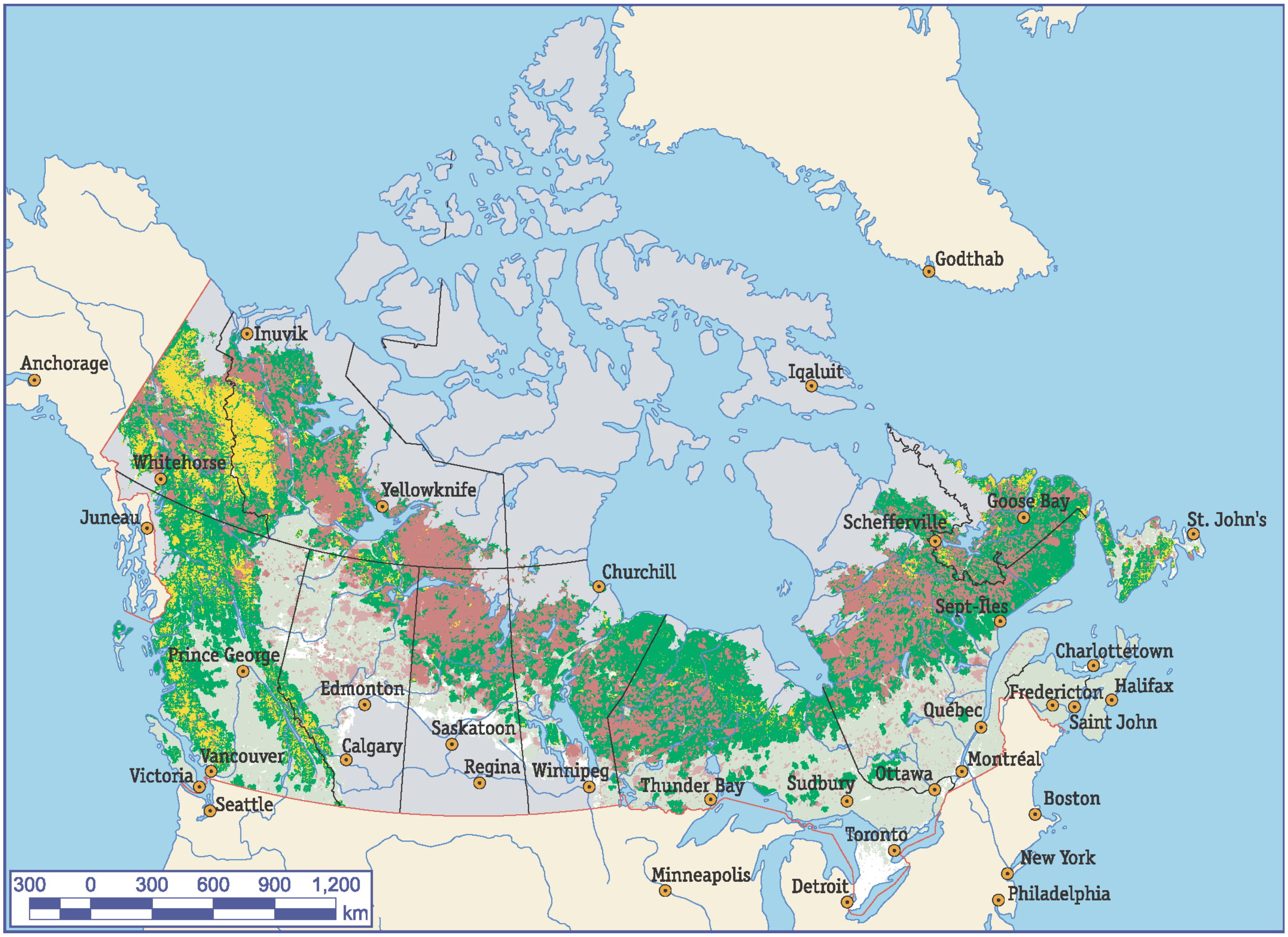


Figure 6. Fire scars (~1950 to ~2000).

Large intact forest landscapes

- Forest area
- Naturally tree-less ecosystems
- Fire scars and post-fire young successional forest*

Landscapes other than large intact forest landscapes, within the study area

- Forest area
- Non-forest area
- Fire scars and post-fire young successional forest*
- Area outside the study area

* Dating from approximately 1950 to the present.

Step 1. Study Area Boundaries

The first step was to define the boundaries of our study area. We used national boundaries to set most of the southern boundary, and used the ecozones of Canada to determine the general regions of interest. After eliminating non-forested ecozones, as described in section 2.1, we then set out to delineate forest extent. The northern boundary was manually digitized based on wintertime medium resolution images, mainly on 300 meter resolution degraded Landsat 7 ETM+ Quicklooks. Using wintertime images allowed us to distinguish tree vegetation from grassy vegetation in sparse tree stands.

Twenty percent canopy density and 2 kilometres width were the basic criteria for identifying forest areas. Narrow strips of forest occurring along the boundary, such as those denser forests typically found along river

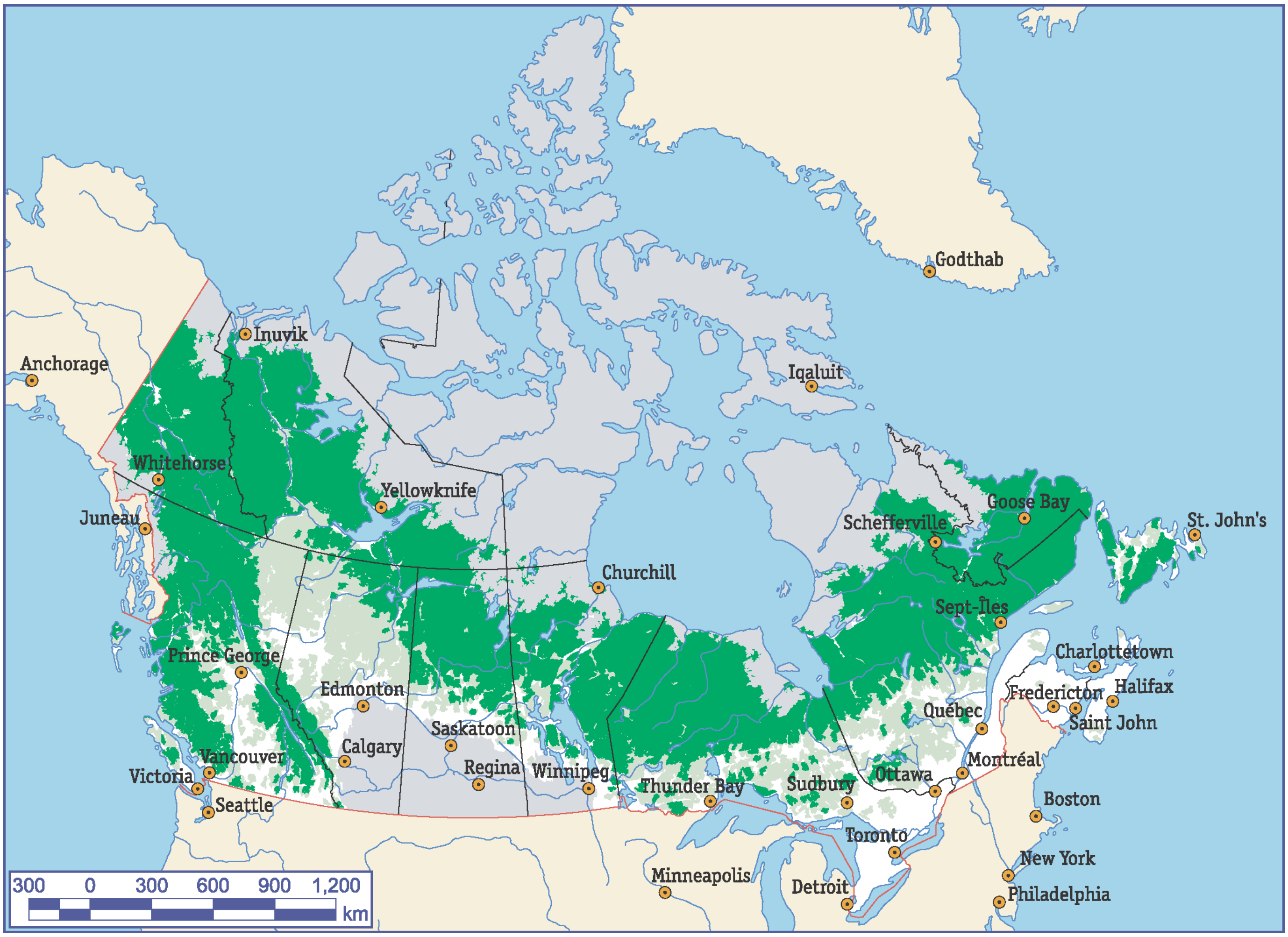


Figure 7. Stepwise approach to mapping

Areas eliminated in step 1. Areas excluded by evidence of infrastructure, detected in topographical maps

Areas eliminated in step 2. Areas excluded by evidence of agriculture, forestry, energy and road developments, detected in high-resolution satellite images

Intact forest landscapes. Areas with no detectable signs of human disturbance (areas remaining after step 2)

Area outside the study area

valleys because of local climatic condition, were excluded, along with treeless tundra zone. The southern boundary was digitized following the southern edge of the southern ecozones that are primarily forested (Pacific Maritime, Montane Cordillera, Boreal Plains, Boreal Shield, Atlantic Maritime and Mixed Wood Plains).

Step 2. Exclusion of Areas Using Existing Datasets

The second step involved reducing the initial study area by using existing datasets of human activity to identify major industrial activities. All linear, point and polygon features, such as roads, railways, pipelines, mines and populated places, described in section 3.2 were buffered to account for the disturbances from roads and other infrastructure. Table 3 provides a list of infrastructure elements and the width of their assumed maximum zone of disturbance (buffer zone).

Buffers of 500 or 1000 metres were applied, depending on the type of infrastructure. The width of buffers was conservative, in that many studies have shown the effects of disturbance greatly exceed 1000 metres for birds, predators and ungulates, in addition to smaller wildlife.[21] An Ontario government study on wildlife areas used 5 and 10 kilometre buffers.[22] Large rivers and lakes were buffered if there was evidence of historic log drives.[23]

The resulting layers of buffered features were combined to create a "disturbance" layer. These areas were then "removed" or eliminated from the intact forest landscape consideration. Additionally, residual areas smaller than 50,000 hectares were removed due to the size constraints discussed in Chapter 2. A map of candidate intact landscapes was then generated.

Table 3. Specific disturbances discernable with satellite imagery.

Type of infrastructure:	Width of buffer zone around or on each side of the object (meters)
Populated places	
Built-up areas	1000
Settlements	1000
Native settlements	500
Camps	500
Industrial and military objects	
Military bases	1000
Airports	1000
Mining and drilling	
Mines	1000
Oil and gas plants	1000
Pipelines, power lines	
Power lines	500
Oil and gas pipelines	500
Road network	
Railroads	1000
Expressways, Trans-Canada Highway, 400 series highways (e.g., Highway 401, Don Valley Parkway); Principal Highways (e.g., Highway 7, Highway 11); Major roads and county roads	1000
Local roads – subdivision roads in a city or gravel road in rural area	500

Step 3. Exclusion of Areas Using Satellite Imagery

The third step involved acquiring and using satellite imagery to identify disturbances in the candidate intact forest landscapes identified in Step 2. High resolution imagery was useful for identifying a number of human activities for which publicly available, detailed datasets were not available. For example, Landsat 7 ETM+ was able to identify areas affected by agriculture, forestry, and recent road developments. ASTER imagery is sufficiently detailed to allow detection of energy (oil and gas) developments and infrastructure such as well sites. Additional datasets, such as the well sites and fires, were used to support image interpretation. The outcome of this step was a reduced area of candidate intact forest landscapes. All imagery analysis was initially done by one interpreter, and verified by two other interpreters.

Visual interpreting of disturbances was normally performed at 1:50,000–1:250, 000 scale for Landsat 5 and 7 and ASTER imagery, and 1:250,000 scale for degraded Landsat. This resulted in a variable accuracy and an overall mapping resolution of approximately 1:1,000,000. The range of imagery results means variable accuracy and an overall mapping resolution of approximately 1:1,000,000–1:1,500,000.

The disturbance layer was overlaid with the study area layer to crop candidate areas. The analysis to identify and digitize additional disturbances on satellite imagery was completed in all blocks of 50,000 hectares or larger within the study area. Linear disturbances were buffered according to the nature of the disturbance before excluding them. Residual areas samller than 50,000 hectares were also eliminated. The result was a map (GIS layer) of Intact Forest Landscapes.

A special class of disturbances identified were various types of cutting lines — relatively thin linear disturbances of straight shape, often forming rectangular grids. The most prevalent of them appeared to be seismic lines, mainly associated with oil and gas development. However, many of them often contained small roads, local power lines and pipelines. Even with the use of high-resolution satellite imagery, it was often difficult to clarify if a particular cutting line had a road, pipeline or power line on it. The only way to classify cutting lines was to use ancillary data. The lines, which connected roads marked in the topographic maps with buildings, clearcuts, mining or drilling spots, were considered roads (pipelines/power lines), which were then allocated 500-metre buffers and excluded from the intact forest landscapes. Other lines (assumed to be simple seismic lines) were excluded only when the distance between them was less than 500 metres. Where the latter occurred, the whole area between lines was excluded.

Although some individual datasets were accurate to 1:20,000 or better, the overall accuracy of the final maps is in the range of between 1:1,000,000–1,500,000. This is due primarily to satellite image rectification issues. It appeared the maximum error on-the-ground was approximately 500 metres, and this error was most prevalent in regions of high topographic diversity, such as the mountainous regions of British Columbia and Yukon Territory.

Various band combinations of the satellite images were selected and enhanced for visibility, and then manually interpreted at a standard scale of 1:50,000–1:250,000.

Areas associated with the following main types of human disturbances were excluded in this step. These areas were excluded only if positive signs of disturbance could be detected in satellite images. Specific disturbances identifiable on the satellite imagery are shown in Table 3.

1. Linear infrastructure and associated buffers:
- roads of all types;
- roads of types not definitely visible in satellite images, but which were (a) marked in other maps or datasets available; and that (b) connected populated areas, industrial objects or other fresh human disturbances visible in satellite images or marked in thematic datasets;
- additional railroads;
- single, wide seismic and other cutlines if they were directly connected with oil wells, quarries or other industrial objects clearly visible in satellite images;
- power lines and communication lines, assuming there was clearing of vegetation along the lines;
- pipelines of all types.
- recent anthropogenic landscapes — completely human-converted areas:
- built-up populated and industrial areas and buildings of all types, excluding seasonal cabins;
- croplands, both current and abandoned, in the latter case only if they were identified in satellite imagery or through other data. Fields abandoned up to 30 years ago could typically be identified, while fields in very dry conditions could be identified up to 50 years ago;
- grasslands, if any one of the conditions below was present:
- they contained drainage or irrigation systems visible in satellite images;
- they had clear signs of grass cover degradation (grass cover less than 50 percent for rich soil conditions, less than 40 percent for dry grasslands and less than 20 percent for very dry grasslands); or
- it could be inferred from other evidence that the grasslands are of human origin; for example, they were located on cleared forest lands, abandoned croplands or previously populated areas that had been abandoned.

2. Areas affected by land use aside from those noted above:
- clearcuts;
- areas affected by highly intensive selective logging or high-grading later than 1930s/1940s;
- areas affected by drainage or irrigation after 1930s/1940s (possess drainage or irrigation systems functioning after 1930s/1940s);
- all types of mining and drilling activity areas, as well as other areas affected by industrial activity (such as processing industry or waste deposit sites);
- areas heavily affected by geological prospecting/energy exploration activity — areas with the high density of seismic and other cutting lines, or temporary roads not directly connected with industrial objects (distance between lines of 500 metres or less);
- areas with vegetation obviously degraded by local industrial pollution (if the degradation was visible in the satellite images).

3. Areas affected by human disturbances before 1930s/1940s if the effect of the disturbances was sufficiently extensive so the areas have not recovered (evidence other than just satellite images was available for each particular case):
- areas affected by historically recorded human-related deforestation, which had not reforested (due to hard environmental conditions or other reasons);[24]
- forest areas with a complete and sustained change of dominant tree species resulting from historical human activities (logging, grazing, etc.);[25]
- areas previously cleared by slash-and-burn agriculture or for settlements, even if subsequently reforested, if:
- there is evidence of previous clearing;
- the previously cleared areas are notably different from neighbouring areas that were not affected by old clearing.

After one interpreter completed the visual interpreting of disturbances, a second interpreter checked the accuracy of the mapping at the same scale. Questionable areas were highlighted, checked and, if necessary, corrected by a third interpreter using a variety of scales and imagery. Areas of uncertainty were resolved through discussion within the interpretation team.

Step 4. Verification of Results

In step four, a combination of aerial photographs, field checks and expert review was used to verify the draft map of intact forest landscapes.

A number of field expeditions were conducted in the fall of 2002 in the intact/non-intact fringe to verify the result of the image interpretation. Field teams were made up of staff from Global Forest Watch Canada, Socio-Ecological Union International, Biodiversity Conservation Centre, Greenpeace Russia, and the Pushchino State University. Image interpreters participated in the field expeditions, all of whom were equipped with GPS receivers and printouts or accessible laptop computers containing all relevant satellite imagery. These expeditions occurred in Québec, Ontario, Manitoba, Alberta, British Columbia and Northwest Territories (Figure 8).

The field verification was not based on random or systematic sampling. Rather, the strategy was to seek out points that were easily accessible by road or truck/trail near the intact/non-intact boundary, but which were within the non-intact area and occurred over a broad geographic range. This process also allowed the general accuracy of the intact/non-intact boundaries to be verified. Areas of uncertainty or difficulty of interpretation, such as gradients and areas of potential historic logging or other land use, were also verified. In excess of 300 field points in the six provinces/territories were checked. Corrections based on the field checkpoints were made.

Additional verification was made using aerial photographs from government archives. These photographs allowed interpreters to refine the initial analysis of disturbance where the disturbances were visible but could not easily be categorised. More than 2,000 aerial photos (1985-2002) for southern British Columbia and northern Ontario, ranging from 1:5,000 to 1:60,000 and including dozens showing pre-1950 Ontario were examined to clarify areas of uncertainty. These aerial photographs mostly covered draft intact forest landscape polygons in the south.

The photographs were examined for human disturbances. Where human disturbance was identified, these disturbances were checked to see if they could be detected on the satellite images; if so, they were mapped to correct the draft intact forest landscape boundaries. Small changes were made as a result of these aerial photo checks. The use of aerial photos dating back to the 1940s served primarily to verify the areas we had preliminarily mapped as intact, were indeed intact at least as far back as the date of the aerial photographs.

Review comments resulted in some minor modifications to the intact forest landscape areas, such as in northwestern British Columbia (see Review Process summary, Annex), and in portions of Alberta.

A final result of the analysis was a selection of un-fragmented landscapes without detectable signs of human disturbance, larger than 50,000 hectares and 10 kilometres in internal width. The final map was constructed based on the results of this step-wise approach.

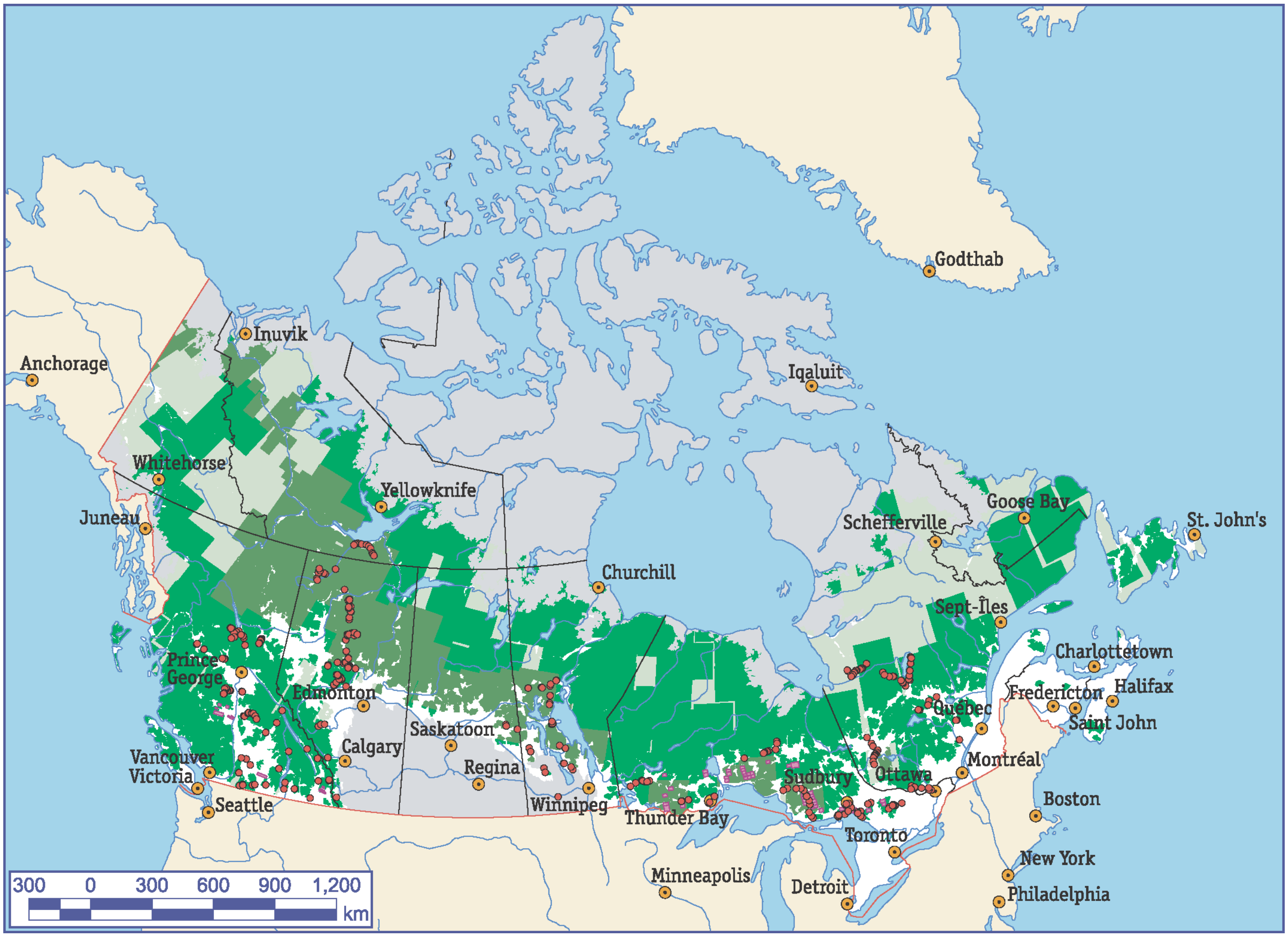


Figure 8. Accuracy and field verifications

Zone 1. Best information. The analysis was based on recent (1998-2002) Landsat 7 images (resolution 30 metres) plus the 8th (panchromatic) Landsat channel or Aster images (resolution 15 metres). The working scale during interpretation was 1:50,000.

Zone 2. Good information. The analysis was based mainly on recent (1998-2002) Landsat 7 images (resolution 30 metres). The working scale during interpretation was 1:100,000.

Zone 3. Intermediate information. The analysis was based primarily on a degraded mosaic of 10 years old Landsat 5 images (resolution 30 metres). Spotchecking was made on regular Landsat 5 images. The working scale during interpretation was 1:250,000.

Zone 0. The analysis was based on topographical maps to detect roads and other obvious disturbances. No satellite images were used.

Area outside the study area

Areas checked by air photographs, ranging in scale from 1:5,000 to 1:60,000

Field verification sites. (The points are not drawn to scale.)

GIS analysis of intact forest landscapes was conducted to assess the status of these landscapes in terms of their protection and their distribution ecozones, provinces and territories, historic treaties and modern land claim settlements and protected areas. To show forested and non-forested land inside and outside intact forest landscapes and to calculate area, the final intact forest landscape dataset was overlaid and clipped with the vectorized landcover dataset.

3.4 Accuracy

The accuracy of the map varies across Canada, depending largely on quality and quantity of available information. Although some individual datasets were accurate to 1:20,000 or better, the overall accuracy of the final maps is in the range of between 1:1,000,000-1,500,000. Owing primarily to rectification issues, it appears the maximum error on-the-ground is approximately 500 metres. This error is most prevalent in regions of high topographic diversity, such as the mountainous regions of British Columbia and Yukon Territory.

The analysis is more likely to overestimate the area of intact forest landscapes. This is inherent in the basic approach, which presumes all area to be intact unless the opposite can be proven. Signs of disturbance are more likely to have been missed than to have been mistakenly found where none exist (although that possibility cannot be ignored). In particular, areas of historic logging (a sign of disturbance) may have been interpreted as areas of historic fire (not considered a sign of disturbance). The decision rule used for classifying burned areas is also likely to err slightly on the side of intactness, as it is likely that frequent human-caused fires in some regions have dramatically altered the species composition and canopy structure.

Chapter 4. Results

We examined about 600 million hectares — 60 percent of Canada's total land area — for large, intact forest landscapes. The results are presented below.

4.1 How Much Is Left?

Our findings indicate that Canada retains extensive, globally significant areas of large, intact forest landscapes (Table 4 and Map 1). Of the 600 million-hectare study area, well over half (339 million hectares) is in large, intact forest landscapes. This represents more than one third of Canada's total land area.

4.2 Where Are They?

The area in intact forest landscapes is not evenly distributed across Canada (see Table 5). Most is found in northern Canada and at higher elevations in western Canada. In the north, there is a broad belt of large, intact forest landscapes running across Canada, passing through the taiga and northernmost boreal forest regions. The most biodiversity-rich and productive forests, which are located in southern Canada, have been the most extensively influenced by human activity.

Table 4. Large intact forest landscapes (>50,000 hectares) of Canada.

	Total area (million hectares)	Proportion
Study area	601	60% of Canada
Large intact forest landscapes (LIFL)	339	57% of study area
		34% of Canada
Forest area within LIFLs	208	55% of Canada's forests
LIFL in historic Aboriginal treaties and	186	56% of large intact forest landscapes
LIFL in modern land claim settlements	87	26% of large intact forest landscapes
LIFL in protected areas	29	9% of large intact forest landscapes
LIFL in national parks	7	2% of large intact forest landscapes

Table 5. Large intact forest landscapes within boreal and temperate regions.

	Study area	Large intact forest landscapes	Proportion of study area in large intact forest landscapes	Forest area in large intact forest landscapes	Proportion of forest in large intact forest landscapes
	(mln ha)	(mln ha)	(%)	(mln ha)	(%)
Boreal	495	308	62%	194	63%
Temperate	106	31	30%	13	42%
Canada	601	339	57%	208	61%

4.2.1 Ecozones

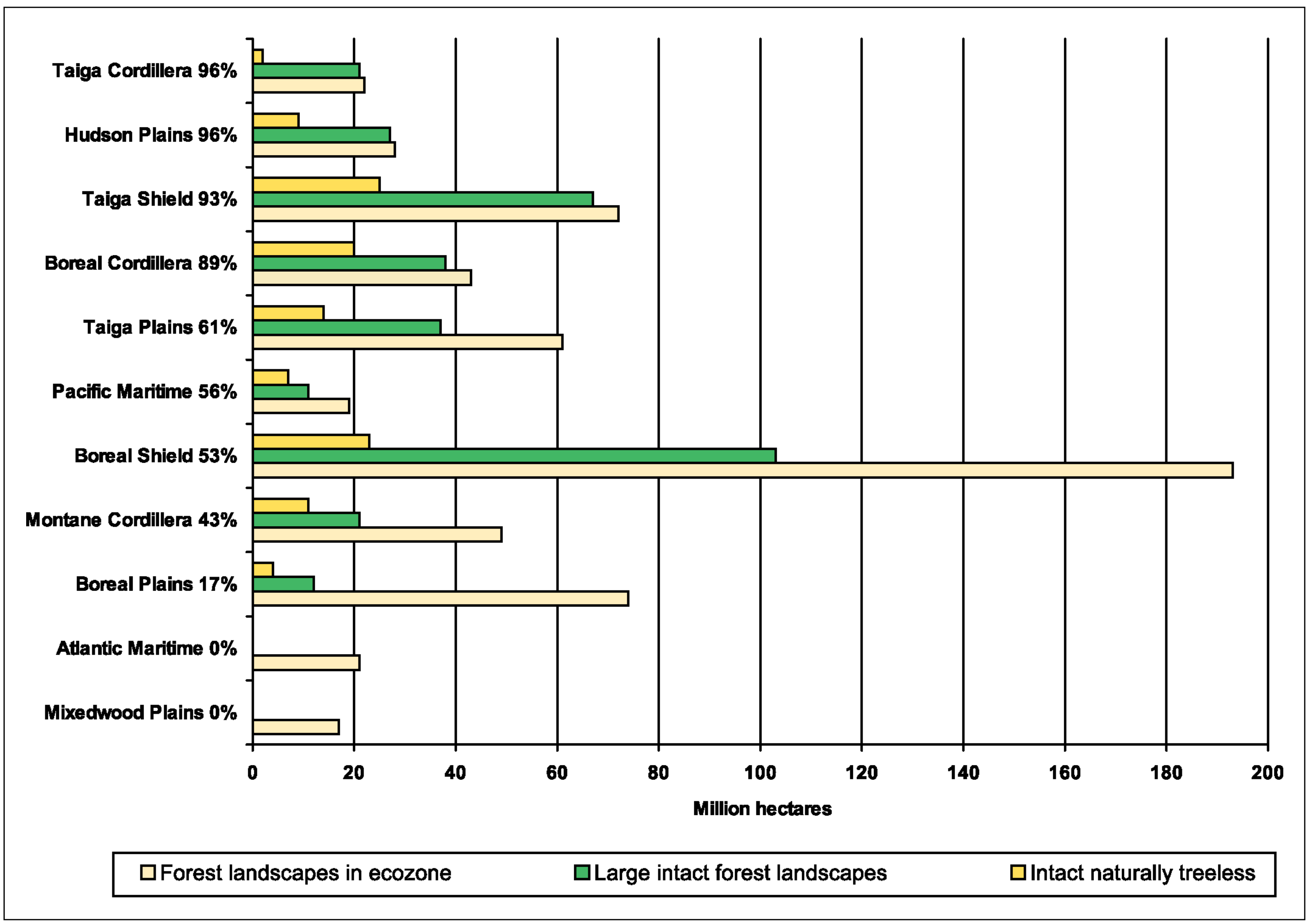
Canada contains 11 ecozones that are generally considered to be forest ecozones, although the northern and mountainous ones contain large areas of treeless tundra. One additional ecozone, the Southern Arctic, contains a small area of forest that was included in the study area. The total area of large, intact forest landscapes within Canada's ecozones is shown in Table 6, Figure 9, and Map 2.

Boreal forest ecozones account for more than 90 percent by area (308 million hectares) of Canada's large, intact forest landscapes. About two thirds of this landscape is covered by forests; the rest is naturally treeless, including bogs, lakes and rivers, and high-elevation alpine tundra, ice, and rock in the western mountains.

The northernmost boreal forest ecozones are mostly intact. Four such ecozones — the Hudson Plains, Taiga Cordillera, Taiga Shield, and Boreal Cordillera — all have at least 89 percent of their study area in large, intact forest landscapes, and the Taiga Plains has almost two thirds of its study area in large, intact forest landscapes.

More than half of the Boreal Shield, Canada's largest ecozone, is still in large, intact forest landscapes. These roughly 100 million hectares represent 30 percent of Canada's total large, intact forest landscapes. Most of these tracts are in the northern part of the Boreal Shield ecoregion; only a few scattered areas are found in the southern part of the region. A similar pattern can be seen in the smaller Boreal Plains ecozone, whose roughly 12 million hectares of large, intact forest landscapes constitute less than one fifth (17 percent) of its total area.

Figure 9 . Area of forest landscapes by ecozone.
(In order of declining portion of large intact forest landscapes.)



Temperate forest ecozones contain some 30 million hectares of large, intact forest landscapes — less than 10 percent of Canada's total area in such landscapes. Most of this area is found in two ecozones — the Montane Cordillera (about 21 million hectares) and the Pacific Maritime (about 10 million hectares). The Montane Cordillera has more than 40 percent of its land area in large, intact forest landscapes, but most of these tracts are at high elevations and a large portion are naturally treeless. The Pacific Maritime, 56 percent intact, exhibits a similar pattern. The relatively rare forested portions of these two ecozones have special ecological significance.[1] Two other temperate forest ecozones — the Atlantic Maritime and the Mixedwood Plains — have no remaining large, intact forest landscapes. This is not surprising, given their history of early and intensive colonization.

4.2.2 Provinces and Territories

All of Canada's ten provinces and three territories contain forest landscapes. (Table 7, Table 8, Figure 10 and Map 1), but the distribution among them is uneven.

Québec and the Northwest Territories together house about one-third of Canada's large, intact forest landscapes, including most of those in boreal ecozones. Nearly two-thirds of the intact forest landscapes are

Table 6. Large intact forest landscape distribution within ecozones.

Ecozone	Total area within the ecozone	Total area within study[1]			Forests within study area[2]		
	Total area	Total area	Large intact forest landscapes	Proportion of large intact forest landscapes	Total forest area	Forest area within large intact forest landscapes	Proportion of forest in large intact forest landscapes
	(000 ha)	(000 ha)	(000 ha)	(%)	(000 ha)	(000 ha)	(%)
Boreal							
Boreal Cordillera	46,802	42,873	37,978	89	20,876	18,048	86
Boreal Plains	73,740	73,740	12,232	17	41,797	8,262	20
Boreal Shield	193,426	193,426	102,719	53	148,207	79,556	54
Hudson Plains	37,352	28,410	27,318	96	19,190	18,614	97
Southern Arctic	84,503	2,012	1,978	98	1,685	1,658	98
Taiga Cordillera	26,519	21,657	20,732	96	2,629	2,349	89
Taiga Plains	65,372	60,934	37,397	61	38,323	23,630	62
Taiga Shield	138,571	72,233	67,369	93	43,884	42,210	96
Total Boreal	**666,285**	**495,285**	**307,723**	**62**	**316,591**	**194,327**	**61**
Temperate							
Atlantic Maritime	20,862	20,862	0	0	16,562	0	0
Mixedwood Plains	16,934	16,934	0	0	2,816	0	0
Montane Cordillera	48,778	48,672	21,075	43	31,499	9,818	31
Pacific Maritime	20,703	18,810	10,539	56	9,595	3,361	35
Total Temperate	**107,277**	**105,278**	**31,614**	**30**	**60,472**	**13,179**	**22**
Total Canada	**995,706**	**600,561**	**339,337**	**57**	**377,063**	**207,506**	**55**

1. The tundra zone, treeless uplands connected with tundra and prairies ecozone are excluded.
2. According to the Canada Centre for Remote Sensing.

Table 7. Large intact forest landscapes distribution within provinces and territories.

Province	Total area within study[1]			Forests within study area[2]		
	Total area	Large intact forest landscapes	Proportion of large intact forest landscapes	Total forest area	Forest area within large intact forest landscapes	Proportion of forest in large intact forest landscapes
	(000 ha)	(000 ha)	(%)	(000 ha)	(000 ha)	(%)
Boreal Forest Zone						
Alberta	45,784	7,304	16	27,561	3,963	14
British Columbia	28,170	16,419	58	16,714	7,369	44
Manitoba	47,893	29,685	62	32,281	23,367	72
Newfoundland and Labrador	33,713	26,275	78	17,257	13,618	79
Northwest Territories	74,076	58,704	79	41,897	35,012	84
Nunavut	439	369	84	263	234	89
Ontario	87,031	47,099	54	69,711	38,191	55
Québec	99,635	62,627	63	69,212	40,141	58
Saskatchewan	38,657	23,997	62	26,424	19,555	74
Yukon Territories	39,886	35,245	88	15,271	12,878	84
Total Boreal	**495,283**	**307,723**	**62**	**316,592**	**194,327**	**61**
Temperate Forest Zone						
Alberta	4,659	3,118	67	2,116	1,130	53
British Columbia	62,824	28,495	45	38,978	12,048	31
New Brunswick	7,279		0	6,116		0
Nova Scotia	5,522		0	4,677		0
Ontario	13,831		0	1,908		0
Prince Edward Island	593		0	153		0
Québec	10,569		0	6,524		0
Total Temperate	**105,278**	**31,614**	**30**	**60,471**	**13,178**	**22**
All Forest Zones						
Alberta	50,443	10,423	21	29,677	5,094	17
British Columbia	90,994	44,914	49	55,692	19,416	35
Manitoba	47,893	29,685	62	32,281	23,367	72
New Brunswick	7,279	0	0	6,116	0	0
Newfoundland and Labrador	33,713	26,275	78	17,257	13,618	79
Northwest Territories	74,076	58,704	79	41,897	35,012	84
Nova Scotia	5,522	0	0	4,677	0	0
Nunavut	439	369	84	263	234	89
Ontario	100,863	47,099	47	71,619	38,191	53
Prince Edward Island	593	0	0	153	0	0
Québec	110,204	62,627	57	75,736	40,141	53
Saskatchewan	38,657	23,997	62	26,424	19,555	74
Yukon Territories	39,886	35,245	88	15,271	12,878	84
Total Canada	**600,561**	**339,337**	**57**	**377,063**	**207,506**	**55**

1. The tundra zone, treeless uplands connected with tundra and prairies ecozone are excluded.
2. According to the Canada Centre for Remote Sensing.

found within four provinces: Québec, Northwest Territories, Ontario and British Columbia. No large intact forest landscapes remain in Nova Scotia, New Brunswick or Prince Edward Island.

Over 90 percent of the temperate large, intact forest landscapes are located in British Columbia, with the rest in Alberta. Less than one half of these intact forest landscapes are forested, and these relatively rare portions have special ecological significance.[2] The remainder is naturally treeless, including high-elevation alpine tundra, ice and rock in the western mountains.

No large, intact forest landscapes remain in the temperate forest ecozones of: New Brunswick, Nova Scotia, Ontario, Prince Edward Island and Québec.

Listed in descending order, seven provinces/territories — Yukon Territory, Nunavut, the Northwest Territories, Newfoundland and Labrador, Manitoba, Saskatchewan, Québec — each have over half of their area in forest ecozones covered by large, intact forest landscapes. Alberta retains by far the lowest proportion of large, intact forest landscapes in its boreal ecozones (16 percent) while other provinces and territories have more than half of their boreal forest ecozones in large, intact forest landscapes.

Figure 10. Area of forest landscapes in Canada by jurisdiction.
(In order of declining area of large intact forest landscapes.)

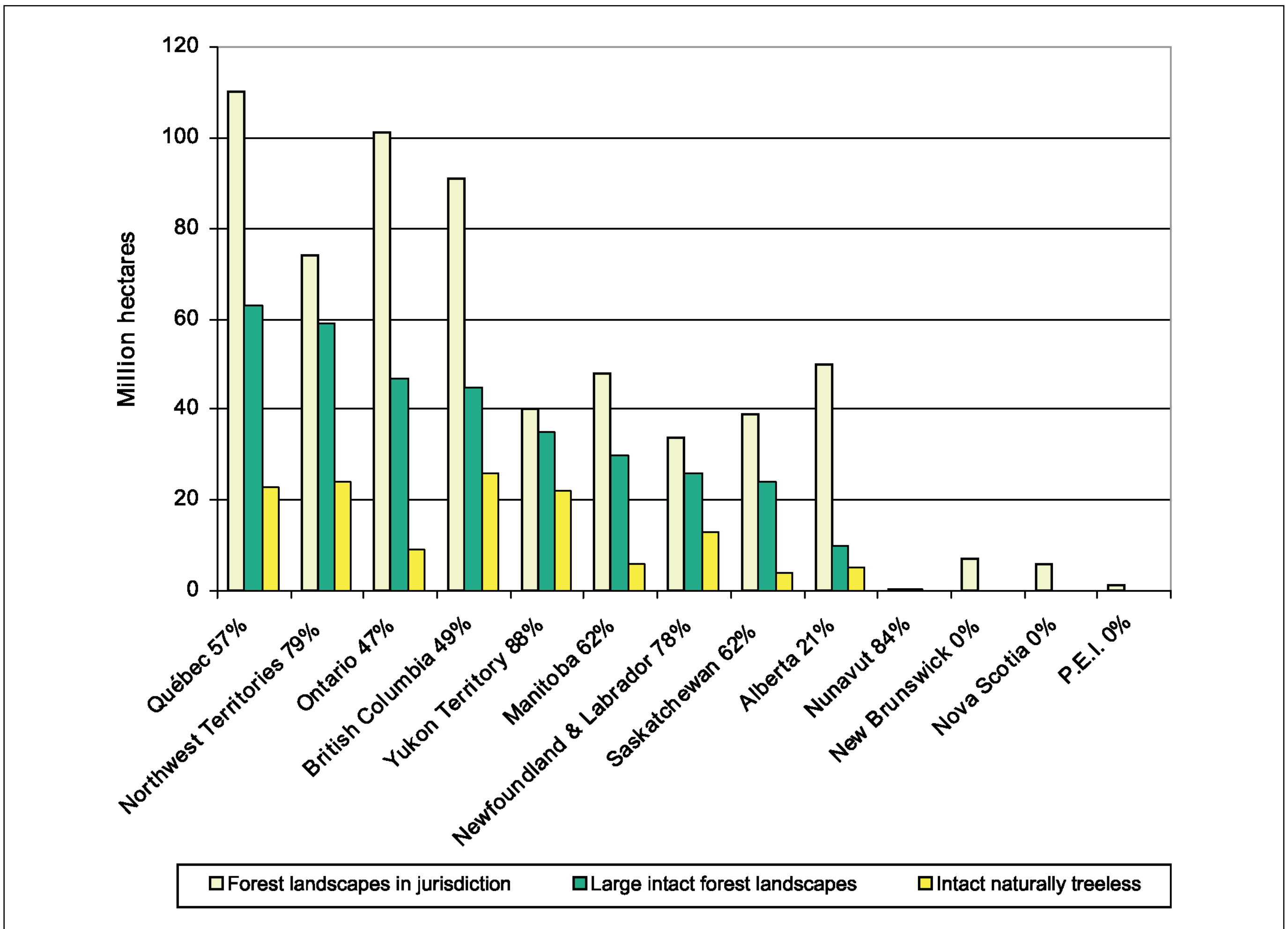


Table 8. Distribution of large intact forest landscapes among provinces and territories in Canada.

Jurisdiction	Proportion of Canada's total area of large intact forest landscapes (percent)
Alberta	3
British Columbia	13
Manitoba	9
New Brunswick	0
Newfoundland and Labrador	8
Northwest Territories	17
Nova Scotia	0
Nunavut	<1
Ontario	14
Prince Edward Island	0
Québec	18
Saskatchewan	7
Yukon Territories	10

4.2.3 Aboriginal historic Treaties and Modern Land Claim Settlements

Aboriginal Peoples assert their legal right to influence land management based on treaties[3] and on modern settled land claims. Historic Aboriginal treaty areas and modern land claim settlements comprise a significant portion of Canada's large intact forest landscapes (Table 9 and Map 3). More than half of Canada's large, intact forest landscapes are in historic treaty areas (see Map 6). Treaties 8 and 9 contain about a quarter of all of Canada's intact forest landscapes and close to half of all the intact forest landscapes that occur within treaty areas. Modern land claim settlements contain about a quarter of Canada's intact forest landscapes.

Table 9. Large intact forest landscapes within historic First Nations treaties and modern land claim settlements.

	Within study area	In large intact forest landscapes within study are	Proportion in large intact forest landscapes arelative to study area	Proportion in large intact forest landscapes relative to total area of such landscapes in Canada
	(mln ha)	(mln ha)	(%)	(%)
First Nations Treaty Areas	346	186	54	55
Modern Land Claim Settlement Areas	104	87	84	26

Table 10. Large intact forest landscapes within protected areas (by forest zone and jurisdiction)

Province	Protected area within the region	Protected area within the study area1	Large intact forest landscapes			Forest area within large intact forest landscapes		
			Total area	Protected area	Protec-ted portion	Total area	Protec-ted area	Protec-ted portion
	(000 ha)	(000 ha)	(000 ha)	(000 ha)	(%)	(000 ha)	(000 ha)	(%)
Boreal Forest Zone								
Alberta		5,151	7,304	3,861	53	3,963	1,828	46
British Columbia		3,366	16,419	3,039	19	7,369	1,181	16
Manitoba		3,371	29,685	2,695	9	23,367	2,187	9
Newfoundland and Labrador		637	26,275	463	2	13,618	138	1
Northwest Territories		1,404	58,704	1,287	2	35,012	673	2
Nunavut		0	369	0	0	234	0	0
Ontario		7,555	47,099	4,868	10	38,191	4,137	11
Québec		3,332	62,627	2,588	4	40,141	1,686	4
Saskatchewan		2,103	23,997	1,192	5	19,555	914	5
Yukon Territories		1,095	35,245	971	3	12,878	116	1
Total Boreal		**28,013**	**307,723**	**20,966**	**7**	**194,327**	**12,858**	**7**
Temperate Forest Zone								
Alberta		2,840	3,118	2,416	77	1,130	711	63
British Columbia		7,340	28,495	5,969	21	12,048	2,705	22
New Brunswick		47	0					
Nova Scotia		436	0					
Ontario		72	0					
Prince Edward Island		2	0					
Québec		163	0					
Total Temperate		**10,901**	**31,614**	**8,386**	**27**	**13,178**	**3,416**	**26**
All Forests Zones								
Alberta	8,154	7,992	10,423	6,277	60	5,094	2,539	50
British Columbia	12,091	10,706	44,914	9,009	20	19,416	3,886	20
Manitoba	5,080	3,371	29,685	2,695	9	23,367	2,187	9
New Brunswick	49	47	0			0		
Newfoundland and Labrador	1,617	637	26,275	463	2	13,618	138	1
Northwest Territories	6,421	1,404	58,704	1,287	2	35,012	673	2
Nova Scotia	445	436	0			0		
Nunavut	11,641	0	369	0	0	234	0	0
Ontario	9,133	7,626	47,099	4,868	10	38,191	4,137	11
Prince Edward Island	5	2	0			0		
Québec	5,251	3,496	62,627	2,588	4	40,141	1,686	4
Saskatchewan	2,279	2,103	23,997	1,192	5	19,555	914	5
Yukon Territories	4,379	1,095	35,245	971	3	12,878	116	1
Total Canada	**66,545**	**38,914**	**339,337**	**29,351**	**9**	**207,506**	**16,275**	**8**

1. Coastal marine areas are excluded.

4.3 How Much Is Protected?

Only a small portion (about 30 million, or 9 percent) of Canada's large, intact forest landscapes are in protected areas (Table 10 and Maps 4 to 8). Of this amount, just under half (about 13 million hectares) is naturally treeless.

National parks make up about one third of Canada's protected areas, but contain only 2 percent of Canada's intact forest landscapes. Indeed, many of Canada's protected areas (351 of 452) are smaller than the 50,000-hectare minimum tract size established for this study.[4] Most large, intact forest landscapes within designated protected areas are under provincial and territorial jurisdiction.

Most (about 70 percent) of the large, intact forest landscapes in protected areas are in the boreal region. Two-thirds of this area is forested. Less than one-third of the large, intact forest landscapes in temperate ecozones are in protected areas. Most of this area is treeless, consisting of high elevation alpine tundra, rock and ice.

The proportion of large, intact forest landscapes within protected areas also varies greatly among the jurisdictions (Table 10). British Columbia, Alberta and Ontario together contain 67 percent of all the protected areas within Canada's forest ecozones, and 69 percent of all the intact forest landscapes that are within protected areas. British Columbia leads other jurisdictions with the largest portion of forest ecozone protected areas, as well as the largest area of protected intact forest landscapes. Most of the intact forest landscapes within British Columbia's protected areas are treeless areas, consisting mostly of high elevation tundra and ice.

Table 11. Large intact forest landscapes within individual national parks.

	Large intact forest landscapes (million hectares)
All protected areas	**22.62**
All national parks	**7.04**
Wood Buffalo	4.00
Jasper	1.04
Banff	0.60
Nahanni	0.48
Pukaskwa	0.15
Prince Albert	0.14
Gros Morne	0.14
Glacier National Park	0.13
Wapusk	0.10
Yoho	0.10
Gwaii Haanas	0.08
Kootenay	0.06
Mt. Revelstoke National Park	0.02

Chapter 5. Conclusions

This study mapped Canada's large, intact forest landscapes and is the first to give detailed answers to the questions:

- How much is left?
- Where are they located?
- How much is protected?

The answers are based on a systematic examination of detailed, recent satellite images covering all forest landscapes of Canada, and are supported by ancillary data, field verification, and contributions from numerous advisors, data collaborators, and expert reviewers.

Although large tracts of intact (i.e., undisturbed) forest ecosystems are becoming increasingly rare across the world, Canada possesses roughly 340 million hectares of such landscapes. This is an extraordinarily large area that rivals virtually any other nation.

These remaining large (50,000 hectares or larger), intact forest landscapes occur mainly in the northern portions of Canada and in high-elevation areas. The vast majority of these landscapes — about 308 million hectares, or more than 90 percent — is within Canada's boreal forest ecozones. The remainder is within the temperate forest ecozones.

In contrast to the large area of intact landscapes in northern Canada, the forest landscapes of southern Canada, in both boreal and temperate forest ecozones, are substantially affected by modern land use. Much of the remaining intact forest landscapes in southern Canada is naturally treeless, consisting of bogs, lakes, rivers, mountain grasslands, alpine tundra, and rock. The most biodiversity-rich and productive forestlands are also the most influenced by human activity.

Almost two thirds of Canada's intact forest landscapes are within Québec, the Northwest Territories, Ontario, and British Columbia. In contrast, Nova Scotia, New Brunswick, and Prince Edward Island have no remaining large, intact forest landscapes, while Alberta has one fifth of its forest ecozones remaining as large, intact forest landscapes. In Canada's temperate forest ecozones, only British Columbia and Alberta retain large, intact forest landscapes; the five eastern Canadian provinces that have temperate forest ecozones no longer possess any large tracts of undisturbed forest.

A significant proportion of Canada's large, intact forest landscapes are located within historic First Nations Treaty areas and within modern land claim settlements.

Only a small portion of Canada's large, intact forest landscapes occurs in designated protected areas.

Future Research

This study represents the first detailed attempt to map the extent and boundaries of large, intact forest landscapes across Canada using high-resolution satellite imagery and ancillary data. The goal was to produce maps that are accurate and detailed enough to guide broad, landscape-level decision-making processes concerning land conservation and management. In the future, it would be desirable to both refine and expand this work.

An obvious approach to refinement would be to incorporate existing provincial and forest management unit-level information — presently unavailable, or not easily available, to the public — on roads, logged areas, and areas affected by energy exploration and developments. This would increase the accuracy of future analysis and enhance its usefulness.

Mapping the location of economic, social and conservation values across the forest landscape — intact as well as non-intact — is an essential expansion of this work. Such information is necessary for a well-considered approach to land-use planning, including setting conservation priorities.

In the large intact forest landscapes, an analysis of operable and potentially commercial forest areas is needed. This would involve examining variations in hauling distance, stocking, site productivity, cost, and probability of regeneration success. Global Forest Watch Canada encourages relevant government agencies with the required forest cover data to undertake this type of analysis.

Outside of large intact forest landscapes, candidate areas for conservation management need to be identified. Smaller, remaining areas of low human disturbance should be mapped in this context, building on the work already done for this study. A crucial part of this effort will be to designate the appropriate threshold tract size.

Monitoring the effect of management strategies outside of large, intact forest landscapes is another important extension of this work. Remote sensing offers the best potential for this. Aside from the need to monitor future changes, mapping past changes would also be useful. This can be done using archived satellite images, and therefore could be undertaken without delay, providing those images are placed in public domain. More study is also needed of the impacts of logging and how to mitigate them. Existing indicators of forest sustainability should be used to study forest condition, and such studies should involve industry as well as independent analysts such as Global Forest Watch Canada. These should be done at relatively fine scales of resolution to ensure usefulness in guiding practical land management.

Beyond Canada, mapping the remaining intact forest landscapes in other parts of the world is a high priority, with a critical need to map the best-preserved specimens of nature. This would allow global approaches to improved forest management to be based on reliable, consistent information. The next step, therefore, should be to identify and map the largest remaining blocks of forest landscapes for each forest ecosystem around the world.

Glossary

Aboriginal Treaty Area: an area that comprises constitutionally binding agreements between First Nations and the Canadian Crown signed between 1850 and 1930 (historic treaties). The two main provisions of most of these treaties were monetary payment and the setting aside of reserve lands.[1]

Commercial Forest Tenures or Logging Concessions: statutorily based agreements whereby the Crown has the rights to timber and other natural resources and these rights have been transferred to the provinces through the Transfer of Natural Resources Act in 1930,[2] then the provinces have transferred the rights to harvest timber or manage forest lands to private parties, primarily forest companies, while retaining title to the land.[3] Federal land, such as parks, Indian reserves, military installations, generally do not allow commercial timber harvesting, although some has occurred, for examples, in Wood Buffalo National Park and Primrose Air Weapons Range. The logging rights of a tenure/concession agreement may relate either to a specified area or to a specified volume of cut within an administrative unit (variously termed forest management unit, forest district, or *aire commune*). The operational implementation of a tenure agreement or concession usually occurs at the forest administrative unit level. Most of Canada's largest forest companies log timber from public and private lands with logging on public land generally far outweighing logging on private land.[4]

Disturbance: any moderately isolated event in time that disrupts the structure of a population, community or ecosystem, and which modifies the availability of the resources in the substrate or in the physical environment.[5] In many types of naturally functioning intact forest landscapes, disturbances such as fires, pests and diseases are spontaneous events that shape the landscape.[6] Human disturbances, such as the fragmentation of landscapes and ecosystems by roads and land use, tend to shape the landscape much less naturally.

Ecoregion (1): a subdivision of an ecozone, according to the National Ecological Framework for Canada which is used throughout Canada. An ecoregion contains large order landforms or assemblages of regional landforms, small order macro- or mesoclimates, and regional ecological patterns such as vegetation, soils and water, as well as regional human activity patterns and land uses.[7] Ecoregions, as defined in this way, usually occur at a sub-national scale and are different from the ecoregions defined by the World Wildlife Fund (see below).

Ecoregion (2): an assemblage of natural communities in a geographically distinctive area that not only share a large majority of their species, dynamics and environmental conditions, but also function effectively together at global and continental scales, according to the World Wildlife Fund.[8]

Ecozone: the most generalized level in the National Ecological Framework for Canada.[9] Ecozones are areas of the earth's surface representative of large and generalized units defined by the interaction of macroscale climate, human activity, vegetation, soils, geological and physiographic features.[10] There are 15 ecozones in Canada. Eleven of these are considered to be forest ecozones, as they are presently, or were historically, predominantly forested.

Endangered Forests: defined within biological, ecological, social and legal categories. The concept was introduced by the Wye River Group and has been used by some corporations to make commitments to adopt and implement ecologically responsible forest procurement policies.

Biological and ecological categories include:

- *Naturally rare forests* — forests that are rare due to natural conditions such as temperate rainforests and cloud forests;
- *Anthropogenically rare forests* — forests so heavily affected on a global or ecoregional scale by humans that they have become rare;
- *Intact forests* — large, unfragmented blocks of natural forests;
- *Other ecologically important forests* — "the best of the rest"; the remaining old growth patches left in otherwise degraded and converted forest areas that are not anthropogenically rare at the ecoregional level.

Social and legal categories include:

- Forests where there are ongoing human rights violations including violations of the rights of Indigenous people;
- Forests where illegal forestry and illegal trade occurs.[11]

Forest Intactness: authentic forest naturalness over a long time and large space.

Forest Landscape: a contiguous mosaic of naturally occurring ecosystems within Canada's forested Ecozones. A forest landscape may also contain naturally treeless areas (see Intact Forest Landscape).

Fragmentation: the breaking up of a habitat, ecosystem or landscape into smaller, disconnected pieces.[12] Although natural disturbances fragment the landscape, human activities are also agents of fragmentation. Agents of fragmentation include roads, cleared lands, changes in land use, urbanization and other human developments.[13]

Frontier Forests: large, relatively intact forest ecosystems. A frontier forest must meet the following criteria:

- It is primarily forested;
- It is large enough to support viable populations of all species associated with that forest type even in the face of natural disasters of a magnitude to occur once in a century;
- Its structure and composition are determined mainly by natural events, and it remains relatively unmanaged by humans, although limited human disturbance by traditional activities is acceptable;
- In forests where patches of trees of different ages occur naturally, the landscape shows this type of heterogeneity;
- It is dominated by indigenous tree species;
- It is home to most, if not all, other plants and animals that typically live in this forest.[14]

High Conservation Value Forest (HCVF): a concept introduced by the Forest Stewardship Council (FSC) in 1999 as part of Principle 9 of the FSC certification standard; any management of these forests must either conserve or enhance these values.[15] High Conservation Value Forests possess the following characteristics:

- Contain globally, regionally or nationally substantial concentrations of biodiversity values (such as endemism, endangered species, refugia); and/or large landscape level forests, where viable populations of most — if not all — naturally occurring species exist in natural patterns of distribution and abundance;
- Exist in, or contain, rare, threatened or endangered ecosystems;
- Provide basic ecosystem services in critical situations;
- Are either fundamental to meeting basic needs of local communities or critical to local communities' traditional cultural identity (for example, areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).[16]

Intact Forest Landscape: a contiguous mosaic of naturally occurring ecosystems in a forest ecozone, essentially undisturbed by significant human influence. An intact forest landscape does not necessarily consist of old-growth trees and may not even be entirely forested. Intact forest landscapes consist of a mosaic of natural ecosystems including forest, bog, water, tundra, and rock outcrops. In some cases, such as the bog-dominated landscapes of Canada's taiga ecozones and mountainous landscapes of western Canada, only 20 to 30 percent of the total area may consist of trees.

An intact forest landscape has the following characteristics:

- Is free from substantial anthropogenic fragmentation (settlements, roads, clearcuts, pipelines, power lines, mines, etc.);
- Is free from substantial human influence for periods that ensure that it is formed by naturally occurring ecological processes (including fires, wind, and pests);
- Contains only naturally seeded indigenous plant species and supports viable populations of most native species associated with the ecosystem;
- Is large enough to be resilient to edge effects and to survive most natural disturbance events.

Modern Land Claim Settlements: agreements that have been reached between Aboriginal communities and the government on comprehensive or specific claims since Canada's Land Claims Policy of 1973. Some level of self-government may be part of the agreement, and these modern settlements/treaties usually have stipulations regarding land base ownership, harvesting rights, financial compensation, participation in management decisions, and resource revenue-sharing.[17]

Protected Areas: a term used in this report to denote any area identified as (a) protected area that meets the World Wildlife Fund Canada's Endangered Spaces criteria (no logging, mining or hydro-electric development), and which is designated by either the federal, provincial or territorial governments of Canada. This definition makes no distinction among management regimes in protected areas. Most of the protected areas in Canada are established and administered at the provincial/territorial level, and the legal framework of protected areas varies among jurisdictions.[18] Some of these protected areas may be subject to industrial resources extraction, intensive recreation and other forms of anthropogenic uses.[19]

Annex — Review Process

In accordance with Global Forest Watch policy, the methods and results of this project have been reviewed by a broad set of experts and stakeholders, including Canadian and international reviewers with expertise in cartography, remote sensing and GIS, forest ecology, forest management, forest industry and wildlife management. The reviewers were drawn from a wide spectrum of organizations, including governments, industry, conservation organizations and Global Forest Watch partners. The project went through two major reviews: an initial review of the methods over two workshops in 2001 and 2002, and a final review of draft results in 2003 by invitation.

Initial Review of Methods by Means of Workshops

The two initial workshops were complemented by an initial methodology review and a subsequent online review. The first workshop was held in Vancouver, British Columbia, in May 2001. Its purpose was to define objectives, criteria, definitions and general mapping methods. The second workshop was held in Edmonton, Alberta, in October 2001, to assess progress and examine preliminary results from pilot areas. A web-based review of the methods took place just before the Edmonton workshop to early 2002.

The major comments received from these earlier workshops are summarized below:

- *Road density analysis should be part of the work.*

  Road (or linear disturbance) density analysis for the non-intact forest landscape area is an important complement to intact forest landscape mapping; however, because of resources constraints, this analysis could not be completed in this phase.

- *Accuracy of ancillary roads and other data may be questionable.*

  Please see the section on accuracy in the main text of this report.

- *Excluding buffered lakes may result in inaccuracies and be an inappropriate methodology.*

  The main reason for buffering lakes greater than a certain size was the assumed high probability that long-term, historic land use around these navigable lakes would have transformed the forest structure, and in some cases, the species composition. These probable changes were difficult to identify clearly on the satellite images that were used. Many navigable rivers were buffered in a similar fashion.

- *Definition of intact forest landscapes should include degree of intactness or integrity, and allow for different threshold sizes.*

  For reasons of practicality and simplicity, a decision was made to use a consistent 50,000 hectare threshold for minimum size for all forest biomes and ecological regions. Further mapping of smaller blocks is a priority for future work.

- *Remote sensing interpretation and modelling approaches cannot be effectively validated when they rely on interpreter expertise.*

  This is a concern common to all such approaches using remote sensing. In this study, validation included hundreds of spot field checks in five provinces and one territory, and thousands of aerial photographs checks (at scales ranging from 1:5,000 to 1:60,000). The approach to mapping, which focussed on excluding clearly visible disturbances, minimized the probability of interpreter error.

- *Regrowth may be misclassified as either intact or not intact.*

  Areas of regrowth were not identified and classified as such, but were classified as either intact or not intact by the known or presumed origin of the succession (fire implied intact, logging implied non-intact). Some inaccuracies are likely to have occurred. Generally, the tendency was to assume fire as the source of disturbance unless there were clear indications of logging; this tendency has resulted in a probable bias in favour of intactness.

- *Methods need to account for recovery of forests over time.*

  The method does allow for the recovery of intactness over time, as only disturbed areas that were included in the initial ancillary datasets, and those that could be identified on satellite images, were excluded as being intact. It is likely that some areas of old disturbance were included as intact areas since they could not be identified using existing data, records and satellite imagery.

- *It is not possible to accurately identify fire disturbance patterns as a factor in identifying intact areas.*

  This is correct, although methods used previously in Russian studies make assumptions about and distinctions between anthropogenic or human-related versus natural cause fires.[1] Our analysis for Canada treated all fires as naturally caused.

- *Methodology needs to ensure international consistency that allows consistent communication.*

  Although international consistency is important, local conditions related to historic land uses and data quality issues necessitate modifications to the methods. For example, although buffers along lakes and rivers were patterned after the Russia work, they were modified to reflect Canada's more recent intensive land uses. A different decision rule concerning fires was also used (see above).

Final Review of Draft Results by Invitation

Following the earlier workshop review of the methods, the draft mapping was completed in 2003 and sent for final review in early July. Reviewers were selected to represent scientific expertise as well as the broad spectrum of sectors that have interests in Canada's forests, including governments, forest companies, First Nations, environmental groups and consultants. Requests to become a reviewer were accommodated. Ninety-six invited reviewers were sent the review package and were asked to respond within three weeks (an extension of the review period was granted at the request of several forest companies, and the review period concluded in mid August). The 96 invited reviewers were selected in order to include all provincial, territorial and federal government forestry agencies and individuals (17), 13 academics, 32 non-government individuals and organizations, 26 forest companies, organizations and retailers, 3 funding foundations and 5 consultants. Twenty-two specific responses were received, representing 33 of the invited reviewers (government = 9; academics = 3; non-government = 8; forest companies/organizations/retailers = 11; consultants = 2).

The major comments were related to editorial changes, background information, overall structure, clarity and flow of the report. Another set of comments dealt with technical details and presentation of the maps. Below is a summary of the major comments on substance and how they were addressed.

Role of Industry

- *Role of industry in using tools to guide corporate policies and purchasing decisions is not clear.*

  Although it is beyond the mandate of Global Forest Watch Canada to recommend, dictate, or predict industries' policies regarding intactness, we believe that maps of large intact forest landscapes will help those companies that desire to take intactness into account when making important conservation policy decisions.

Rationale for Project

- *Rationale for the project should not be to recommend policy, and should not imply that intactness is the only value to consider for sustainable forest management.*

  We removed much of the policy-related language and focused on the original purpose of the project, which was to map intactness. This refined focus also provides a more substantive, data-oriented approach that is compatible with Global Forest Watch's mandate and mission. The report also clarifies that non intact forested areas may have high conservation values, but were beyond the scope of this study to identify and map.

Geographic Scope of Project

- *Results should include mapping intactness across national boundaries.*

  This can only be done for Canada once mapping in the USA is completed. A comparative study may be possible afterwards; however, methodological differences may preclude the ability to make international comparisons.

- *Some key areas were missing within the study area (e.g., northwestern British Columbia and southwestern Yukon).*

  We checked the definitions and data for this area and made minor changes that are consistent with the northern forest boundary.

Significance of Intactness and the findings

- *Why intactness is important needs to be clearer — reviewers found the concept and definition new and diffuse, and the scientific explanation weak. Some reviewers were concerned that our work implies that the benefits within and values of intact areas cannot be found within non-intact areas. (Other reviewers stated that our definition and application of the term "intact" will increase knowledge and awareness of forest intactness.)*

  A discussion of how the scientific literature defines intactness and an additional explanation of our own definition is now included. The value of large, un-fragmented areas is now referenced. Additional statistics regarding forest and non-forest areas within the intact forest landscapes were added.

- *Why are the results significant? We have known for a long time that Canada has a large area of undisturbed forest.*

  This study is an additional contribution to the efforts of many to map the extent and location of remaining un-fragmented and intact forest landscapes in Canada. For the first time, satellite imagery is extensively used to provide more detailed maps on forest landscape intactness than have ever before been produced for Canada.

Definitions

- *More clarity is required about the difference between intact forest landscapes and intact forests. Also, reviewers noted that perhaps intact forest landscapes were not the most appropriate term in some jurisdictions/regions* *owing to the large amount of non-forested areas (e.g., British Columbia), and indicated that we should use the amount of actual forest within intact forest landscapes versus total forest intact forest landscape area as the key statistic.*

We modified our results and the highlighted key findings. We also highlighted and discussed the findings in key regions, such as coastal and interior B.C. (Pacific Maritime and Montane Cordillera).

Threshold Size

- *The selection of one threshold size (of 50,000 hectares) has a weak scientific basis. A series of patch sizes would be more helpful for policy-setting.*

  The text was changed to reflect the possibility of lower thresholds for the size of intact forest landscapes. Scientific references were added to address the threshold issue.

Technical Issues

- *Reviewers wanted more details and clarity on technical procedures.*

  More detail was added.

- *Consistency of methodology between countries is needed so cross-country comparisons can be made. In particular, comparisons with Russia are important, as Russia and Canada share boreal/taiga ecosystems.*

  The two major methodological differences between the Canadian and Russian studies are "fire" and "satellite image resolution." For Russia, Global Forest Watch applied a decision rule that excluded anthropogenic fires from intact forest landscapes. For Canada, during the earlier methodology reviews, reviewers indicated fires should not be used to remove intact forest landscapes. In general, higher resolution images, such as ASTER, were used more extensively in Canada than in Russia. Therefore, methodological differences considered the availability of satellite images, different perceptions of the role of fire, and different land use histories and land management regimes. Comparative statistics between countries will require additional work.

- *The amount of forest was perhaps overestimated.*

  We used a clearly specified dataset in order to be as consistent as possible. We welcome more accurate forest cover data from the relevant jurisdictions as it becomes freely available.

- *The value of the verification methods are questionable, especially the use of older aerial photos with the fact that verification was not statistically based. Field verification needed more than 300 points and more aerial photography checking would improve the verification. Some reviewers indicate it brings into question accuracy of entire project.*

  Aerial photographs and field check sites were not used to statistically verify the draft mapping results, but simply to check and improve the general accuracy of the satellite-based digitizing. Older (some from the 1940s) and recent aerial photographs assisted in verifying features within intact and non-intact areas. The field checks and aerial photographs in the verification procedures were limited by time and resources. More would have improved the accuracy of the results.

- *Why are some activities not included (e.g., selective logging)?*

  We only identified and subsequently removed from the intact category areas with detectable evidence of disturbance. (This was clarified in the method description.)

- *Due to limitations on the methods and data, forest landscape intactness may have been overestimated. Many noted this raises issues about the value of the project and the results.*

  It is true the amount of intact forest landscapes is likely over-estimated; we clarified the parameters of our mapping and the restrictions that influenced it (e.g., resolution of imagery).

- *Some datasets, like protected areas and forest cover, are outdated.*

  Following the final review, we compiled a new national protected areas dataset from the most up-to-date datasets available for each provincial and territorial jurisdiction. For other datasets, such as forest cover, further analysis can be undertaken once provincial datasets are freely available. Global Forest Watch Canada will be happy to undertake further analysis once these datasets are in hand.

- *Over what period must an area have been free from significant human activity before it is considered intact?*

  This is difficult to estimate because of differences in the degree of disturbance and the restorative capacity of the disturbed site. For example, in boreal regions, aerial photographs from the 1940s confirmed that we could detect disturbances such as clearcutting from about that period (and likely slightly earlier) using Landsat imagery. The period for regeneration of highly productive forests, such as those found in coastal and interior British Columbia would be much shorter.

- *Clarity is needed on why various buffering was used for different infrastructures; more subjective than objective.*

  References have been added to support the use of (variable) buffering.

- *The decision rules regarding mapping of seismic and other energy developments is weak, especially the use of Landsats which, at 28.5 metre resolution, is inadequate to detect most recent seismic activity due to recent reductions in width of most seismic lines. This is important to rectify, as seismic and other energy developments have significant ecological impacts, especially on sensitive species like woodland caribou.*

  The Western Canada Sedimentary Basin was re-mapped using higher resolution ASTER imagery plus the 8th (panchromatic) Landsat channel and using, as a guide to image interpretation, ancillary data such as the National Topographic Series maps.

- *New areas have been disturbed by clearcutting since the date of the imagery used in this study.*

  The mapping was re-done where evidence of such disturbance was supplied by reviewers, or newer imagery could be rapidly obtained for areas that were brought to our attention during the review process. The boundaries of some intact forest landscapes are undergoing rapid changes in some regions; consequently, our work is only a snapshot in time.

- *The report does not recognize changes in forest management, instead all anthropogenic disturbances are treated equally.*

  This is correct. This study is the first detailed attempt to map intact forest landscapes in Canada using satellite imagery. Further work is needed to discriminate and map areas of anthropogenic impact and areas of conservation priority in the non-intact forest landscape.

- *Some areas that are mapped as intact have numerous seismic lines.*

  The Western Canada Sedimentary Basin was re-mapped using higher resolution ASTER imagery plus the 8th (panchromatic) Landsat channel and using, as a guide to image interpretation, ancillary data such as the National Topographic Series maps. Despite using this higher resolution imagery, some seismic lines were not detected as they frequently had too narrow a width (frequently one metre wide) to be detected by ASTER imagery.

Protected Areas

- *There was some confusion about the use of the term "special protection areas"; "officially-recognized protected areas" should be used, or alternatively, included under this category should be all the policy-restricted areas such as stream-side buffers, steep slopes, etc. A reviewer suggested we categorize all protected areas according to the IUCN classification for Protected Management Categories.*

  A new dataset was compiled since the final review. The protected areas dataset was updated by obtaining a list of protected areas that met WWF Canada's Endangered Spaces standards; a nation-wide spatial dataset of these sites was then compiled. In a few cases (e.g., New Brunswick, Manitoba), consultations with local experts resulted in corrections and improvements). Categorizing all protected areas in Canada according to the international IUCN system would be a useful exercise but was beyond the scope of this study. Instead, we used the Canada-recognized national Endangered Spaces standards developed by World Wildlife Fund Canada.

Future Research/Work

- *The impacts of logging and how to mitigate them should be studied. As part of the suggestion to explore/map conservation values, understanding more about forest condition is a critical part of resource planning and setting conservation priorities. Species composition, seral stage distribution, site productivity, and habitat suitability for regionally significant species are important elements to understanding the conservation importance of un-fragmented forest landscapes. Global Forest Watch Canada should use already-established indicators of forest sustainability and work with industry in measuring these.*

  These suggestions were added to the section on Future Research.

Language

- *The report is not neutral enough; too much descriptive and biased language and too speculative (e.g., about logging within tenures).*

  We significantly reduced the non-essential, descriptive components of the report. The result is a much thinner report that focuses on the original intent of the project—to map intact forest landscapes.

- *The distinction of Aboriginal settlements in the buffered layers could appear racist.*

  Aboriginal populated places are distinguished in the buffered dataset because this is a separate data set, with attached attribute files containing population levels, obtained from Statistics Canada. As many other populated places did not have attached population levels, and as Aboriginal populated places tend to have small populations, we decided to distinguish using the more accurate Aboriginal dataset.

Review

- *There was a lack of forest industry involvement.*

  The opportunities for forest industry involvement are now included at the beginning of this Annex.

- *The choice of stakeholder reviewers and how they were/are approached needs to be clarified.*

  Details on the choosing of stakeholders are now included in the beginning of this Annex.

Footnotes

Chapter 1. Introduction

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20 Global Forest Watch recognizes the forest landscape contains many features of potential conservation priority. One certification system (the Forest Stewardship Council, Principle 9, on high conservation value forests) lists them as follows:

(a) forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g., endemism, endangered species, refugia), and/or large landscape level forests contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance;
(b) forest areas that are in or contain rare, threatened or endangered ecosystems;
(c) forest areas that provide basic services of nature in critical situations (e.g., watershed protection, erosion control);
(d) forest areas fundamental to meeting basic needs of local communities (e.g., subsistence, health) and/or critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

Ideally, all areas of potential conservation priority should be mapped in such detail that they can be taken into account in the planning, conduct and monitoring of forest management. To do this would be a huge undertaking, made difficult not only by the difficulty of mobilizing the necessary resources but also by the lack of a generally agreed and operational set of definitions (although World Wildlife Fund and ProForest are in the process of developing High Conservation Value toolkits internationally and Forest Stewardship Council Canada is developing a national High Conservation Value Forest toolkit that will likely be finalized with the national boreal standard). Global Forest Watch has therefore chosen to initially focus on forest intactness, defined (by Global Forest Watch) as intact forest landscapes, as an aspect of forest condition of high relevance to forest management.

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Chapter 2. Intact Forest Landscapes: Study Area, Definitions and Criteria

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Chapter 3. Methods

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Chapter 4. Results

1 Over 70 percent of Canada's mammalian species are found in B.C. and 24 of those species are endemic or exclusive to the province (B.C. is home to over 1,086 species of vertebrate animals and 2,073 species of vascular plants: The Ministry of Water, Land and Air Protection. http://wlapwww.gov.bc.ca/wld/bio.htm [Aug 16, 2002]). Sixty (60) percent of these mammals are forest dependent. Forty-four (44) percent of forest dependent mammals with known range trends have contracting ranges. Eighty-eight (88) percent of forest-dwelling vertebrates use low elevation, valley bottom riparian habitat for basic needs such as food, shelter and reproduction. Ninety (90) percent of riparian vertebrate species are threatened by logging in these low elevation forests, many of which are within intact forest landscapes (Ministry of Environment, Lands and Parks, *Environmental Trends in British Columbia [2000]* [Victoria: Ministry of Environment, Lands and Parks, 2001], pp. 46-47.).

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3 The text of most of the historic treaties between Canada and its Indigenous peoples, which were found by this study to contain remaining intact forest landscapes (Treaties 3—11 and the Robinson—Superior and Robinson—Huron Treaties), contain articles promising these people the right to hunt and fish as they had done previously. These treaty rights are constitutionally guaranteed. The texts of Canada's historic treaties are available on-line at http://atlas.gc.ca/maptexts/map_texts/english/trytxt_e.html#NU (July 14, 2003). The text of a typical article from Treaty 5 provides a good example: "Her Majesty further agrees with Her said Indians, that they, the said Indians, shall have right to pursue their avocations of hunting and fishing throughout the tract surrendered... saving and excepting such tracts as may from time to time be required or taken up for settlement, mining, lumbering or other purposes." (Available on-line at http://www.ainc-inac.gc.ca/pr/trts/trty5_e.html [July 14, 2003]). The Supreme Court of Canada has instructed that these treaties be interpreted liberally, "in the sense in which they would be naturally understood by the Indians.» *Constitution Act, 1982*, being Schedule B to the *Canada Act 1982* (U.K.), 1982, c. 11, s. 35, available on-line at http://laws.justice.gc.ca/en/const/ (July 14, 2003). Only intact forests are capable of maintaining the full suite of populations of fauna necessary for Canada to honourably fulfill its constitutional promise to those First Nations peoples with which it has settled treaties.

4 There are many different protection regimes and significant differences exist among Canada's jurisdictions. Some of the areas may still be subject to industrial logging, energy developments and other types of human activity. However, the protected areas of this study meet higher-protection criteria established by the Endangered Spaces criteria of World Wildlife Fund Canada

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Annex

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