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Enhancing Sustainable Forest Management Practices in Canada

NATIONAL RESEARCH AGENDA (2019–2029)

CANADIAN FOREST SERVICE, NATURAL RESOURCES CANADA

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Acronyms

C&I – Criteria and Indicators

CCFM – Canadian Council of Forest Ministers

CFS – Canadian Forest Service

DAP – Digital Aerial Photogrammetry

EBM – Ecosystem Based Management

FAO – Food and Agriculture Organization

IFL – Intact Forest Landscape

LiDAR – Light Detecting and Ranging

MP – Montreal Process

NFD – National Forest Database

NFI – National Forest Inventory

NFIS – National Forest Information System

NRCan – Natural Resources Canada

RS – remote sensing

SARA – *Species at Risk Act*

SDG – Sustainable Development Goals

SFM – Sustainable Forest Management

UN – United Nations

UNDRIP – United Nations Declaration on the Rights of Indigenous Peoples

UNFF – United Nations Forum on Forests

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Executive Summary

Canada is committed to ensuring that its forests maintain their environmental, social, cultural and economic values now and in the long term. Sustainable forest management (SFM) is a recognized approach to achieving that goal. SFM also provides assurance to consumers in the global marketplace that Canada's forest products are sourced from forests that are managed sustainably.

In Canada, forestry decisions and activities are based on strong scientific research, rigorous planning processes, and meaningful consultation with stakeholders. Laws, regulations and policies enforce sustainable management standards and practices across the country. While the provinces and territories have jurisdiction over the majority of Canada's forests, Natural Resources Canada (NRCan) has responsibilities nationally and internationally, including conducting research related to forests to support the responsible development of Canada's natural resources. This National Research Agenda has been developed with input from academia, industry, governmental and non-governmental collaborators on national data and research priorities to enhance sustainable forest management practices. It reflects national interests and priorities for the next 10 years, outlining the research needed to fill knowledge gaps and ensure Canada remains a leader in SFM.

The vision of this National Research Agenda is ***Canadians benefit from sustainable forests.***

The Enhancing Sustainable Forest Management Practices Research Agenda identifies two main themes. The first theme focuses on providing authoritative **national data, monitoring and reporting** on the status of Canada's forests. NRCan – Canadian Forest Service (NRCan-CFS) plays a lead role in data monitoring and reporting, in collaboration with the provinces and territories. The second theme of this National Research Agenda, **forest ecosystem research and social dimensions**, focuses on ecosystem research to accurately portray the state of Canada's forests and to enhance sustainable forest management practices under the complex influences of natural disturbances (e.g., pests), climate change, and different forest management practices. Additionally, factors influencing the social acceptability of forest management practices must be understood to inform decision-makers and increase the effectiveness of knowledge exchange activities. Through the collective implementation of many key actions outlined in this National Research Agenda, the following objectives will be achieved:

- Canada has authoritative, long-term data and tools to monitor the state of Canada's forests and support science-based decision-making;
- Remote sensing technologies are applied to long-term monitoring and are developed to fill data gaps at both national and finer scales;
- Continuous reporting and visualization tools are used to provide accessible and trusted information about SFM to Canadian citizens and other stakeholders;
- Increased understanding of Canada's forest ecosystems informs SFM practices, in particular the natural range of variation in the context of a changing climate;
- Assessments of forest management practices on ecosystems, and associated knowledge exchange, contribute to adaptive forest management and resilient forests;
- Increased understanding of social acceptability of forest management practices informs decision-makers; and
- New methods and tools are developed to improve assessment of SFM.

The knowledge and tools generated through research described within this National Research Agenda will contribute to decision-making regarding many national issues, including climate change, market access for Canada's forest products, preserving ecosystem services (e.g., habitat for wildlife) and cumulative effects assessment.

NRCan-CFS will lead the implementation of this National Research Agenda. Collaborative action throughout the next decade among provinces and territories, academia, federal government, Indigenous peoples, non-government organizations, industry and research groups will be essential to achieve the desired vision and outcomes. This will continue to build a strong forest science foundation enabling public confidence in SFM in Canada.

Introduction

What is sustainable forest management?

The Canadian Council of Forest Ministers (CCFM) agreed on the following definition of SFM:[1]

> *"Management that maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social and cultural opportunities for present and future generations."*

It is generally accepted that SFM can be achieved by applying ecosystem-based management (EBM).[2] Broadly speaking, EBM seeks to adapt management and planning (e.g., forest management) to the dynamics of the whole ecosystem. There are two pathways to measure for EBM adoption:[3]

1. Social and institutional factors where measures of success include degree of participation, diversity of knowledge, and trust among actors; and,
2. Ecological aspects where status and outcomes in different ecological settings are considered/measured.

Often, EBM aims to reduce the gaps between natural and managed landscapes to ensure the long-term maintenance of multiple ecosystem functions, thereby retaining the social and economic benefits that we derive from those ecosystems.[4] EBM is occurring across Canada through different approaches and mechanisms depending on the context (e.g., type of resource development, ecosystem).[5]

Implementation of sustainable forest management demonstrates that Canada is committed to balancing environmental, social and economic issues associated with managing our forest resources. Canada has been successful in continuously adapting its forest practices based on data, science and best management practices, with an eye on balancing these issues while continuing to receive benefits from its rich forest resources.

The Canadian context

In 2017, Canada's forest industry contributed $24.6 billion to Canada's economy, accounted for 7.2% of Canada's total product exports, and directly employed 209,940 people across the country.[6] Canada's forests also make significant contributions to ecosystem services, including the global climate system, water and carbon cycles, and biodiversity. Forested lands are the traditional lands of Canada's Indigenous peoples and have cultural and spiritual significance. Canada's forests and forest products also provide significant opportunities to help transition to a low-carbon economy, through the sequestration of carbon and increased development and use of renewable products for society through the bioeconomy.[7,A]

Provinces and territories have jurisdiction over the majority of Canada's forests, with some 90% of forests in public ownership, and they play a key role in SFM.[8] The Canadian Forest Service (CFS) at Natural Resources Canada (NRCan) plays a central role in SFM for Canada because of its mandate to speak for the Canadian forest sector nationally and internationally; to conduct leading-edge science related to the protection, management and utilization of forest resources; and because of the vast forest knowledge and tools developed in collaboration with stakeholders, such as Canada's National Forest Inventory (NFI).[9,10] With partners, NRCan-CFS also plays a key role in advancing Canada's reputation in the global marketplace as a leader in SFM.

[A] *"The forest bioeconomy refers to economic activity generated by converting sustainably managed renewable forest-based resources, primarily woody biomass and non-timber forest products, into value-added products and services using novel and repurposed processes."*

Social acceptability of forest management practices

The social license to operate is a priority for the forest industry. Although some generalizations can be made at the national level, social acceptability issues in relation to forest management are affected by local history, land ownership patterns and institutional arrangements to manage natural resources, including provincial laws and regulations for forest management.

Social acceptability of forest management practices is not a new issue for Canada's forest sector. The 'War of the Woods' in the 1990s, regarding forest practices in Clayoquot Sound, British Columbia, brought the social acceptability of forest management practices to national and international attention.[11] Current technology and information systems, including social media, now create dynamic platforms for disseminating information and engaging society on all possible topics. Additionally, citizens from Canada as well as countries around the world are placing increasing value on environmental protection and socially responsible practices.[12] With the globalized economy and associated distribution of Canada's forest products worldwide, consumer concerns in foreign markets about Canada's forest management practices can have real impacts on our forest industry and the livelihoods of rural Canadians.[13]

Canada's forests and forest products are contributing positively to global issues such as climate change.[14,15] Forests play an important role in carbon storage and moderating impacts associated with climate change. Additionally, forest products, such as lumber and furniture, can store carbon for centuries. Globally, it is estimated that forests harbour up to 80% of all terrestrial biodiversity.[16,17] Forests have been, and will continue to be, a provider of ecosystem services valued by many people. Just as the social acceptability of practices can change over time, forests are dynamic ecosystems that evolve continually. Climate change, pests and fire continue to alter the forest landscape, in addition to human disturbances. This increases the need to have timely, credible, accessible data and science-based information about Canada's forests to support decision-making. There is also a need to better understand societal concerns regarding Canada's forests and increase public understanding about Canada's forests and forest management.

Canada's international commitments towards SFM

Globally, Canada stands as a leader in SFM and a recognized partner in helping other countries around the world improve their forest knowledge and practices.[18] Canada's forest managers are committed to sustainably managing the country's forest resources. Additionally, Canada has the largest area of third-party-certified forests in the world, providing even more assurance that forests are managed under recognized standards of SFM.[19]

SFM contributes to Canada's progress toward the global Sustainable Development Goals (SDGs),[20] specifically *Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss*. Canada adopted the SDGs in 2015 and seeks to achieve multiple targets by 2030, in partnership with other nations. Canada's SFM knowledge and practices also support progress in meeting various international commitments (outlined in Annex 3), such as the United Nations (UN) Convention on Biological Diversity Targets (e.g., Aichi Targets by 2020).[21]

Canada is a member of several international forest research and reporting initiatives, such as the Montreal Process (MP),[22] which encourages participating countries to report on the state of their forests using a series of agreed-upon criteria and indicators (C&I). Collecting data and reporting on indicators of SFM has been and remains a national priority. NRCan-CFS actively collaborates with partners to develop and validate sound C&Is. While Canada was a leader in the development of the Montreal Process, it is still unable to report in an effective and timely manner on some C&Is (e.g., conservation and

maintenance of soil and water resources), especially in the context of climate change, knowing that it will increase the requirement for adaptability of SFM.[23] In order for Canada to achieve timely, accurate and transparent reporting on the state of Canada's forests, additional data and research are needed to develop the required knowledge and tools.

Forest knowledge supporting national priorities

Given that 35% of Canada's area is forested,[24] it is understandable that the condition and management of Canada's forests is relevant to many national issues, including climate change, clean growth and a low-carbon economy, conservation of biodiversity, preserving ecosystem services, and managing the cumulative effects[25] of natural resource development.

Canada's government is committed to being more open, inclusive and accessible.[26] This includes open data, ensuring that high-quality government data are discoverable, accessible and reusable.[27] The forest data and knowledge generated within the scope of this National Research Agenda informs decision-making by many stakeholders regarding the state and use of Canada's forests. The knowledge and data are also important to assess the effectiveness of policies. In combination with other NRCan efforts, this knowledge contributes to delivery of the Minister of Natural Resources Canada's mandate commitment to "…tackle Canada's most pressing environmental challenges and create more opportunities for Canadian workers. This should include new approaches for sustainable forest management given more frequent wildfires." [28]

Forest data and science-based tools will also help inform the implementation of Canada's *Species at Risk Act (SARA)*[29] and Canada's new impact assessment regime for natural resource projects.[30] Understanding forest ecosystem processes and dynamics provides foundational knowledge about many valued ecosystem services, including wildlife habitat (e.g., caribou, moose).

There is concern about declining caribou populations in Canada's forests.[31] Woodland caribou are listed as threatened under *SARA*, as well as under provincial legislation in a number of provinces and territories. NRCan-CFS is collaborating with Environment and Climate Change Canada and others to develop knowledge needed to achieve Canada's commitment to caribou recovery. For example, the two departments are investing in science and modelling to better understand, at the site and landscape levels, dynamics and components of boreal forest habitat, ecosystems and disturbances, and climate change. NRCan-CFS's work is also done in collaboration with other key partners, including provinces, territories and Indigenous peoples, and will improve the evidence base and provide decision support tools for boreal caribou conservation and range planning. Research conducted within the scope of this National Research Agenda will complement other research efforts (e.g., NRCan-CFS Cumulative Effects program, NRCan-CFS Forest Climate Change program, academia) and contribute fundamental forest data and ecosystem knowledge to address current and emerging forest issues.

The Government of Canada is implementing a new Impact Assessment system for major projects such as new mining and energy development, which will foster public engagement, advance partnerships with Indigenous peoples and consider sustainability for present and future generations.[32] This new system aims to better manage cumulative effects with practices informed by science, knowledge and data.[33] Cumulative effects of development in a region are changes to the environment over time caused by a variety of disturbances, both natural and anthropogenic, such as climate change, natural resource development and conversion of land use (e.g., agriculture to urban).[34] Forest management is one form of change on the landscape, and therefore improving forestry practices can lessen the impacts of cumulative effects. Additionally, forest data, monitoring and ecosystem research provide fundamental information, which can be used to better understand and manage cumulative effects within Canada's forests.

Indigenous knowledge

One of the most important social issues of the 21st century for Canada is reconciliation with Canada's Indigenous Peoples. Canada has committed to reconciliation through the Truth and Reconciliation Commission's Calls to Action and as a signatory to the UN Declaration on the Rights of Indigenous Peoples (UNDRIP).[35]

> *"Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and*

cultures …. They also have the right to maintain, control, protect and develop their intellectual property over such cultural heritage, traditional knowledge, and traditional cultural expressions."[36]

– UNDRIP, Article 31(1)

Indigenous knowledge and Western science are complementary tools of discovery. Each uses observation, data collection and logic to make sense of the world.[37] "Indigenous knowledge and [Western] science can work together to… address a jointly defined problem, each bringing their own expertise to the table."[38]

Recognition of Indigenous knowledge and collaboration with Indigenous knowledge holders presents a complex challenge for Canada's scientific communities, especially in regards to ownership, control, access and possession of knowledge.[39] Nevertheless, there is an opportunity and high interest to honour reconciliation, grow meaningful relationships and share knowledge associated with Canada's forests and SFM practices.

It is recognized that Indigenous Peoples have prior claim, or title, to lands they occupied prior to colonization and the Crown's assertion of sovereignty. Canada's Indigenous people continue to have strong connections to the land and forests. Approximately 70% of Indigenous people in Canada live in or near forests, which provide spiritual, cultural and ecosystem services, and often provide employment opportunities for communities.[40] A better understanding of the values and interests of Indigenous communities is needed to support enhanced SFM practices in Canada. Specific actions will be developed in collaboration with Indigenous partners.

Spotlight on long-term collaborative research

Long-term, collaborative research projects are improving our understanding of how forest ecosystems respond to disturbances. This knowledge is helping the forest sector improve and adapt operational practices, make informed management decisions, and maintain market access. It is also helping decision-makers develop policies and best practices to maintain healthy, sustainable forest ecosystems for future generations.

Ecosystem-Based Management Emulating Natural Disturbance (EMEND), Alberta

Special features:

- Over 7,000 hectares in the boreal forest
- Designed to span one forest rotation (e.g. up to 120 years)

Key research topics:

- Effects of forest management practices (i.e., variable retention harvesting) on biodiversity

North America Long Term Soil Productivity (LTSP), Various sites

Special features:

- Largest international, long-term, replicated study of silviculture and soil productivity
- Established in 1989 in conjunction with the United States Forest Service

Key research topics:

- Effects of soil porosity and organic matter on soil processes and site productivity

Turkey Lakes Watershed, Ontario

Special features:

- 40 years of research in a mixed hardwood forest
- Designed as a whole-ecosystem watershed study

Key research topics:

- Impacts of forest harvesting practices, climate change and acid rain on terrestrial and aquatic ecosystems

Impacts of Spruce budworm Outbreak on Forest Ecosystem Dynamics (ISOFED), Quebec

Special features:

- In the epicenter of a major spruce budworm outbreak
- Research at the interface between natural and anthropogenic northeastern boreal forest environments

Key research topics:

- Effects of ongoing spruce budworm outbreak on ecosystem processes (e.g., regeneration, mortality, nutrient fluxes), black spruce forests, and northern forests

National Research Agenda

Target audiences

The target audiences for this Research Agenda are forest management decision-makers and practitioners across the country as well as research funders, providers and users, many of whom contributed to developing this plan through consultations held in 2017 and 2018 (see Annex 2). These audiences include but are not limited to:

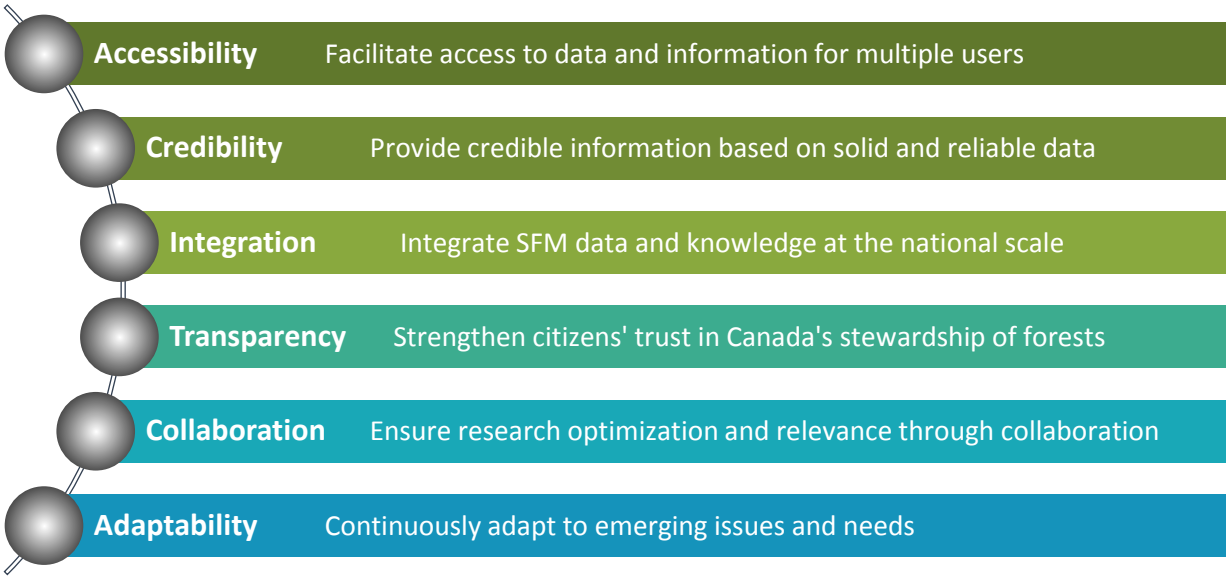
- Federal government;
- Provincial and territorial governments (either directly or through intermediaries such as the CCFM);
- Private sector (e.g., industry, woodlot owners);
- Indigenous peoples;
- Non-profit organizations; and
- Research and international organizations (e.g., academia, United States Forest Service).

Vision

Canadians benefit from sustainable forests

Principles

This National Research Agenda is based on the following set of guiding principles:



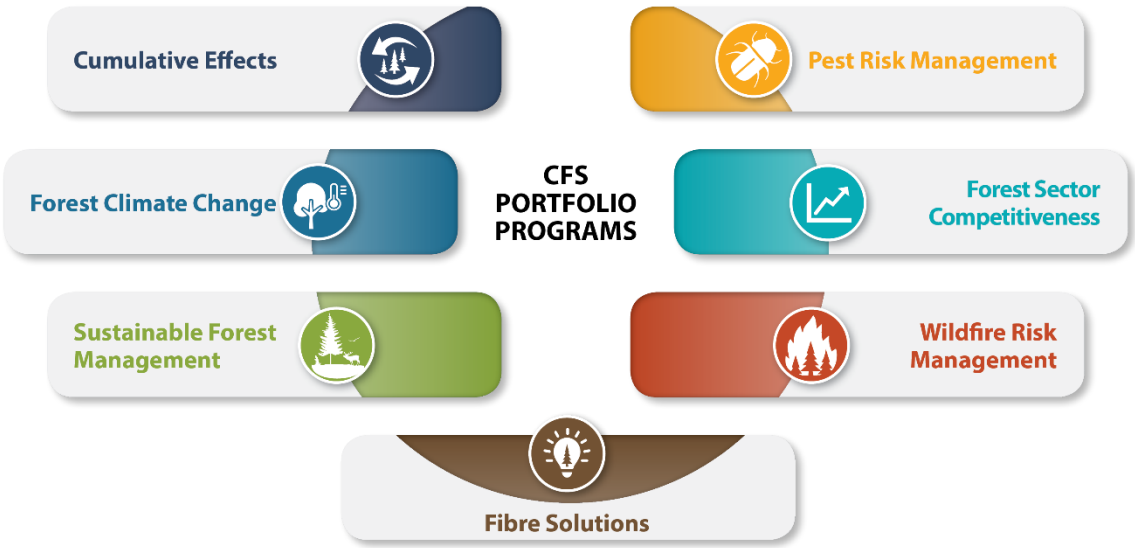
Context and scope

SFM as a concept is cross-cutting and includes all aspects of forests and forest management. This National Research Agenda focuses on addressing national challenges regarding enhancing and assessing SFM practices. It complements the other National Research Agendas developed by NRCan-CFS and partners (see Annex 1 for more information). The National Research Agenda aims to identify and promote forest management practices to minimize the differences between managed and unmanaged forest conditions and processes, and to enhance forest resilience (i.e., EBM). Climate change is impacting forest ecosystems, thus considering climate change in the establishment of realistic and adapted benchmarks for forest management falls within the scope of this Research Agenda. This Research Agenda provides high-level science direction. The specific activities needed to address research themes and priorities may change over time as issues evolve and scientific

understanding matures. Therefore, this Research Agenda will be revisited and adjusted as relevant and necessary over the ten-year period.

The Enhancing SFM Practices National Research Agenda has been developed with input from diverse forest sector stakeholders, including the research community and Indigenous peoples, through a multi-step process including specific groups and areas of expertise (see Annex 2). This Research Agenda is designed to provide strategic direction for a ten-year period. Research and activities conducted under the auspices of NRCan-CFS's internal Enhancing SFM Practices research program will make significant contributions to deliver on objectives and key actions outlined in this document. These national efforts are rooted in collaboration with the diverse forest management and research community in Canada (e.g., industry, academia, provincial and territorial governments, federal government and Indigenous peoples).

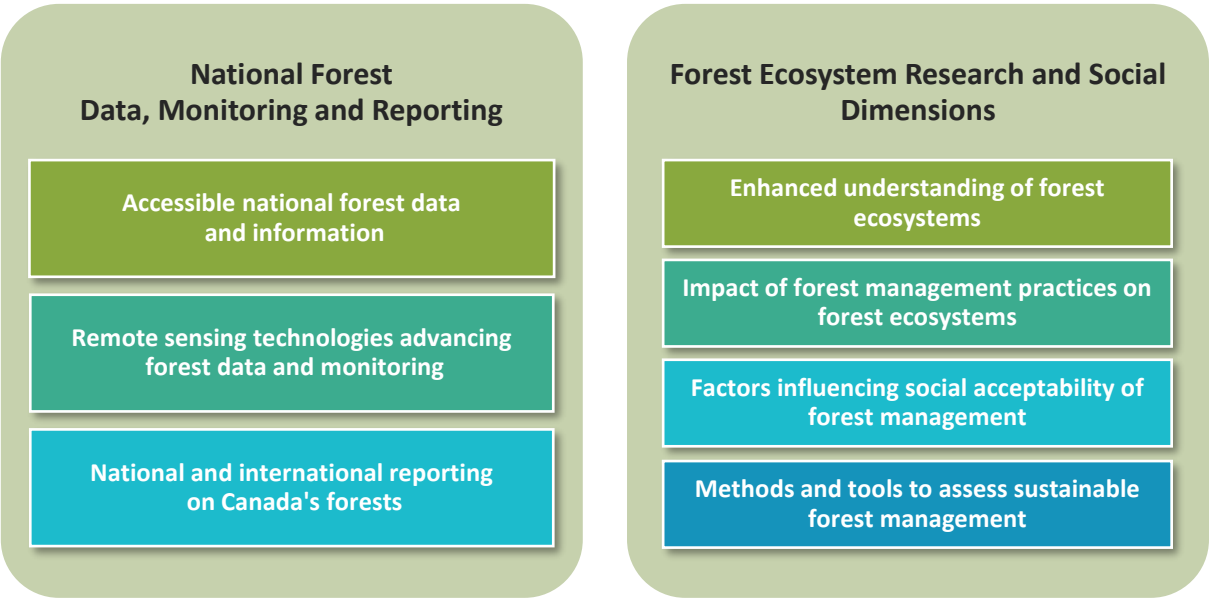
Figure 1. NRCan-CFS programs



Research themes and priorities

The Enhancing Sustainable Forest Management Practices National Research Agenda has two themes: National Forest Data, Monitoring and Reporting; and Forest Ecosystem Research and Social Dimensions (Figure 2).

Figure 2. Research themes and priorities



Theme 1: National Forest Data, Monitoring and Reporting

Data, information products, and monitoring and reporting tools for the generation, integration and dissemination of scientific and socio-economic data and knowledge regarding Canada's forests

The federal government (NRCan-CFS) has a leadership role in national forest monitoring and reporting in collaboration with provincial and territorial government agencies to collect, process and disseminate data.[41,42] National-scale forest monitoring is a major undertaking that must have a long-term focus to establish trends and the current state of Canada's forests given a changing climate. A broad array of partners and stakeholders are already engaged in the scoping, production, monitoring and reporting, use and communication of Canada's national forest inventory, and this collaboration will need to continue to ensure we are able to assess trends in our forest ecosystems and the effectiveness of climate change policy and mitigation approaches.

Even though there are significant inventory and monitoring programs at sub-national scales, Canada's national forest data efforts, including the NFI,[43] must be strengthened to achieve a similar standard to many other major forested countries internationally.[44] The Canadian jurisdictional context for forestry is complex, with public land ownership, various tenure systems within and amongst different jurisdictions, and Indigenous rights and titles. Furthermore, forest data are lacking for a great part of the northern region of Canada as well as for private forests. Collaboration is needed to capture information on all of Canada's forests, given the vastness of our country and the significant human and financial resources required to collect, process and maintain credible data nationally. The long-term goal regarding national forest data is an established network of sufficiently dense ground sample plots in Canada's forests, distributed across forest ecozones, to enable authoritative analyses at many scales, and with greater use of remotely sensed data.

A challenge for Canada concerning SFM is the design and implementation of robust national forest monitoring and assessment systems that can be sustained in the long term to see the trends over time with available resources. Effort is needed to maintain, collect and consolidate authoritative data on Canadian forest ecosystems; facilitate data and information sharing among stakeholders; and enable more efficient and cost-effective reporting regarding SFM.

Over the next 10 years, advances in technology and statistical analyses will provide new opportunities for data collection, management and analysis. The use of new technologies will increase for purposes such as biodiversity data collection, including the mapping of species habitats (e.g., species at risk), forest resource conditions, water quality, and soil productivity. The use of remote sensing (RS) technologies will also help fill the current geographical gaps of the NFI, specifically in northern and remote regions. Current and new technologies require ongoing scientific research to harness their potential and understand their limitations regarding forest data and SFM practices. As RS technologies and data analysis opportunities (e.g., modelling) increase, there is still a strong need for field data for calibration, validation and error assessment. Modelling tools are likely to evolve greatly in the next 10 years with the development of artificial intelligence. Canada's forest experts need to stay at the forefront of these advances.

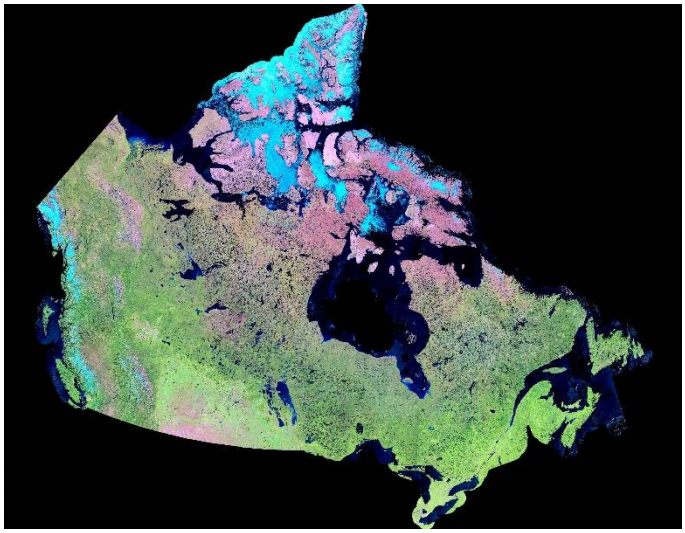


Figure 3. Summary of key objectives and associated expected outcomes within the National Forest Data, Monitoring and Reporting theme

THEME	PRIORITY	OBJECTIVE	EXPECTED OUTCOME
National Forest Data, Monitoring and Reporting	A. Accessible national forest data and information	Canada has authoritative, long-term data and tools to monitor the state of Canada's forests and support science-based decision-making	Changes in Canada's forests are tracked over time and inform decision-makers (e.g., policy decision-makers, researchers, forest practitioners, etc.)
	B. Remote sensing technologies advancing forest data and monitoring	Remote sensing technologies are applied to long-term monitoring and are developed to fill data gaps at both national and finer scales	Applications of remote sensing technologies provide new methods, tools and products for assessing forest changes and SFM at multiple scales
	C. National and international reporting on Canada's forests	Continuous reporting and development of visualization tools are used to provide accessible and trusted data and information about SFM to Canadian citizens and other stakeholders	National forest data, information and tools contribute to increased knowledge of SFM and public confidence in Canada's forest sector

1-A Canada has long-term authoritative data and tools to support science and monitoring of forests

Key actions:

- Standardize, consolidate and manage data according to sound information management principles and the use of common metrics and protocols.
- Produce and openly disseminate statistically rigorous, spatially exhaustive national datasets on the most significant key forest attributes (i.e., forest cover, land use, ownership, protection status, tenure, stocking, height, species, age, volume, biomass, natural and anthropogenic disturbances).
- Make forest data accessible via the Open Science and Data Platform, in development by the Government of Canada, and other open science and data mechanisms to support science-based decision-making and national priorities.[45]
- Continuously improve the current forest information, monitoring and reporting system (including the NFI,[46] National Forest Database [NFD][47] and National Forest Information System [NFIS][48]) to take advantage of emerging technologies, techniques, funding and partnership opportunities.

- Seek funding and partnership opportunities to realize the long-term goal of 6,000 ground sample plots in forested areas across Canada, thereby enabling more comprehensive and statistically rigorous reporting on the state of Canada's forests.

- Improve data integration at different scales through the use of a common *data dictionary*[B] and/or create compatible systems for data collection and sharing (depending on the context).

1-B Remote sensing technologies are applied to long-term monitoring and are developed to fill data gaps at both national and finer scales

Key actions:

- Develop methods to produce national, spatially explicit datasets of key forest inventory attributes (e.g., forest extent, height, volume, biomass) and ecosystem attributes (e.g., soil properties, stream classification, wildlife habitat) using various remote sensing technologies.

- Advance and deploy specific technologies, such as Light Detection and Ranging (LiDAR) and digital aerial photogrammetry (DAP), among others, as requisite calibration and validation data for national datasets of key forest ecosystem attributes (e.g., timber volume).

- Harness advances in statistical analyses (e.g., big data analytics, data fusion, model-assisted estimation) to leverage remote sensing technologies and field data to their fullest. For example:

    - Integrating series of passive (optical) and active (e.g., LiDAR, radar) remote sensing data over time to improve national and regional characterizations of Canada's forests;

    - Monitoring of forest growth over time as well as regeneration post-disturbance, and development of methods for data assimilation and exploitation; and

    - Developing forecasting systems to project forest attributes of interest forward in time.

1-C Continuous reporting and visualization tools are developed and used to provide accessible, trusted data and information about SFM to Canadian citizens and other stakeholders

Key actions:

- Contribute to national and international reports to meet Canada's obligations and commitments (e.g., Global Forest Resources Assessment, UN Framework Convention on Climate Change, UN Convention on Biological Diversity, UN SDGS, MP, Federal Sustainable Development Strategy) using statistically rigorous and transparently produced data.

- Coordinate activities, lead initiatives and represent Canada within MP, FAO, UNECE, UNFF and other intergovernmental and international organizations with an interest in forest reporting to: streamline data collection requirements and schedules; review and refine SFM-related indicator frameworks; and design and prepare reports and communications materials to ensure global forest-related indicator frameworks are aligned with internationally agreed definitions, consistent with Canadian forest management practices and supported by data collection networks.

- Publish and disseminate *The State of Canada's Forests* annual report, the *Forestry Fact Book*, associated web content with interactive graphics, and other communications materials to inform public dialog, enhance public confidence in forest management in Canada and support forest sector competitiveness.

[B] Centralized repository of information about data such as meaning, relationship to other data, origin, usage and format.

- Review and improve Canada's suite of forest-related indicators for national reporting based on the best available science and data produced through NRCan-CFS science programs. Increase the number of MP indicators Canada reports on to better demonstrate leadership in SFM and more consistently report on SFM with other MP countries.

- Modernize the online NRCan-CFS forestry statistics database[49] to increase the information available, enhance the user experience and integrate this database with the data management system for national reporting data.

Theme 2: Forest Ecosystem Research and Social Dimensions

Forest research to accurately portray the state of Canada's forests and continually optimize management practices in the context of SFM

Canada is currently a leader in forest ecosystem science and in the development of criteria and indicators for monitoring forest condition and trends. In order to continue Canada's leadership and address emerging issues, there is an ongoing need for forward-looking research and adapting forest management practices in the context of SFM. NRCan-CFS will pursue the key actions outlined in this theme in collaboration with provinces, territories, academia, industry, Indigenous Peoples and others. New funding and partnership opportunities will be necessary to fully achieve the key actions and desired outcomes.

There is a need to advance understanding of functional relationships among soil, water, biodiversity and ecosystem processes. Specifically, we need to understand and assess variability in ecosystems by evaluating the impacts of natural disturbances and a changing climate. This fundamental knowledge can then be used for the development of tools and models regarding sustainable forest management. In some cases, new baseline information will be required (e.g., soil, water, biodiversity), pertaining to new research questions and local conditions.

Assessing effects of both emerging and current forest management practices is essential to inform SFM practices, and to ensure biodiversity conservation, healthy watersheds and sustainable resources for future generations. Deliberate application of research in continuous improvement of forest management practices will be needed to contribute to the development or validation of third-party certification standards, and to maximize ecosystem services that managed forests provide.

In addition to biophysical forest ecosystem research, there is also a need for social science research regarding forest management. As societal expectations change and forest management practices evolve, there is a need to continuously assess the factors influencing the social acceptability of forest management practices. The success of Canada's forest industry in the global marketplace is founded on sustainable forest management practices, which includes socio-economic and cultural aspects.

Finally, there is a need to develop cost-effective, easy-to-use, meaningful tools and methods to monitor ecosystem processes and enhance reporting on Canada's national and international commitments (see Annex 3 for further details), including the MP C&Is.[50] There is a need for advancement in the following areas:

- Alignment of current C&I reporting with emerging priorities, such as bioeconomy and climate change;

- Cost-effective monitoring tools and data at various scales for some C&Is, such as those associated with forest productivity (including soils), water (quantity and quality), associated biodiversity and species at risk;

- Clear metrics and data to assess some aspects of socio-economic forest benefits; and
- Ecosystem-based metrics to answer inquiries about new concepts such as intact forest landscapes (IFL), which have gained traction among stakeholders both nationally and globally.

Figure 4. Summary of key objectives and associated expected outcomes within the Forest Ecosystem Research and Social Dimensions theme

THEME	PRIORITY	OBJECTIVE	EXPECTED OUTCOME
Forest Ecosystem Research and Social Dimensions	A. Enhanced understanding of forest ecosystems	Increased understanding of Canada's forest ecosystems, in particular the natural range of variation in the context of a changing climate, informs SFM practices	Broader and strengthened knowledge base to understand and assess forest sustainability in Canada
	B. Impact of forest management practices on forest ecosystems	Assessments of forest management practices on ecosystems, and associated knowledge exchange, contribute to adaptive forest management and resilient forests	Canada's SFM practices continue to be enhanced, in the context of a changing climate
	C. Factors influencing social acceptability of forest management	Increased understanding of social acceptability of forest management practices informs decision-makers	Governance and communication about forest management are more effective, informed by social science research
	D. Methods and tools to assess sustainable forest management	New methods, tools and enhanced indicator frameworks are developed to improve assessment of SFM	More efficient and cost-effective tools for SFM assessment, and enhanced indicator frameworks, enable better forest management

2-A Increased understanding of Canada's forest ecosystems, in particular the natural range of variation in the context of a changing climate, informs SFM practices

Key actions:

- Leverage long-term and watershed-scale study sites and large-scale research networks in Canada's forest regions as benchmarks for forest biodiversity, soil productivity, quality and quantity of water, and ecosystem processes at various scales.
- Document the biodiversity and ecosystem dynamics in northern forested zones considered for potential commercial use, to guide the development of emerging biomass and forestry operations along SFM principles.

- In collaboration with provinces and territories, examine regional- to national-scale impacts of ecological stressors on ecosystem integrity. These collaborations could lead to the creation of spatial data sets; the ability to model processes such as fire, insect disturbance, forest growth and succession; and the assessment of current and potential future impacts under a changing climate.

- Through increased engagement, improve understanding of Indigenous knowledge and perspectives and, with the guidance of Indigenous knowledge holders, explore opportunities to co-create a common understanding of and priorities for forests in the context of a changing climate.

2-B Assessments of forest management practices' impacts on ecosystems, and associated knowledge exchange, contribute to adaptive forest management and resilient forests

Key actions:

- In support of enhancing SFM practices, assess near- and long-term effects of emerging (e.g., biomass harvesting, use of hybrid species, fertilization, ash amelioration) and current forest management practices (e.g., retention forestry, riparian buffers, partial harvesting, forest regeneration management, zoning of forest management intensity, salvage logging) at various spatial (stand, watershed, landscape) and temporal scales (stand development stages) on forest ecosystems and biodiversity.

- Assess planning and operational practices intended to maintain ecosystem characteristics (e.g., connectivity, age class distribution, productivity) that protect soil, water and biodiversity, including species at risk.

- Develop methods to refine our assessment of forest dynamics in response to forest management, considering both Indigenous and scientific knowledge.

- Translate scientific knowledge into the development of guidelines and best management practices for SFM.

2-C Increased understanding of social acceptability of forest management practices informs decision-makers

Key actions:

- Assess communities' uses of, and values related to, the forest and their implication in forest management.

- Evaluate modes of public involvement in decision-making in view of their implication for social acceptance of forest management practices to improve governance practices.

- Assess Canadian citizens' understanding of concepts associated with forest management practices (plantations, vegetation and pest control, etc.) and forest sustainability to facilitate their consideration in decision-making processes regarding forest management as well as in engagement, knowledge exchange and communications activities.

2-D New methods and tools are developed to improve assessment of SFM

Key actions:

- Use modelling tools to forecast the impacts of current and alternative forest management practices on forest ecosystems and on the provision of forest ecosystem good and services.
- Use advanced scaling methods and integrative approaches to optimize the use of long-term study sites to assess the impacts (biotic and abiotic) and spatial and temporal trends associated with forest management practices in the provision of forest ecosystem services.
- Develop, improve and validate current and emerging methods to assess soils (condition, productivity), water (quality and quantity), biodiversity (populations, habitat, and species), regeneration and productivity. These methods should be cost-effective, easily applicable, meaningful, and allow for more effective assessment of reporting on SFM.
- Clarify indicators used in international reporting such as "primary forests" to better define their relationships to ecosystem services, and design methods to operationalize them in a way that is consistent with Canadian forest management practices, such as the development of indices of the resilience of forest ecosystems.
- Improve understanding of Indigenous knowledge and perspectives and, with the guidance of Indigenous knowledge holders and science practitioners, explore new ways of knowing and/or new tools and methods to assess SFM practices.

Implementation: Collaboration and Knowledge Exchange

Research related to the sustainability of Canada's forest ecosystems is extremely diverse in scope (e.g., biodiversity, forest regeneration, soil, water), geographically dispersed, and involves a wide variety of actors. Significant collaboration is already occurring among the many forest sector stakeholders including academia, provincial and territorial governments, forest industry, federal government, other research institutes, Indigenous groups, non-profit organizations and communities. New relationships and long-standing partnerships have immense value and provide opportunities for new and integrated research. New partnerships will be pursued throughout the lifespan of this Research Agenda to address the complex and cross-disciplinary aspects of SFM research; integration of data, models and tools; and knowledge dissemination to a variety of audiences. Collective action among diverse stakeholders is needed to address key research priorities, identify future areas of interest, and mobilize the use of science-based information, data, knowledge and tools by decision-makers.

NRCan-CFS will lead the implementation of this National Research Agenda and will continue to provide leadership for SFM practices in Canada through science excellence and as a trusted source for knowledge about Canada's forests and management practices for national and international audiences. NRCan-CFS seeks to leverage additional value from existing national forest research and long-term projects (e.g., Long-Term Soil Productivity network, AshNet), and welcomes new collaboration opportunities. This Research Agenda is intended to be evergreen and implemented through collaborative action. Additional resources will be required to realize its full implementation.

Several existing multi-jurisdictional groups strategically inform and implement national forest data initiatives, specifically the NFI, NFD and NFIS collaborators' group. Additionally, the CCFM's Data Task Team facilitates the production of cross-jurisdictional data products for the CCFM, including those related to SFM, and improvements to the collection, management and sharing of forest sector data across jurisdictions. These groups will continue to collaborate and jointly implement key activities supporting this National Research Agenda. Additionally, new partnerships among diverse actors will be explored.

Internationally, Canada's membership in intergovernmental organizations with a mandate for forest reporting enables Canada to strategically influence and implement internationally-agreed definitions, data collection initiatives and reporting structures to support domestic and global reporting requirements, such as the SDGs. This allows us to ensure that international reporting requirements are consistent with Canadian forest management practices, underpinned by existing data collection

systems and supported by existing forums to exchange knowledge and information. Collaborative implementation of this National Research Agenda among forest sector stakeholders and Indigenous peoples will contribute to a strong science foundation, enabling public confidence in the sustainable management of Canada's forests.

Annexes

Annex 1: Linkages with other National Research Agendas and NRCan-CFS programs

All of the National Forest Research Agendas and associated NRCan-CFS programs are relevant, in different ways, to the broad concept of SFM. The Enhancing SFM Practices National Research Agenda shares several cross-cutting research issues with other National Research Agendas and NRCan-CFS programs. For example, climate change must be considered in the conception and application of ecosystem-based management and SFM practices. Considering climate change in the establishment of realistic and adapted benchmarks for forest management falls within the scope of the Enhancing SFM Practices National Research Agenda. Specific research and activities focused on climate change mitigation and adaptation would fall within the scope of the Forest Climate Change National Research Agenda. There will also be shared areas of work, for example, exploring interactions between Forest Change indicators and SFM criteria and indicators to assist forest management planning and demonstrating sustainability in the long term.[51]

There are also strong linkages with the NRCan-CFS Fibre Solutions program, which investigates the impact of forest management practices at the tree and stand level, while the Enhancing SFM Practices program focuses on the broader state of the forest, including forest ecosystem conditions. Research regarding new tools (e.g., remote sensing) and forest management practices is needed and being conducted in both contexts.

The NRCan-CFS Enhancing SFM Practices research program is focused on forest stakeholders and forest management practices. This complements the research conducted within the NRCan-CFS Cumulative Effects program, which is focused on management of cumulative effects of natural resource development activities (e.g., forestry, oil and gas, mining), as well as forest disturbances and climate change on Canada's forests, with a broader set of stakeholders.

Research priorities and activities within the Enhancing SFM Practices National Research Agenda related to national data, information, RS research, and reporting (domestic and international) contribute broadly to the other National Research Agendas. For example, the NFI and NFD contribute authoritative data and information for researchers, which can be used to investigate a variety of forest issues including climate change, pests and fire.

The integration of data from long-term research sites and large-scale forest research networks will be an opportunity to structure and share data from sites used by various CFS programs as well as partner research organizations.

The NRCan-CFS National Research Agendas and programs are complementary and will work together to provide comprehensive leadership of national forest research priorities. Effective collaboration and communication will be essential during the implementation phase.

Annex 2: Contributors to and development of Enhancing SFM Practices Research Agenda

The development of this National Research Agenda was informed through NRCan-CFS's long-term, ongoing dialogue and collaboration with diverse stakeholders, and ongoing analysis of gaps and needs regarding forest data, knowledge, research and tools about Canada's forests and SFM. For example, a 2016 report detailed recommendations to improve the confidence in Canada's NFI.[52]

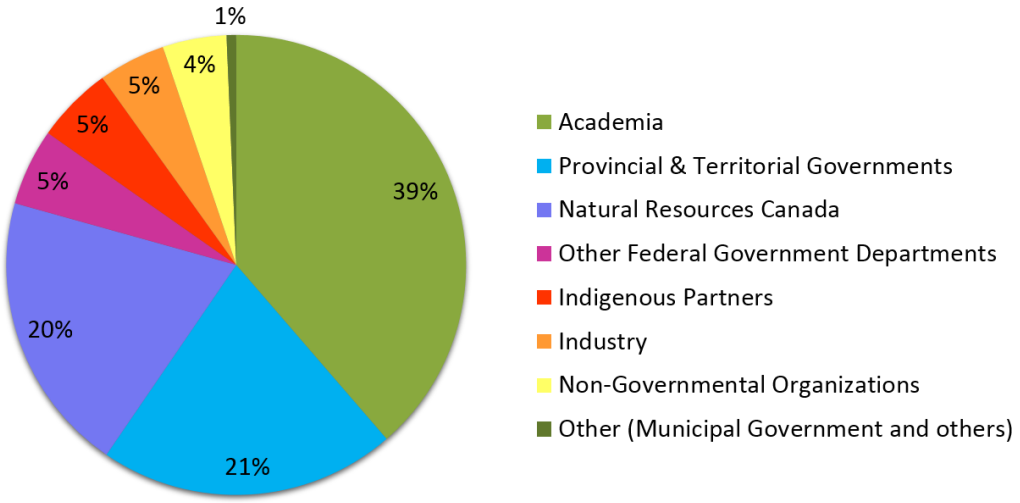
The development of this National Research Agenda has also been informed by cross-cutting consultations for all of Canada's National Research Agendas being led by the CFS, specifically the *Beyond the Canopy* events in September 2017 and February 2018. Targeted engagement with partners and stakeholders was also undertaken to:

- understand current and emerging issues and priority needs within the scope of the Enhancing SFM Practices National Research Agenda:
- build and strengthen relationships with collaborators;
- better understand each other's priorities; and
- position the 10-year National Research Agenda for success through relevance and collaboration.

Figure 5. National Research Agenda development process and timeline

Together, the various outreach and engagement initiatives involved over 400 representatives from diverse organizations to inform the development of this National Research Agenda (see Figure 6).

Figure 6. Groups engaged while developing this National Research Agenda



We thank everyone for their input during the development of this National Research Agenda.

This Research Agenda is intended to be evergreen and implemented through collaborative action. Discussions among potential collaborators and existing partners will continue to achieve the key actions and outcomes, and facilitate knowledge exchange during the coming decade.

Annex 3: International and National Reporting on the State of Canada's Forests

United Nations Committees and treaties

The United Nations is an important international forum for advancing issues that matter to Canadians and engaging with partners from around the world to meet global challenges.[53] The UN has advanced international cooperation on issues related to sustainable forest management through a variety of mechanisms, including:

- 17 Sustainable Development Goals in the 2030 Agenda for Sustainable Development;[54]
- the Convention on Biological Diversity (CBD) – an international legally-binding treaty with three main goals: conservation of biodiversity; sustainable use of biodiversity; and fair and equitable sharing of benefits arising from the use of genetic resource;[55]
- the Food and Agriculture Organization (FAO) – a specialized agency of the UN that leads international efforts to defeat hunger, including actions related to land use and forestry;[56] and,
- Forum on Forests – an intergovernmental subsidiary body of the UN with the main objective to promote "…the management, conservation and sustainable development of all types of forests…" [57]

Canada's participation in the United Nations and specific international treaties or initiatives obligates Canada to participate and report on national initiatives to advance global goals. Reporting requirements vary by initiative, and new initiatives may be created to address global issues. Canada contributes to the following UN initiatives/reports regarding Canada's forests:

- Global Forest Resources Assessment (FAO)[58]
- FAO Yearbook of Forest Products[59]
- United Nations Convention on Biological Diversity[60]
- United Nations Sustainable Development Goals (i.e., Goal 15: Life on Land)[61]
- United Nations Strategic Plan on Forests[62]

Montreal Process

Canada is also a member of the Montreal Process (MP), an international working group of nations committed to sustainable forest management. Since 1995, the twelve member countries of the Montreal Process have used a common set of science-based criteria and indicators to measure progress toward the conservation and sustainable management of 90% of the world's boreal and temperate forests.[63] The MP framework consists of 7 criteria and 54 indicators.[64] Canada contributes significantly to the ongoing activities of the Montreal Process working group, and reports annually by providing *The State of Canada's Forests* annual report.

The State of Canada's Forests and other national reporting

Regulations under the *Department of Natural Resources Act*[65] require a report about the state of Canada's forests be prepared annually by the federal Minister of Natural Resources. This report provides timely, relevant information for many forest stakeholders (e.g., industry, non-profit organizations). NRCan-CFS also produces an annual Forestry Fact Book.[66] The data and information also contributes to other national reporting initiatives, including:

- Canadian Environmental Sustainability Indicators;[67] and
- Federal Sustainable Development Strategy.[68]

Canada's leadership in international and national forums is important in advancing the goal of sustainable forest management shared by many nations.

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