



Natural Resources
Canada

Ressources naturelles
Canada

Addressing cumulative effects of natural resource development in Canada's forests

NATIONAL RESEARCH AGENDA (2019–2029)



CANADIAN FOREST SERVICE, NATURAL RESOURCES CANADA



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National Research Agenda: Addressing cumulative effects of natural resource development in Canada's forests (2019–2029)

The National Research Agenda presents a coordinated vision for research within NRCan-CFS to address cumulative effects occurring in Canada's forests. It is a collaborative effort that builds on past, present, and future research, and the knowledge and tools needed over the next decade for on-the-ground and strategic decision making. This Research Agenda focuses on developing science-based decision-making tools that will help land managers and decision makers prepare for and respond to the different challenges regions experience. It recognizes the importance of integration of Indigenous knowledge and values, and the need to proactively develop tools to effectively manage increasingly complex landscapes. It will also help land managers implement appropriate strategies to optimize mitigation solutions at the landscape and site levels. Outputs of this research agenda will help ensure that environmental aspects are considered in resource development, and will help maintain the environmental reputation of the natural resource sector, ensuring competitiveness.

NRCan-CFS will lead in implementing this Research Agenda. Success, however, will depend on strong partnerships with other federal departments, Indigenous peoples, academia, industry, and governmental and nongovernmental partners to achieve the strategic objectives identified in this document. This Research Agenda reflects national interests and priorities for the next 10 years, and may be revisited to adjust its goals and needs as new issues and challenges arise.

Vision statement

Cumulative effects in Canada's forests are effectively managed.

Mission statement

Develop knowledge, data, tools, strategies, and capacity to manage cumulative effects in Canada through multidisciplinary science and collaborative partnerships.

Abbreviations

AAFC: Agriculture and Agri-Food Canada

ADM: Assistant Deputy Minister

CanNor: Canadian Northern Economic Development Agency

CCME: Canadian Council of Ministers of the Environment

CCMEO: Canada Centre for Mapping and Earth Observation

CEAC: Cumulative Effects Advisory Council

CFS: Canadian Forest Service

CNSC: Canadian Nuclear Safety Commission

DFO: Fisheries and Oceans Canada

DM: Deputy Minister

ECCC: Environment and Climate Change Canada

EIA: Environmental Impact Assessment

GoC: Government of Canada

HC: Health Canada

INAC: Indigenous and Northern Affairs Canada

LMS: Lands and Minerals Sector

MPMO: Major Projects Management Office

NEB: National Energy Board

NGO: Nongovernmental organization

NRCan: Natural Resources Canada

NTFPs: Non-timber Forest Products

OCS: Office of the Chief Scientist

VECs: Valued ecosystem components

Executive summary

Forests cover approximately 347 million ha of land in Canada (NRCan 2018a). While Canadians are proud owners of this vast resource, forest ecosystem health and sustainability are increasingly at risk due to natural and anthropogenic pressures, such as wildland fires, pest infestations, resource development, landscape fragmentation, urban expansion, pollution, and climate change. Individually, these changes may pose relatively small stresses on forest ecosystems. When combined, however, **cumulative effects** result, with potentially devastating ecological, cultural, social, and economic outcomes. Addressing cumulative effects in the context of natural resource development broadly consists of three interrelated components: 1) understanding and assessing risk and scale of effects; 2) understanding the impact on and trends of ecosystem values; and 3) management actions to minimize the impacts on values.

Canadian industries are export oriented and have a strong national and international reputation for sustainable development founded on science. However, regulatory safeguards are increasingly criticized for being too project oriented, socially exclusive, and insufficient to deal with the growing complexity of resource development and the uncertainty posed by climate change. Forest ecosystem sustainability is important to Canadians and critical to maintaining a strong resource sector with social license and market competitiveness. Therefore, new research is urgently needed to better manage cumulative effects to support forest ecosystem resilience. Furthermore, this research must consider the needs and perspectives of all of those who have a stake in the sustainability of Canada's forests, including Indigenous peoples, industry, government, private sector, and civil society.

Natural Resources Canada's Canadian Forest Service (NRCan-CFS) is committed to improving knowledge, strategies, and tools to support sustainable natural resource development. To manage cumulative effects of multiple stressors on a given land base, a proactive, integrated, planning-based approach to regional or landscape management is required, one that establishes overall management objectives and specific thresholds and indicators to support responsible and sustainable industrial activities in forest landscapes.

By recognizing the unique ecological and socioeconomic challenges facing Canada's forests as a result of cumulative effects, this national NRCan-CFS Research Agenda will help chart our collective path toward more integrated and coordinated land-use/landscape planning and management, based on science. Four main policy drivers provide context and guidance for current and future work on cumulative effects under this Research Agenda:

- 1) sharing responsibility for sustainable resource development,
- 2) enhancing Indigenous engagement and reconciliation,
- 3) ensuring compliance with legislative and regulatory requirements, and
- 4) enhancing social license, environmental reputation, and market access.

This Research Agenda identifies research gaps and sets priority areas for NRCan-CFS research over the next 5–10 years that will help Canada manage cumulative effects to support forest ecosystem resilience and sustainable resource development. The Agenda further describes the role of NRCan-CFS, key partnerships, and potential collaborations for its implementation. Five themes have been identified to provide an adaptive management framework to identify impacts and deliver solutions. These themes are directly linked to the previous policy drivers and to ongoing NRCan-CFS research.

Theme 1	Theme 2	Theme 3	Theme 4	Theme 5
Risks and impacts	Socioeconomic factors	Data and tools	Practices and techniques	Caribou
Improve spatial and temporal baseline data, indicators, and thresholds to better identify risks and to more accurately predict impacts of cumulative effects from multiple stressors on forest ecosystems.	Achieve more balanced and inclusive consideration of socioeconomic factors in resource development and forest management decisions, based on partnerships and trust with Indigenous peoples and all forest stakeholders.	Develop data collection and management and integration protocols to enable data sharing and knowledge exchange on open data platforms.	Improve practices and techniques for sustainable natural resource development and cumulative effects management (e.g., integrated land-use planning, trade-off analysis, mitigation, reclamation, restoration, etc.).	Use woodland caribou to indicate forest ecosystem health and integrity, and develop tools to better understand and mitigate the impacts of cumulative effects on caribou populations and habitats.

NRCan-CFS would like to thank all the individuals and organizations including the Cumulative Effects Advisory Council (CEAC); CFS scientists; CFS directors and other professionals; other NRCan sectors; and federal, provincial, and territorial governments who helped develop this Research Agenda.

Introduction

Canada is rich in natural resources with established industrial activities that benefit Canadians. Overlapping development of renewable and nonrenewable natural resources increases the complexity of land-use management throughout Canada's forest ecosystems. The combined activities of forestry, energy, and mining, for instance, impose cumulative effects on ecosystems that can be difficult to predict, manage, and recover from, especially under a changing climate. Cumulative effects pose potential threats to ecological goods and services and to policy and management objectives. The effects accumulate over time and space (Fig. 1).

Cumulative effects are the changes to economic, environmental, social, and cultural values caused by the combined effects of past, present, and potential future actions or events, both natural and anthropogenic.

In principle, the term “cumulative effects” represents a complex phenomenon consisting of several characteristics, such as linear, nonlinear, additive, amplifying, exponential, continuous and discontinuous effects, and structural surprises (Sonntag et al. 1987; CEARC 1988). Cumulative effects can emanate from a broad range of activities that may consist of direct or indirect, significant or insignificant impacts occurring over small or large geographic areas at a certain point in time or over several years and decades (Sonntag et al. 1987). While linear, direct, and significant effects may be more obvious and relatively easy to foresee and account for, a series of individual, nonlinear, and indirect insignificant effects, such as building roads and wells, extracting water, and harvesting timber, are more challenging to estimate, especially at a regional level. These minor effects can accumulate over time and space, resulting in more significant environmental, social, and economic impacts. Environmental problems associated with cumulative effects are landscape fragmentation, habitat alteration, loss of biological diversity, soil acidification, sedimentation, and chemical pollution of freshwater and marine habitats (Kennett 1999).

Social, cultural, and economic issues related to cumulative effects are multifaceted and require understanding and consideration of multiple stresses in relation to their environmental, economic, and social contexts (Franks et al. 2011). Cumulative effects are likely to affect ecological goods and services, community and regional well-being, and to pose serious challenges to decision making and democratic processes (Weber et al. 2012). The challenges posed by cumulative effects are particularly acute for Indigenous communities that may have culturally unique concerns and solutions for managing natural resource development (Parlee et al. 2012). Cumulative effects may have devastating ecological, cultural, social, and economic outcomes. Therefore, a proactive, planning-based approach to regional or landscape management that establishes overall management objectives and specific thresholds and indicators is required to support responsible and sustainable industrial activities on forested landscapes.

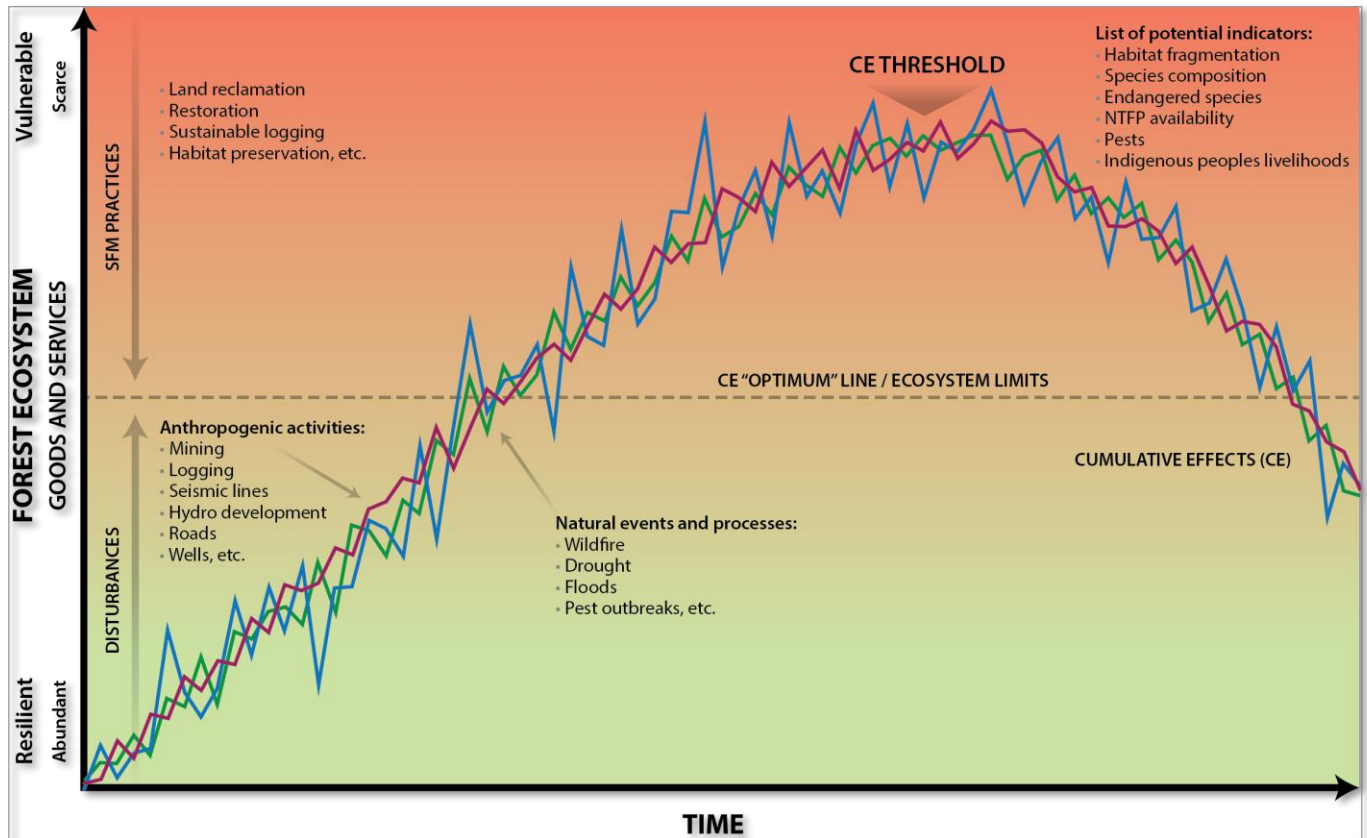


Figure 1. Cumulative effects in forests (Evisa Abolina). (SFM: sustainable forest management; NTPF: non-timber forest products)

An example of the impact of cumulative effects is the case of woodland caribou (*Rangifer tarandus caribou*), a wildlife species native to Canada's mountains and vast boreal and taiga forests with cultural and spiritual significance for both Indigenous and non-Indigenous Canadians. Caribou habitats that have been severely impacted by cumulative anthropogenic activities and natural events and processes have resulted in sharp caribou population decline (ECCC 2018). Road construction, timber harvesting, agriculture, mining, development of seismic lines for petroleum exploration, drilling of wells, construction of pipelines, and in situ mining destroy and fragment caribou habitat, and increase predator access to remaining habitat. New early-seral growth in disturbed areas also provides habitat for moose and deer, increasing the number of predators in and around caribou habitat. Climate change compounds the effects of the previous anthropogenic activities by decreasing winter severity, which increases overwinter survival of deer and the number of predators. Although individually these effects (i.e., climate change, habitat loss, and increased predation pressure) might pose a relatively small stress on the caribou population(s), cumulatively, they result in fragmented landscapes that cannot support self-sustaining woodland caribou populations (Fig. 2) (Environment Canada 2012). In addition, avoidance behavior by caribou that is associated with these developments has displaced caribou into habitats and conditions that are undermining their existence and recovery (Dyer et al. 2001).

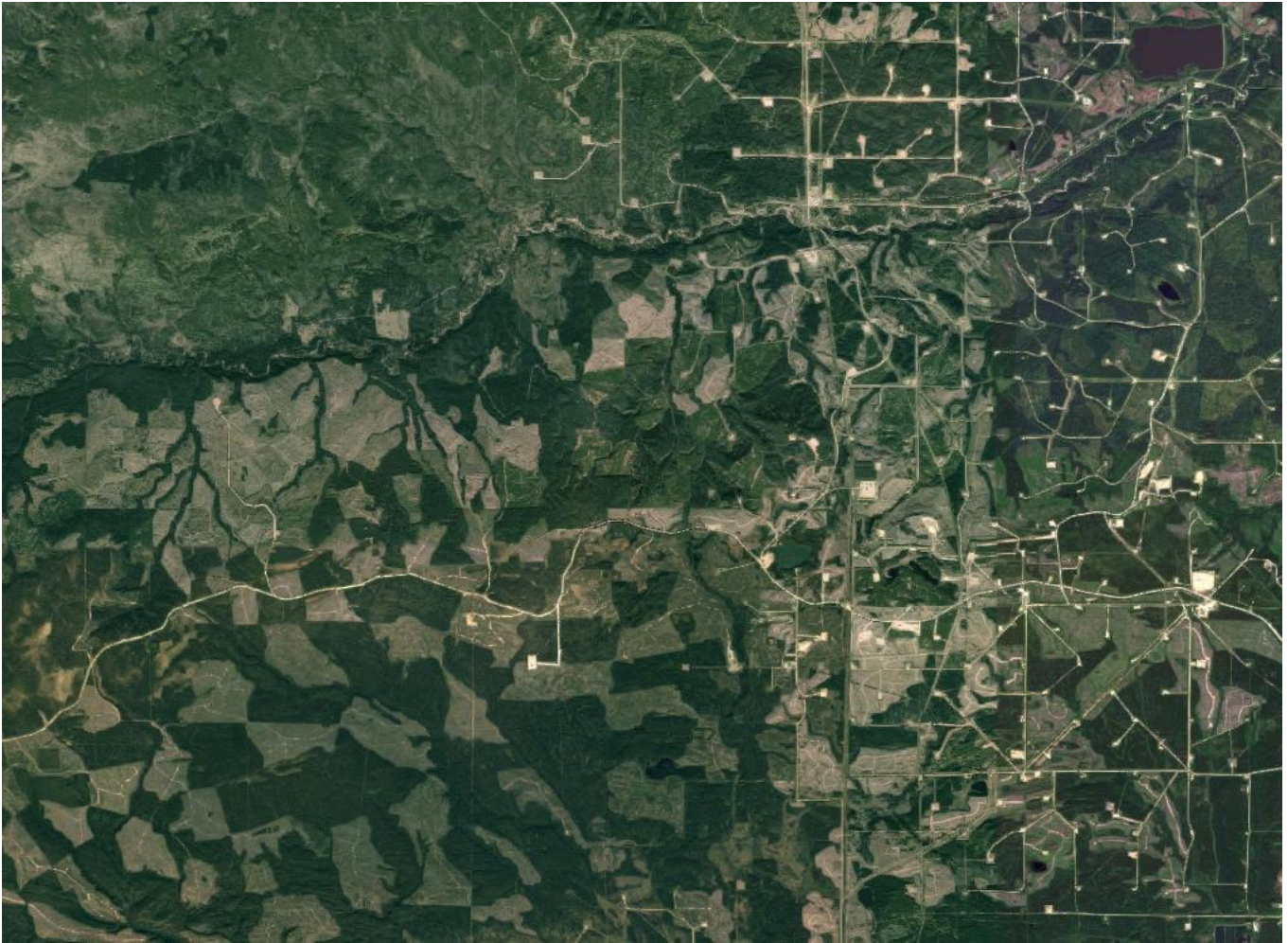


Figure 2. Landscape fragmentation caused by different types of land use in Alberta (Google Earth).

Woodland caribou is an indicator of boreal forest ecosystem health and integrity. Several scientific studies and simulation models within the Athabasca Oil Sands region have sent warning signs, indicating the occurrence of significant cumulative effects under the “business as usual” scenario and calling for coordinated integrated planning and forest management plans to minimize the industrial footprint (CAPP 2004; Schneider et al. 2003; Schneider and Dyer 2006; Yamasaki et al. 2008). Better understanding of the risks and impacts of multiple anthropogenic activities and natural events and processes on caribou habitat is needed to predict outcomes, and improved techniques are needed to minimize and/or mitigate impacts. Furthermore, sharing data and knowledge, and more inclusive consideration of stakeholder perspectives, are critical to transparent and consistent decision making for natural resource development that maintains forest ecosystem sustainability.

Policy drivers

This section provides a brief overview of the overarching political, socioeconomic, and cultural factors driving research of cumulative effects. It also explains the linkages between Canada's national and international commitments and how these relate to this cumulative effects Research Agenda.

1. A shared responsibility for sustainable resource development

In September 2015, the United Nations (UN) adopted the 2030 Agenda for Sustainable Development, which contains 17 sustainable development goals (SDGs) and 169 targets (UN 2015). Canada is committed to playing a lead role in implementing development of SDGs and has developed the Federal Sustainable Development Strategy (FSDS) as a primary vehicle for sustainable development planning and reporting (GoC 2016). Among the 13 FSDS goals, the strategy includes a commitment to **sustainably managed lands and forests** to support biodiversity and provide a variety of ecosystems and services for generations to come. This commitment includes increasing the scientific knowledge of forest ecosystems and factors that affect them and sharing that information with Canadian governments, industry, and nongovernmental organizations (NGOs) to assess risks, forecast impacts, and develop appropriate mitigation and adaptation strategies (NRCan 2017 and 2013). Top priorities for NRCan include improving understanding of mitigation of the cumulative effects of natural resource development and better integrating development activities between resource sectors.

2. Enhancing Indigenous engagement and reconciliation

Indigenous knowledge is crucial to the success of cumulative effects management and sustainable development. The Earth Summit in 1992 recognized the importance of Indigenous knowledge in forest conservation and sustainable development in the form of the UN Forest Principles:

Appropriate Indigenous capacity and local knowledge regarding the conservation and sustainable development of forests should, through institutional and financial support and in collaboration with the people in the local communities concerned, be recognized, respected, recorded, developed and, as appropriate, introduced in the implementation of programs. Benefits arising from the utilization of Indigenous knowledge should therefore be equitably shared with such people. (UN Forest Principle No.12 (d)) (UNGA 1992)

Addressing the “cultural, social and spiritual needs and values,” and among them, the spiritual and cultural connections of Indigenous peoples to forests, is one of the indicators of The Montréal Process, of which Canada is a member (The Montréal Process 2015). Under the United Nations Declaration on the Rights of Indigenous Peoples (UNDESA 2007), the Government of

Murray River Coal Project Tumbler Ridge, British Columbia

In April 2016, HD Mining International Ltd. proposed to construct, operate, and decommission an underground metallurgical coal mine (used in steel production) located 12.5 km south of Tumbler Ridge, British Columbia. The project aimed to produce 6 million t of metallurgical coal per year over a 31-year mine life, contributing approximately \$91.2 million to the local economy. To receive an EIA certificate, the project had to meet 24 conditions, including

- Develop a plan to address the risks and impacts of subsidence;
- Develop a suite of management plans for matters that include wildlife, fish and fish habitat, wetlands, air quality, noise, groundwater and surface water, and impacts from invasive plants;
- Develop plans to support healthy communities and identify measures to mitigate socioeconomic effects;
- Continue to participate in the work of the Murray River Aquatic Cumulative Effects Assessment Framework Steering Committee; and
- Develop a plan to share information between HD Mining and First Nations and to identify measures to avoid impacts on Treaty 8 rights (CEAA 2018; HD Mining International 2014).

Canada (GoC) committed to recognizing and implementing Indigenous rights. In addition, governments have a responsibility to consider cumulative effects when making resource management and development decisions that impact Indigenous peoples and to consider Indigenous knowledge that has been provided for impact assessment in the project approval process (GoC, 2019). The consequences of cumulative effects could affect the ability of Indigenous communities to sustain their way of life.

Across the country, in every place we visited, the presentations from Indigenous Peoples moved us. We heard how multiple developments in the northeast of British Columbia had impacted more than 80 per cent of Treaty 8 land without any effective assessment of impacts. (CEAA 2017).

A collaborative approach to cumulative effects that builds trust and supports reconciliations would enable Indigenous communities to better plan for the future.

In light of the world view that I bring forward as an Anishinaabe man from this part of the world, the ceremonies that I've participated in have taken me to [a] place where I recognize that relying on empirical data, relying on western science is like trying to tie your shoe with only one hand (Grand Chief Nepinak, Assembly of Manitoba Chiefs) (CEAA 2017).

3. Ensuring compliance with legislative and regulatory requirements

The science generated by NRCan-CFS and its partners must be relevant to existing and future regulatory frameworks, and support decision making within them.

Industry is expected to comply with provincial regulations, such as Alberta's *Environmental Protection and Enhancement Act* (EPEA) and British Columbia's *Environmental Assessment Act* and *Environmental Management Act* (GoA 2017; GoBC 2002 and 2003). The research generated under this Research Agenda could support industry with the tools needed for compliance.

As Canada's commitments under the Intergovernmental Open Government Partnership include making publicly funded science more accessible to the public, the research and data generated by work in the context of this cumulative effects Research Agenda will be made publicly accessible via federal open science and data platforms. In addition, the data and science products generated under this Research Agenda will contribute to meeting reporting obligations under international agreements, such as the UNSDGs. The work described by this Research Agenda will also fulfill federal priorities, such as the conduct of scientific research for sustainable natural resource development (*Forestry Act*), and the collection and dissemination of information (*Resources and Technical Surveys Act*) (GoC 1985a and 1985b).

4. Enhancing social license, environmental reputation, and market access

"Responsible consumption and production" is one of the SDGs to reduce future economic, environmental, and social costs, and to strengthen economic competitiveness and reduce poverty (UN 2015).

Canada's natural resource sectors are export oriented and have enjoyed an international reputation for sustainable development founded on science. Canada is a leader in forest certification with 161 million ha or 43% of forests that are third-party independently certified (FPAC 2019). Securing and maintaining market access for Canada's natural resource products is a top priority for the Canadian government and industry. However, there is growing awareness of environment and social justice, and civic concerns over the boreal forest ecosystem health and integrity (e.g., industry impact on caribou populations and other wildlife species and NTFPs and rights of Indigenous peoples (Skene et al. 2018). Altered domestic and global perceptions about, and confidence in, Canada's commitment to sustainable resource development could have a negative impact on the acceptance of Canada's forest products, as well as the energy and mining sector products.

For example, the European Union (EU), one of Canada's export markets for forest products, is developing a voluntary certification system as proof of a sustainable source of forest products. The revised Renewable Energy Directive introduces certain sustainability criteria that will require all biofuels produced or consumed in the EU to be produced sustainably and in an environmentally friendly manner (EP and EC 2018).

Voluntary schemes verify compliance with the EU's biofuels sustainability criteria. They check that biofuel production did not take place on land with high biodiversity, that land with high carbon stock was not converted for biofuel production, and that the production of biofuels leads to a sufficient level of greenhouse gas emissions savings. (EC 2010)

For Canadian exports, this means that forest products (including wood pellets and forest residues) sold in the EU market for biofuel production and consumption would have to be certified for sustainability. Considering the growing renewable energy market demand in Europe and the potential trade opportunities for Canadian industries and forest companies, it would be important to ensure that Canadian forest products qualify for European markets. Many other countries, including the United Kingdom, are implementing similar schemes to ensure product sustainability.

Some of the biggest companies in the world have also developed their own certification schemes and sustainability criteria for wood products as part of their procurement policies (e.g., Kimberley-Clark Ltd. 2009; Pacific BioEnergy 2014)). Creating new, greener market opportunities, such as gaining green premiums for sustainably produced and harvested forest products, creates opportunities for environmental and socially responsible production and profit generation.

NRCan-CFS research should provide the basis for more integrated and coordinated land-use planning within a cumulative effects management framework, allowing Canadian companies to maintain their strong social and environmental reputation, to create new market opportunities, and to increase their global market share of sustainably produced forest products.

The increasing technological advancement and intensity of resource development (e.g., open-pit mines and in situ oil sands) combined with the social pressures, growing jurisdictional complexity, and uncertainty of climate change and other natural events and processes (e.g., more frequent wildland fires) require a more integrated and coordinated approach to be sustainable (CCA 2019). NRCan-CFS research should support natural resources industries operating in forested landscapes, with knowledge and data on the potential cumulative effects of development activities, supporting a more robust impact assessment process. In addition, NRCan-CFS partnerships with stakeholders and Indigenous peoples will lead to a more informed understanding of regional interests, concerns, and common objectives.

Role of the Canadian Forest Service

NRCan-CFS will lead in implementing this Research Agenda. The core mandate of NRCan-CFS is to conduct scientific research on Canada's forests. NRCan-CFS provides a national perspective and expertise on forest issues and undertakes long-term, large-scale research and data collection focusing on complex challenges that require multilayered responses. As a member of the NRCan family, the CFS is well placed to strengthen relationships with other NRCan sectors and partnerships (i.e., Indigenous, mining, and energy). Over the past 10 years, NRCan-CFS has developed strong working relationships and collaborative research initiatives with nearly 50 organizations.

NRCan-CFS has demonstrated that it is well equipped to create and mobilize knowledge, tools, and techniques needed for cumulative effects assessment, prevention, mitigation, and restoration. However, given the breadth of forest science and research today, as well as the cross-sectoral nature of the challenges it is facing, no single organization, including the CFS, can conduct all the science and research needed to properly address cumulative effects of resource development and climate change.

Linkages to other natural resource sectors, departmental and federal initiatives, and frameworks

In 2017, NRCan-CFS created a new program – Addressing Cumulative Effects of Natural Resource Development in Canada's Forests (CE Program)—which became a cornerstone for cumulative effects research and policy development. The CE Program fits directly under NRCan's Core Responsibility of Innovative and Sustainable Natural Resources Development (NRCan 2018b). The CE Program focuses on impacts and risks to forest ecosystem values resulting from all resource development activities, in addition to natural events and processes and climate change.

The CE Program contributes to

- 1) NRCan's Protection for Canadians and Natural Resources Program Activity by conducting research and analyses to develop scientific knowledge of forest disturbances which can be used to assess risks, forecast impacts, and develop mitigation strategies;
- 2) NRCan's Strategic Outcomes through the Responsible Natural Resource Management Program Activity by conducting research and developing monitoring approaches to develop scientific knowledge of Canada's forest ecosystems; and
- 3) NRCan's new Science and Technology Framework by contributing to two goals under the theme Environmental Sustainability:
 - Goal no. 1—Improve understanding of the impacts of natural resource development on ecosystems, and
 - Goal no. 2—Improve understanding of ecosystem processes and functions to strengthen sustainable resource management practices.

The work under this program encourages NRCan-CFS to work collaboratively with other resource sectors (e.g., energy and mining) and nontraditional partners, to apply its scientific knowledge and expertise to help them advance their environmental leadership on forested land. The CE Program contributes more broadly to the government's new proposed approach to Impact Assessment and Regulatory Processes, working in close collaboration with other NRCan sectors and federal government departments and initiatives. The CE Program also works with provinces, territories, Indigenous peoples, and civil society to address cumulative effects. Under the broader Cumulative Effects Initiative, NRCan contributes to the Open Science and Data Platform and provides research leadership, information, and data to the Regional Assessments (Fig. 3).

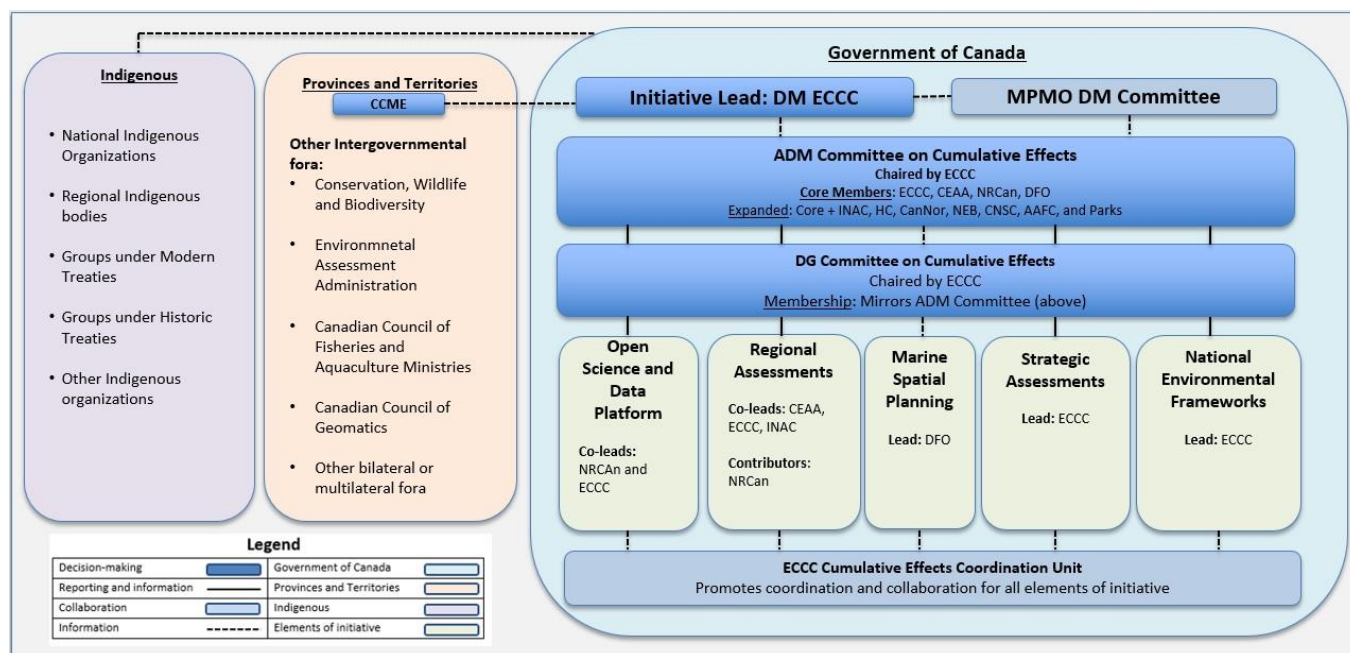


Figure 3. Governance for deliberate approach to cumulative effects.

NRCAN-CFS work within this Research Agenda aligns with the Directive on Open Government and the prime minister's commitment to it. The data and science products generated under this Research Agenda will also contribute to meeting reporting obligations under international agreements, such as the UNSDGs.

Cumulative effects knowledge gaps

The following describes cumulative effects knowledge gaps:

- **Accurate prediction of risks and impacts of cumulative effects:** Understanding cumulative effects requires knowledge of patterns of, and interactions between, anthropogenic activities and natural events and processes, including climate change. Understanding these patterns is critical to understanding how ecosystem services and functions and socioeconomic variables change over time in response to cumulative effects of multiple ecosystem stressors. Research is needed to improve spatial and temporal baseline data, to identify indicators and thresholds to better identify and quantify risk, and to more accurately predict impacts of cumulative effects of multiple stressors on forest ecosystems. While the importance of cumulative effects has been known for some time, integrating the potential impacts of multiple concurrent and/or consecutive disturbances over space and time has been a challenge. In particular, it is not yet clear how to consider the various levels of uncertainty associated with individual disturbances in predicting cumulative effects (Sonntag et al 1987). A review of risk assessment approaches, biophysical baseline and response data, Indigenous concerns, and socioeconomic information is needed to balance assessments of impacts on environmental and social values, natural resources, geography, and human well-being. A national cumulative effects risk assessment framework is needed to assist provincial governments to provide consistent, transparent, and fair impact assessments and to support sustainable resource management across the country. There is a significant opportunity for new science in the development of interdisciplinary risk assessment and mitigation tools, as well as contributing to and leveraging expertise in the improvement of environmental performance of renewable and non-renewable resource sectors operating in Canada.
- **Integration of socioeconomic dimensions:** Social and ecological systems are intertwined, and changes in one system may lead to impacts on the other, resulting in echoed shifts in both ecosystems and social systems at many different spatial and temporal scales (Parlee et al. 2012). Holistic assessment of cumulative effects considers effects on both natural ecosystems and social systems. Historically, socioeconomic modeling has relied on economic indicators such as revenues or jobs. However, a broader list of social indicators may be needed to measure community and regional well-being (Mitchell and Parkins 2011). There is a need to develop social indicators for all potentially impacted groups to build scenarios to support complex and sustainable communities and multiple resource use. Collaboration with all stakeholders in forest resources, both within and across multiple sectors and disciplines, is needed to assess and interpret cumulative effects of multiple resource development activities occurring across spatial and temporal scales of the Canadian landscape.
- **National level data and tools to respond to the increasing complexity of landscape management:** The limitations of project-specific environmental impact assessment in the face of the growing complexity of landscape management have been well recognized (Kennett 1999; Duinker and Greig 2006). A major challenge lies in accessing and integrating multiple datasets collected over different spatial and temporal scales to provide a holistic picture of multiple pressures occurring on the same land base and to support decision making. Infrastructure, guidelines, and tools for data collection and management are needed to facilitate integration of data from multiple sources and enable data sharing and knowledge exchange on open data platforms.
- **Developing practices and techniques to manage cumulative effects:** Much work has been done to develop techniques for landscape restoration and reclamation following resource extraction by specific industries. However, managing cumulative effects of multiple resource development activities on the same landscape requires new knowledge, tools, and techniques. In particular, tools and techniques for integrated land-use modeling and planning will be essential to predict combined impacts and balance trade-offs within and between various resource development activities as well as natural events and processes. Research is required to develop predictive landscape tools and techniques that account for different potential climate scenarios to set and adapt integrated cumulative effects thresholds. As Canada is vast and varied, with many unique landscapes, climatic zones, and ecological systems, regionally appropriate climatic, soil, hydrological, and ecological data will be needed to support predictive land-use modeling tools.

- **Woodland caribou as a case study for understanding and mitigating cumulative effects in forest ecosystems:** Declining populations in the face of forest ecosystem fragmentation from multiple anthropogenic activities and natural events and processes identify woodland caribou as an indicator of forest ecosystem health and integrity. In addition, caribou hold varied social, cultural, and economic value for many stakeholders in forest resources, including industry, academics, conservationists, Indigenous communities, and the public, making this species a case study for the new methods and approaches to managing cumulative effects in forest ecosystems. Research is needed to better understand and mitigate the impacts of cumulative effects of resource development, landscape fragmentation, climate change, and natural forest disturbances on caribou populations and habitats.

Priority areas for research

NRCan-CFS and its collaborators (see Annex B) will support a national science approach for understanding, predicting, reducing, and mitigating the risks and impacts of cumulative effects to support sustainable resource development in Canada. In addition to core areas of biophysical research, there is a need to build capacity in the emerging fields in integrated approaches to impact assessment, risk assessment and analysis, implications under climate change, and socioeconomic research including social values and motivators, and market preferences. The research priority areas have five themes that align with the knowledge gaps identified in the previous sections.

Theme 1. Improving our understanding of the risks and impacts of cumulative effects on forest ecosystems

Theme 1 will (through science and Indigenous knowledge) improve spatial and temporal baseline data, indicators, and thresholds to better identify risks and to more accurately predict impacts of cumulative effects of multiple stressors on forest ecosystems. Knowledge gained will position NRCan-CFS to partner with other NRCan sectors and government departments to develop natural resource development policy, as well as strategies to address cumulative effects. Increased certainty in risk prediction is expected to improve public confidence in natural resource management, increase global market share for Canada's natural resources products, and recognize NRCan-CFS as a leader in assessing risk and predicting impact of cumulative effects on forest ecosystems.

Theme 1	Research needs	Approach	Outcomes
Improving our understanding of the risks and impacts of cumulative effects on forest ecosystems	<ul style="list-style-type: none"> Identify, understand, and define cumulative impacts and effects on forest ecosystem goods and services Identify, understand, and define spatial and temporal aspects and boundaries Understand the impact on and trends of ecosystem values Identify, understand, and define the interactions between cumulative effects of natural events and processes, climate change, and natural resource development Determine statistical relationships between multiple cumulative effects factors Identify, understand, and define cumulative effects thresholds and limits Identify, understand, and define ecosystem vulnerabilities due to cumulative effects 	<ul style="list-style-type: none"> Establish partnerships with Indigenous peoples, academia, scientists, and experts working in this field (and develop a list of contacts for each category/research question/field) In collaboration with stakeholders and partners, develop an inventory of the existing information, knowledge, and data (scientific publications, projects, databases, etc.) 	Improved knowledge and understanding of the risks and impacts of cumulative effects of multiple resource developments

Theme 2. Partnership building, engagement, and integration of socioeconomic factors, including Indigenous knowledge and values, in cumulative effects research and management

Theme 2 will focus on the integration of socioeconomic components in assessing the risks and impacts of cumulative effects on forest ecosystems, with emphasis on maintaining existing, and building new, partnerships to increase our understanding of social aspects at different scales and to develop social indicators for all potentially impacted groups. Better understanding of Indigenous values and knowledge regarding cumulative effects is one way to enhance Indigenous engagement and reconciliation, and helps fulfill the recommendations of the Expert Panel on Environmental Assessment (see policy drivers). As many natural resource developments have the potential to impact Indigenous ways of life, communities must understand the present and future impacts of these developments. This theme will also aim to create a better understanding of how NRCan-CFS can initiate, develop, and maintain productive collaborations with Indigenous communities.

Theme 2	Research needs	Approach	Outcomes
Partnership building, engagement, and integration of socioeconomic factors (including Indigenous peoples values and knowledge) in cumulative effects research and management	<ul style="list-style-type: none"> Define issues, needs (social, cultural, economic, VECs), science gaps, and opportunities Identify community-relevant (social) indicators and thresholds related to ecosystems and social systems. Understand and consider Indigenous values and knowledge on indicators, thresholds, ecological information, and best practices in research Understand existing or potential cumulative effects on Indigenous peoples Enhance Indigenous capacity to participate in cumulative effects management Identify potential trade-offs, different stakeholder values (industry, Indigenous communities, conservationists, government, etc.) 	<ul style="list-style-type: none"> Engage and partner with Indigenous communities and organizations in the planning and execution of research relevant to cumulative effects Develop public participation and mediation strategies Establish trust with Indigenous peoples communities involved (or aiming to be involved) in cumulative effects research Perform socioeconomic research focused on Indigenous peoples knowledge and data. Apply communication and engagement tools using behavioral economics and psychology Forest sector's contributions to renewal, diversification, and sustainable development of Indigenous peoples community-based economies 	<p>Better understanding and integration of the socioeconomic factors in cumulative effects research and management</p> <p>Established partnerships and Indigenous engagement — integrated Indigenous peoples needs, expertise, and knowledge in cumulative effects research and management</p> <p>Indigenous peoples communities have tools, knowledge, and practices necessary to manage (and cope with) the (potential) impacts of cumulative effects</p>

Theme 3. Provide national level data and tools for cumulative effects research and management

Effective cumulative effects management depends on the availability of information and data on, and tools for, the areas to be studied. Following a recommendation of the Expert Panel “to post all monitoring and follow-up data, including raw data, results and any actions taken to address ineffective mitigation, on a public registry” (CEAA 2017), NRCan-CFS will work closely with other NRCan sectors and federal government departments to contribute its data to federal open data platforms.

Empirical data generated under the CE Program will help model the impacts of cumulative effects and develop optimal resource allocation strategies for decision-making tools. The tools will allow federal and provincial regulatory and legislative review processes to incorporate more accurate baseline, indicator, and threshold information into their decision making, helping increase public and global confidence in Canadian environmental assessment. Tools must consider data quality, uncertainty, and forecasting for future conditions, including climate change.

Theme 3	Research needs	Approach	Outcomes
Provide national level data and tools for cumulative effects research and management	<ul style="list-style-type: none"> Gather empirical data to support cumulative effects research Define and quantify baseline conditions, (key) indicators, and thresholds Develop (monitoring) protocols for enhanced tracking and forecasting of cumulative effects on selected socioeconomic and environmental values Simulate future landscapes under multiple resource development scenarios Develop risk assessment methods and tools for VECs and socioeconomic values at multiple scales 	<ul style="list-style-type: none"> Work collaboratively with academia and provincial and other government sectors and agencies to establish common platforms for data storage and exchange Contribute data to the integrated open science data platform 	<p>Established data platform(s) and tools for enhanced tracking and forecasting of identified socioeconomic values and ecosystem components</p>

	<ul style="list-style-type: none"> • Open access of baseline conditions for monitoring purposes • Develop and implement ecologically and culturally relevant benchmarks and management action triggers • Establish information and databases on cumulative effects (federal data platform), inclusive of historical land use and resource development activities, natural events and processes, and socioeconomic data • Collect spatial data on vegetation cover to help identify critical habitats for species at risk (e.g., caribou) 		
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Theme 4. Developing and testing sound practices and techniques for sustainable natural resource development and cumulative effects management

Responsible integrated resource management practices rely on the capacity of land managers to make evidence-based informed decisions that take multiple values into account, whether it is environmental, cultural, social, or economic. This theme will improve practices and techniques to proactively manage cumulative effects on forest ecosystems through integrated land-use planning, trade-off analysis, mitigation, reclamation, restoration, and other activities.

Science-based evidence is needed to support federal and provincial policies on landscape management, land reclamation, and habitat restoration, as well as to meet the GoC's goal to improve environmental performance and leadership. Given the complexity of the land base and uncertainties related to ecosystem sustainability and resilience due to multiple disturbances, there is a need for more knowledge and tools to reclaim land that has been impacted by resource development and to restore ecosystems, including their processes and functions. A suite of tools and practices to boost or measure the success of reclamation/restoration activities will be developed in partnership with decision makers and rights holders to ensure that the research leads to implementable solutions. These new tools will improve the rate and predictability of forest recovery, and help rebuild functioning ecosystems following resource exploration and development.

The research in this theme is expected to result in increased engagement with nonrenewable natural resource sectors and development and application of science leading to successful restoration practices and monitoring methods.

Theme 4	Research needs	Approach	Outcomes
Developing and testing sound practices and techniques for sustainable natural resource development and cumulative effects management	<ul style="list-style-type: none"> • Develop science-based decision-making tools to improve integrated landscape planning and mitigate (cumulative) impacts of resource development • Improve tools to reclaim and restore ecosystem integrity of forests affected by multiple natural resource development • Develop tools and practices to restore impacted ecosystems for multiple values and needs • Test approaches to quantify multiple benefits of forest land reclamation • Develop indicators of restoration success • Test remote sensing applications for monitoring of restoration success • Model greenhouse gas emissions • Model biomass supply • Develop and test forest certification models for cumulative effects 	<ul style="list-style-type: none"> • Engage multiple resource sectors, industry, and Indigenous peoples communities to contribute data, information, and expertise • Engage energy and mining regulators • Link with the international community such as the Global Partnership for Forest Landscape Restoration and the International Union for the Conservation of Nature 	Developed strategies and tools to manage cumulative effects from resource development, including reclamation and restoration of affected (forest) landscapes

Theme 5. Understanding the impact of cumulative effects on caribou populations and habitats

The federal Action Plan for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population in Canada, 2018, has three pillars: knowledge to support caribou recovery, recovery and protection, and reporting on progress. NRCan-CFS has committed to, and partnered with, ECCC to enhancing understanding of the impact of 1) disturbances and their cumulative effects, and of 2) climate change, on the population status of boreal caribou. Additionally, NRCan-CFS will conduct research that investigates 3) habitat restoration tools to optimize habitat recovery and resiliency, and 4) methods for monitoring and assessing habitat recovery (Dyer et al. 2001), which is critical to the assessment of recovery effectiveness and will inform policy and decision making for caribou recovery.

Consideration of anthropogenic actions, natural events and processes, predation, and climate change effects in the context of cumulative effects provides a framework in which to integrate information about different stressors on caribou habitat. Work on boreal caribou will also provide insight into how to best define and measure critical habitat for other species at risk in Canada's forests.

Theme 5	Research needs	Approach	Outcomes
Understanding the impacts of cumulative effects on caribou populations and habitats	<ul style="list-style-type: none"> Enhance understanding of the relationship between disturbance and caribou population response to inform range and action planning Improve understanding of cumulative effects on caribou habitat and local populations through risk-based analysis Analyze effectiveness (and challenges) of the 65/35 rule for caribou habitats 	<ul style="list-style-type: none"> Pilot studies Partner with industry, Indigenous peoples, other government departments, provincial and territorial governments 	<ul style="list-style-type: none"> Improved caribou habitat forecasting and recovery A strategic framework for defining, protecting, and recovering habitats for species at risk in forested areas of Canada

The way forward

Principles for implementation

NRCan-CFS will implement this Research Agenda following a set of key guiding principles for cumulative effects management (adapted from CCME 2014):

- **Collaborative approach:** Given its long organizational history, national partnerships, and knowledge of forest ecosystems, NRCan-CFS is well positioned to enhance national collaboration with other resource sectors and organizations by acting as convenor. In doing so, NRCan-CFS will apply its expertise and capacity by collaboratively identifying, developing, and carrying out the required science on ecosystem responses and recovery. Success will depend on collaboration and communication. The CFS has been working with the CEAC representing Indigenous peoples, federal and provincial governments, as well as academia and industry on the development of this Research Agenda. They will remain key partners in its implementation.
- **Knowledge-based approach:** Knowledge is needed to assess the cumulative effects of activities on air, water, land, and biodiversity. Effective science and monitoring systems and networks provide the information needed to measure performance and support the development of outcomes and objectives. The knowledge will be critical to develop strategies and tools to effectively plan and manage landscapes to minimize the impacts of resource development. Indigenous knowledge is also an important element to include, and one that will require collaboration and engagement to respectfully address issues that have been highlighted by our partners.
- **Proactive approach:** Cumulative effects denote the combined impacts of past, present, and reasonably foreseeable human activities on the region's environmental objectives. It requires a broader, proactive, and forward-looking approach to planning and management that balances environmental factors with economic and social (including cultural and spiritual) considerations. Being proactive will ensure that landscapes are efficiently planned to minimize the resource development footprint and reduce the potential for future cumulative effects.
- **Integrative approach:** Addressing cumulative effects will require the integration of science and knowledge from many disciplines. Hence, the expertise from various federal, provincial, industrial, academic, and Indigenous partners will need to be integrated to effectively manage cumulative effects. This will be done using the concept of adaptive management cycle to 1) identify risks, 2) engage partners, 3) develop tools/solutions, 4) work with others to disseminate and implement; and 5) assess results. Such integration will ensure that Canada can undertake and use analytical, predictive, synthesis, and interpretative tools to understand the risks and impacts of cumulative effects of multiple resource development activities. NRCan-CFS will continue to expand its partnerships to engage more broadly with various organizations, sectors, and professionals. Pooling the knowledge and expertise will strengthen this Research Agenda and increase its value for stakeholders and end users.

Knowledge exchange and transfer

Under the five themes of this Research Agenda, NRCan-CFS will develop tools for understanding and assessing the risk and impacts of cumulative effects; will contribute data to federal open data platforms; and will develop monitoring tools, knowledge, and strategies for mitigation of cumulative effects. These tools and knowledge are of little benefit if they do not reach stakeholders, partners, and end users; federal, provincial, and territorial governments; Indigenous peoples; industry; and NGOs. Knowledge exchange allows for sharing best practices and promotes collaboration on how to address cumulative effects.

Methods and approach to knowledge exchange and transfer

- Publication of research findings:
 - Peer-reviewed journal papers; gray literature, reports, etc.
 - Conference and workshop presentations
 - Special reports

- Dissemination of tools and strategies:
 - Special workshops and conferences (with partners)
 - Co-development of dissemination pathways with partners as needed
 - Joint projects with industry, other government departments, Indigenous communities, etc.
 - Technical notes
 - Webinars
- Communication of research findings to the public:
 - The media—social media, radio, and TV interviews
 - Departmental reporting (web-based and through senior management)
 - Interdepartmental reporting
- CEAC engagement:
 - The CEAC comprises representatives from Indigenous communities; federal, provincial, and territorial governments; NGOs; academia; and industry. These individuals are engaged in research or activities to address cumulative effects in their fields. They will act as conduits for the dissemination of research results that are relevant to their sectors.

Measuring success

Performance indicators have and will be developed for both corporate and programmatic reporting. These indicators are based primarily on how the tools developed within this research agenda are disseminated, communicated, and used by our partners and stakeholders. The indicators will track

- stakeholders' awareness of assessment tools and models to inform decisions and responses; and
- the trends in use of tools, products, and approaches by key decision makers to enhance informed decisions and responses.

These indicators will be assessed annually through interviews with NRCan-CFS staff and feedback from decision makers and end users. Community health trends (social, environmental, and economic) related to projects that have been assessed using cumulative effects tools/approaches will also be tracked annually through mining data from publicly available sources (e.g., Statistics Canada, media scans, provincial reports).

Glossary

cumulative effects: changes to economic, environmental, social, and cultural values caused by the combined effects of past, present, and potential future actions or events, both natural and anthropogenic.

cumulative effects assessment: an assessment of any cumulative effects of existing or future activities that are likely to result from the designated project in combination with other physical activities that have been or will be carried out (GoC, 2019).

cumulative effects data: a collection of information (in the form of facts, values, and statistics) gathered or available for analysis to understand cumulative effects of natural resource development.

cumulative effects management: a series of actions taken to prevent, minimize, and mitigate cumulative effects of multiple resource development activities such as developing and improving knowledge, tools, and techniques to gather and analyze data; risk assessment; monitoring; and landscape level reclamation and restoration activities.

cumulative effects research: a series of investigative actions (e.g., case studies, experiments, review of scientific materials) taken to enhance understanding of the positive and negative cumulative impacts of resource development. Cumulative effects research aims to integrate environmental, community, and health values and perspectives, and accounts for diverse forms of knowledge and information.

cumulative effects science: investigative study focused on building and organizing knowledge on cumulative effects through systematic research and providing testable explanations and predictions.

ecosystem functions: physicochemical and biological processes that occur within the ecosystem to maintain terrestrial and/or aquatic life.

ecosystem integrity: the ability of an ecosystem to maintain its functions and services in the face of changing environmental conditions (Kay 1991).

ecosystem services: the benefits people obtain from ecosystems, including provisioning services, such as food and water; regulating services, such as flood and disease control; cultural services, such as spiritual, recreational, and aesthetic benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on earth (WRI 2005).

effective (cumulative effects) management: one or many well-informed, proactive, and timely responses/actions taken to address and resolve a particular issue.

impact assessment: an assessment of the effects of a designated project that is conducted in accordance with the *Impact Assessment Act*. (GoC 2019).

mitigation: measures taken to eliminate, reduce, control, or offset the adverse effects of a project or designated project, including restitution for any damage caused by those effects through replacement, restoration, compensation, or any other means (GoC 2019).

monitoring: a systematic process of observing, tracking, and recording activities or data. In the context of the National Research Agenda, monitoring is primarily (but not exclusively) focused on measuring progress and success in land restoration, reclamation, and mitigation activities.

reclamation (land reclamation): the process of turning previously disturbed, contaminated, or otherwise affected land into a productive or other desired and sustainable landscape (CAPP 2018).

regional assessment: a study undertaken to provide a better understanding of the “big picture” of environmental issues outside the context of individual project assessments. Regional assessment helps guide planning and management of cumulative effects (including on biodiversity and species at risk), identify the potential impacts on the rights and interests of Indigenous peoples, and inform project assessments.

restoration: the process of restoring a site (i.e., natural landscape and/or habitat) to its original state, based on a baseline scenario before the disturbance.

risk assessment: a systematic process of evaluating the potential risks that may be involved in a projected activity or undertaking.

sustainability: the ability to protect the environment, contribute to the social and economic well-being of the people of Canada, and preserve their health to benefit present and future generations (GoC 2019).

threshold: the limit beyond which cumulative effects become a concern, such as extensive disturbance to a habitat results in a rapid collapse of a caribou population, or pollutants in potable water supplies threaten human health (CEAA 1999).

valued ecosystem component (VEC): the environmental element of an ecosystem that is identified as having scientific, social, cultural, economic, historical, archaeological, or aesthetic importance. The value of an ecosystem component may be determined on the basis of cultural ideals or scientific concern (CEAA 2006).

Annex A. NRCan-CFS Cumulative Effects Program research priorities 2018–2023

The NRCan-CFS funding priorities for CE Program C-base research during the next five years will focus predominantly on cumulative effects science and monitoring in support of regional assessments, improvement of caribou habitats, and the development of tools and strategies for cumulative effects risk assessment and mitigation.

Research priorities	Research areas
Advance cumulative effects science and monitoring to support regional assessments	Provide credible and relevant terrestrial ecosystem science to support regional assessments
	Develop science for regions with actual or anticipated cumulative effects for the shared benefit of private sector, government, and Indigenous peoples; ecosystem and socioeconomic values; and human well-being
	Mobilize new science capacity to align with regional assessments, providing data to federal data platforms
	Analyze and interpret complex environmental issues that could influence Canada's forest sector
	Provide indicators, thresholds, and science-based methods to analyze, interpret, and forecast future ecosystem conditions
Improve forecasting of caribou habitat, distribution, and populations stability for evidence-based decision making	Improve the pan-Canadian spatial database of caribou range conditions
	Assess (multiyear and historic) caribou populations and their habitats
	Accelerate caribou habitat recovery by restoring forest landscapes fragmented by development activities
	Assess climate change impacts on caribou food supply, predation risk, and habitat quality
	Assess ecosystem integrity using caribou as a key indicator by predicting land integrity over space and time and the risk of ecosystem shifts
	Provide data to decision makers and the public
Develop tools to understand the risk and impacts of cumulative effects of multiple resource developments	Work with industry, Indigenous groups, universities, and governments to implement adaptive strategies for recovery and help monitor success
	Assess risk and improve the understanding of cumulative effects in forest ecosystems
Develop forest ecosystem-based strategies and tools to mitigate cumulative effects and restore ecological integrity of forests impacted by nonrenewable natural resource development	Coordinate and partnership build to assess and manage cumulative effects
	Develop science-based knowledge and decision-making tools to improve integrated landscape planning and mitigate impacts of resource development on forest ecosystems
	Improve tools to reclaim and restore ecosystem integrity of forests affected by nonrenewable natural resource activities

Annex B. Key partnerships and collaborators

Federal government

The federal government's role in resource development is to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resource sector.

A **whole-of-government** regional approach to integrated resource development and sustained engagement with provinces and territories could be used to build relationships among stakeholders, strengthen the application of regional science to decision making, align federal programming, and unlock resource potential to promote socioeconomic growth. There is an opportunity to create regional data hubs through the Federal Geospatial Platform that would bring together federal science and Indigenous knowledge, where possible, and that would be accessible to all Indigenous communities and stakeholders. NRCan in partnership with ECCC will leverage the Federal Geospatial Platform to establish a new, online platform that will provide integrated public access to information that supports cumulative effects assessments, including the following:

- ECCC is the national federal lead for cumulative effects management, caribou management, regional assessments, and impact assessment. NRCan-CFS will complement ECCC expertise and collaborate on research to manage cumulative effects.
- CIRNAC is playing a leading role at the federal level on Indigenous partnerships, engagement, and joint research projects. CIRNAC is creating a center of excellence on cumulative effects that NRCan-CFS could leverage.
- Other NRCan sectors (i.e., LMS, CCMEQ, MPMO, and OCS) all have roles in open science and data, regional assessments, restoration, and caribou management. NRCan will undertake remote sensing, modeling, and on-the-ground validation to provide authoritative data on the status and trends for ecosystem parameters (e.g., forest biomass, habitat for species at risk) that are critical for cumulative effects and project impact assessments.

Provincial and territorial governments

The provinces and territories (PTs) all have a great interest in addressing cumulative effects within their jurisdictions as they are responsible for sustainable natural resource use and management. The PTs leadership, collaboration, and data sharing will be essential for the success of the regional assessments in facilitating the involvement of all interested partners, including sharing best practices and expertise. Some provinces, such as British Columbia, have already developed cumulative effects strategies and others, like Alberta, have undertaken regional assessments. The PTs could share their experiences and data with the federal government to support monitoring and data collection, which could be fed into federal data platforms. NRCan-CFS has experience partnering with the PTs and has already signed agreements with all the PTs under the National Forest Inventory.

Research organizations and academia

NRCan-CFS recognizes the significance of scientific expertise that academia and other research organizations can contribute to address and effectively manage cumulative effects. NRCan-CFS (jointly with other NRCan sectors) will partner with research organizations and academia in all aspects of cumulative effects management ranging from research to Indigenous engagement to mitigation strategies. It has successfully partnered with the Saskatchewan Research Council to explore regional studies on cumulative effects, and has jointly worked with the Alberta Innovates and NAIT-Boreal Research Institute on landscape restoration techniques in Alberta. It is looking to partner with academia to jointly develop research projects and coapplications of grants and funding from granting agencies such as the Natural Sciences and Engineering Research Council of Canada/Social Sciences and Humanities Research Council of Canada and with universities across Canada to develop a Big Data/Data Fusion/Machine-learning Knowledge Harvester initiative geared toward terrestrial monitoring.

Nongovernmental organizations

Partnering with NGOs who have the interest and expertise in cumulative effects could provide an efficient way to address cumulative effects. NRCan-CFS has initiated collaboration with NGOs on caribou habitat recovery and socioeconomic analyses of caribou recovery strategies. These partnerships are essential to create synergies among the federal government, the PTs, and the forest industry. Collaborating with NGOs may also lead to potential funding opportunities.

Indigenous groups

The importance of Indigenous engagement to the success of this Agenda cannot be overemphasized. Indigenous communities are affected by resource development and natural events and processes, including climate change. Better understanding of how cumulative effects will impact the ability of Indigenous communities to maintain their way of life and traditional land use is needed, and will be achieved partly through consideration of Indigenous peoples expertise and knowledge in assessing, tracking, and mitigating cumulative effects and by undertaking collaborative science involving Indigenous peoples at appropriate scales. Engagement with Indigenous communities and the inclusion of Indigenous knowledge and values will help set social, cultural, and ecological thresholds to manage cumulative effects.

Hence, Indigenous peoples communities and groups will be key partners from the onset in all research projects to manage cumulative effects. In the first four years of implementation, contribution agreements will be signed with some Indigenous communities to build their capacity to support caribou habitat recovery and to facilitate inclusion of Indigenous values and knowledge in cumulative effects management.

Industry

Several natural resource industries (e.g., mining, oil and gas, and forestry) will contribute to cumulative effects through their extractive activities. However, they are also part of the solution and are working actively at improving their environmental performance through research to address cumulative effects and working collaboratively with NRCan-CFS. The oil and gas industry, for instance, has a vested interest in seeing cumulative effects addressed or it might risk losing the social license to operate. Also, the existing industrial activities could become a hindrance to further resource development if cumulative effects concerns are not addressed. Industry could also provide funding and contribute its knowledge of forest landscapes on which it operates, including collecting data and monitoring identified ecosystem values and socioeconomic variables.

A key feature of the CE Program is the development of risk assessment and mitigation tools to restore sites impacted by resource development. Industrial partners will act as conduits for knowledge transfer from NRCan-CFS to industry and will have access to these tools through partnerships with federal and provincial governments.

COSIA

Canada's Oil Sands Innovation Alliance

Some partners have already developed a set of criteria and goals to reduce their operational footprint and enhance environmental sustainability.

For example, COSIA's Land Environmental Priority Area is focused on reducing the footprint intensity and impact of oil sands mining and in situ operations on the land and wildlife of northern Alberta. The goal is to reduce the operating footprint intensity of in situ operations by 10% by 2022, including

- 1) more efficient use of land by reducing the extent and duration of industrial footprints;
- 2) timely reclamation and restoration of disturbed land; and
- 3) maintaining natural diversity including bird, mammal, and fish species with a focus on species of management concern (COSIA <https://www.cosia.ca/initiatives/land>).

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