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Climate-Smart Forestry: Characteristics, Benefits, and Trade-Offs

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1.0 Introduction

Climate change is transforming Canada's forest ecosystems, with its boreal and temperate forests across the country expected to experience major shifts in temperature and precipitation patterns (NCASI 2026). Consequently, increased drought, wildfire, and insect and disease outbreaks are already being observed, contributing to higher carbon emissions, tree mortality, and regeneration challenges. These stressors threaten forest ecosystem integrity, long-term productivity, and the capacity of forests to provide multiple ecosystem services, including habitat for wildlife, carbon storage, timber, water regulation, and cultural values.

Canada's forestry sector has traditionally relied on sustainable forest management (SFM) to balance the environmental, social, and economic values of forests. Despite SFM increasing recognition of climate risks and growing efforts to strengthen adaptation to climate-related disturbances (Edwards et al. 2015), recent assessments indicate that conventional SFM has struggled to fully integrate adaptation and mitigation objectives cohesively, particularly under accelerating natural disturbances and emerging uncertainties (Williamson et al. 2017; Antwi et al. 2024).

In this context, climate-smart forestry (CSF) has emerged as a strategic evolution of SFM, explicitly integrating strategies to (1) improve forest adaptation to a changing climate, (2) advance climate change mitigation through forests and forests products, and (3) ensure the continued provision of social values from forests (Bowditch et al. 2020). This Briefing Note introduces CSF, summarizes how its components align with and extend SFM in Canada, reviews key ecosystem services trade-offs among CSF objectives, and identifies major barriers and opportunities for advancing climate-responsive forest management in Canada. For more detailed information on CSF, please refer to National Council for Air and Stream Improvement, Inc. Technical Bulletin No. 1097 (NCASI 2026).

2.0 What is CSF?

CSF was developed primarily in Europe through multinational processes, where it is defined as:

"Sustainable adaptive forest management and governance to protect and enhance the potential of forests to adapt to, and mitigate climate change. The aim is to sustain ecosystem integrity and functions

and to ensure the continuous delivery of ecosystem goods and services, while minimising the impact of climate-induced changes on mountain forests on well-being and nature's contribution to people."

Bowditch et al. (2020)

This definition does not present CSF as a replacement for SFM but an evolution of it that makes climate objectives explicit and emphasizes their interaction with social and economic values. Adapting the concept to Canada requires greater emphasis on public land ownership, Indigenous rights and knowledge, and existing SFM frameworks. Drawing on the international literature and Canadian institutional context, this Briefing Note uses the following working definition for CSF: an integrated approach to sustainable forest management that seeks to enhance the potential of forests to adapt to and mitigate climate change, while promoting the social and economic values of the forests in the form of rendered ecosystem services.

2.1 Core Components of CSF

CSF is commonly framed around three interconnected components to classify all the strategic, operational, and logistic actions contributing to the goals of CSF (Figure 1). These three components—adaptation, mitigation, and the social dimension—help ensure that the environmental, economic, and social dimensions of sustainability are considered jointly.

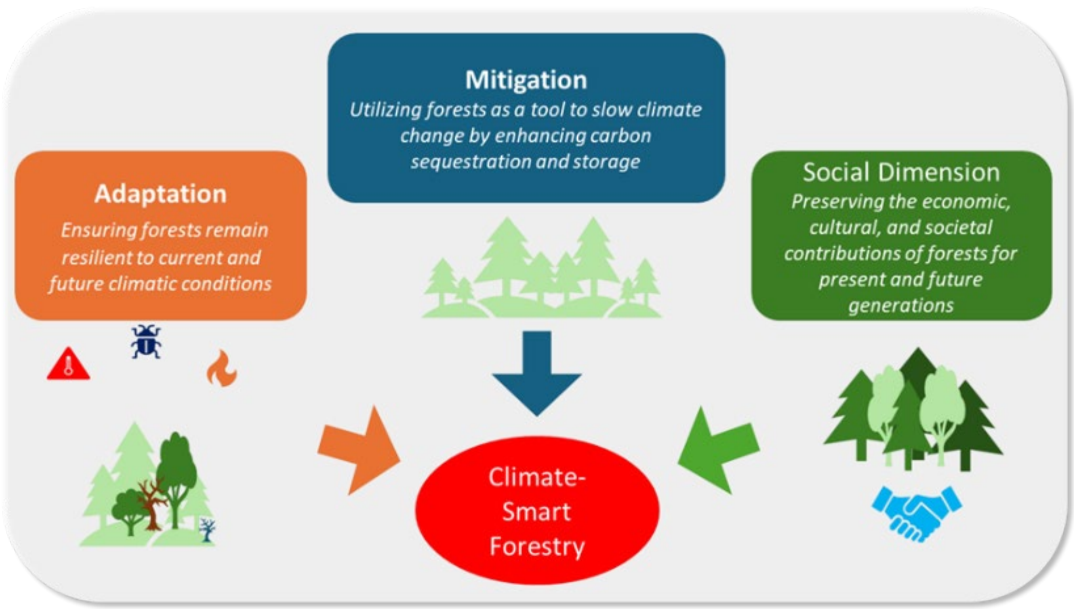

Figure 1: *CSF encompasses three core components: adaptation, mitigation, and the social dimension.*

2.1.1 Adaptation

The adaptation component focuses on maintaining or enhancing forest resilience under current and future climatic conditions (Bowditch et al. 2020). In practice, adaptation typically begins with climate vulnerability assessments that identify key risks and priorities for action. Strategies may involve the following measures:

- **Restoring or maintaining ecological function**: e.g., reducing competition, maintaining fire-adapted ecosystems.

- **Managing biotic disturbance(s)**: e.g., pest-resistant breeding, invasive species control.
- **Reducing disturbance risk and severity**: e.g., diversifying forest structure, reducing fuel loads, using prescribed fires.
- **Strengthening ecosystem stability and redundancy**: e.g., conserving diverse habitat, enhancing species and structural diversity, maintaining connectivity.
- **Supporting genetic adaptation**: e.g., conserving genetic diversity, facilitating assisted species migration.

A growing suite of decision-support tools, workbooks, and climate data platforms in Canada supports these efforts (e.g., Adaptation Options).

2.1.2 Mitigation

The mitigation component seeks to slow down the progression of climate change by enhancing carbon sequestration and storage in forests and harvested wood products and by minimizing emissions from disturbances and operations. Within a CSF framework, mitigation can involve a combination of:

- **Improved forest management**: e.g., low-impact harvesting, extended rotations, retention harvesting, fuel management, pest and disease control.
- **Managing for disturbances**: e.g., reducing wildfire intensity through reduced fuels, using prescribed or cultural burns, or other fire-smart approaches.
- **Strategic use of wood products—substituting high-carbon materials**: e.g., using renewable wood-based alternatives to substitute more carbon-intensive materials such as steel, concrete, or fossil fuels.
- **Enhancing carbon sequestration**: through forest establishment and retention through afforestation, reforestation, or diversified stand structures.

2.1.3 Social Dimension

The social dimension encompasses the economic, cultural, spiritual, scientific, recreational, and other societal benefits forests provide, as well as the governance processes that determine how these benefits are distributed. Although much of the CSF literature has focused on adaptation and mitigation (NCASI 2026), the social dimension is essential to the legitimacy and long-term success of forestry decisions in Canada. Examples of actions in this component include:

- **Meaningful engagement with and leadership by indigenous rights-holders** consistent with the United Nations Declaration on the Rights of Indigenous Peoples and the Truth and Reconciliation Commission's Calls to Action (TRCC 2015): e.g., the Indigenous Forestry Initiative (NRCan 2025).
- **Community well-being and local economic development** in forest-dependent regions: e.g., the Nature Smart Climate Solutions Fund (Government of Canada 2025).
- **Education and communication** to build public understanding and resource capacity: e.g., the Outland Youth Employment Program, Sustainable Forestry Initiative's Project Learning Tree.

3.0 CSF Application in Canada

Many CSF-aligned practices are already widely reflected in Canadian forest management even if not formally identified as "CSF." Over the past two decades, the Canadian Council of Forest Ministers, SFM certification bodies, and provincial agencies have promoted climate vulnerability assessments, adaptation workbooks, and climate-informed planning tools (Edwards et al. 2015; Williamson et al. 2019). These efforts have influenced silviculture and operational planning in different ways. A recent review of adaptation and mitigation initiatives reported uneven implementation across provinces and limited long-term evaluation (Antwi et al. 2024). Use of climate-based seed transfer, fuel management, and enhanced silviculture is particularly reported in western provinces. Other actions such as post-disturbance reforestation, species diversification, and integrated fire management are used operationally, but their results remain underreported.

Industry-led CSF is increasingly visible in corporate sustainability programs, even if not described using CSF terminology. Mosaic Forest Management Corp, for example, integrates climate-informed silviculture, climate-based seed transfer, fuel reduction, and carbon projects with strong commitments to Indigenous partnerships and local communities, illustrating how adaptation, mitigation, and social objectives can be combined within a single organizational strategy (NCASI 2026).

Overall, CSF in Canada reflects a growing alignment between long-standing SFM practices and explicit climate-smart objectives. While reporting gaps persist, adaptation, mitigation, and social values are increasingly integrated in both public and private sector initiatives.

4.0 Ecosystem Services and Trade-Offs

4.1. Ecosystem Services Provided by Forests

Ecosystem services are the benefits people obtain from nature. Forests provide provisioning services (e.g., timber, fibre, non-timber forest products), regulating services (e.g., carbon storage, climate and water regulation, erosion control), and cultural services (e.g., recreation, spiritual and cultural values, education). In addition, forests provide habitat for many plant and animal species. In Canada, forests hold particular significance to Indigenous communities, supporting traditional foods systems, cultural practices, and long-standing stewardship relationships. Biodiversity, ecosystem functioning, and ecological resilience are critical to sustaining these services over time, particularly as climate change alters disturbance regimes and forest dynamics.

4.2 Trade-Offs and Synergies Among Forest Ecosystem Services

The quantity and quality of ecosystem services vary over time and space in response to forest succession, disturbance, management, and climate change. Particularly, forest management strategies for climate adaptation, mitigation, and sustainability can generate trade-offs among ecosystem services. Trade-offs occur when enhancing one ecosystem service reduces another (e.g., increasing timber production at the expense of habitat quality or carbon storage). Alternatively, synergies arise when a management action benefits multiple ecosystem services simultaneously (e.g., mixed-species regeneration that supports both biodiversity and long-term carbon sequestration). Managing all three

CSF components simultaneously could exacerbate unintended trade-offs if ecosystem service interactions are poorly understood and unaccounted for.

Reviews of forest ecosystem services under different management regimes show that timber production frequently trades off with biodiversity, habitat quality, carbon storage, and water regulation, while showing synergies with carbon sequestration and emissions reductions when harvested wood products and substitution are considered (NCASI 2026). However, the magnitude and direction of these effects are context-dependent and influenced by forest type, management regime, time horizon, and spatial scale.

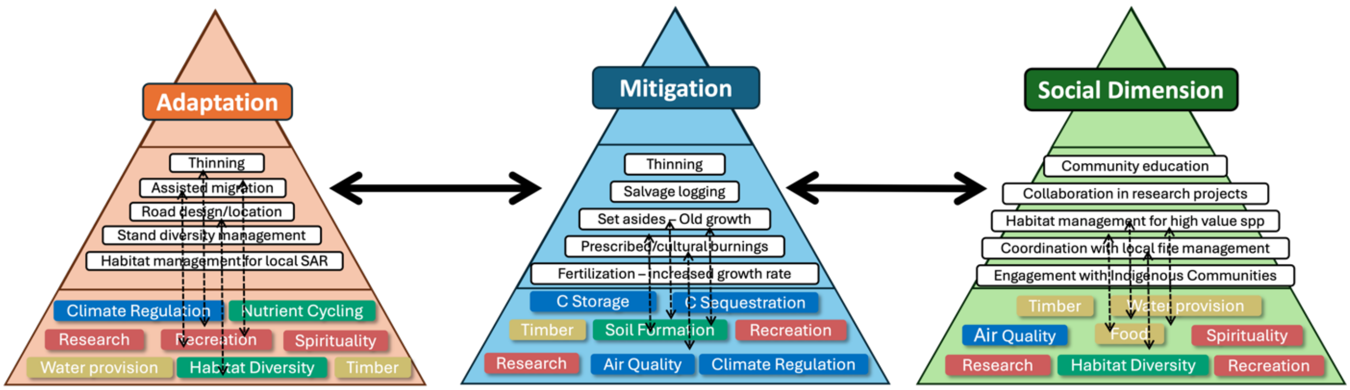

Figure 2: *CSF goals guide management strategies, which in turn affect ecosystem services. Strategies can enhance some ecosystem services while reducing others, and simultaneous implementation across the landscape can create complex interactions among CSF components and ecosystem services.*

Recognizing the close linkages among ecosystem services, CSF goals, and SFM strategies is essential to minimizing these trade-offs. Actions taken under a given CSF component (e.g., an adaptation measure such as drought-focused thinning, or a mitigation measure such as extended rotations) can have a positive, negative, or neutral effect on multiple services, including those associated with other CSF components (Figure 2). Identifying these cascading effects explicitly is a key step toward designing forest management strategies that minimize trade-offs and increase synergies.

4.3 Assessing Ecosystem Service Interactions in Practice

Balancing ecosystem service trade-offs and synergies requires turning complex ecological interactions into usable decision information. Within a CSF framework, even relatively simple ecosystem service assessments can help managers (1) make trade-offs explicit; (2) identify options that deliver multiple benefits; and (3) communicate consequences of choices to rights-holders, stakeholders, and the public. In Canada, guidance such as the Ecosystem Service Assessment Toolkit and similar tools provides stepwise approaches to identify ecosystem service interactions and evaluate possible management strategies (Value of Nature to Canadians Study Taskforce 2017). Modelling tools, such as InVEST (Natural Capital Project 2025), enable spatial and scenario-based assessments. In practice, the use of these tools is still limited by data gaps, competing priorities, and capacity constraints.

4.4 Balancing Ecosystem Service Trade-Offs through Forest Management

Trade-offs among ecosystem services tend to appear at the stand level, especially among provisioning services such as timber, while synergies in regulating services (e.g., carbon, water) are more likely to appear at heterogeneous landscape scales (NCASI 2026). This points to a two-tier approach: stand-level interventions to minimize local trade-offs (e.g., thinning, fuel reduction, mixed-species planting), coupled with landscape-level planning to allocate different objectives to different areas to reconcile production and conservation goals. Landscape zoning frameworks such as the TRIAD approach operationalize this logic by dividing forests into intensive production zones, ecological reserves, and multiple-use forests (Himes et al. 2022). Decision support systems help planning and monitoring the spatial and temporal variation of ecosystem services under different management and climate scenarios. By distributing objectives spatially and using decision support systems to compare scenarios, CSF can reduce conflicts among timber, carbon, biodiversity, and social values and make trade-offs more transparent.

5.0 Potential Ecosystem Service Trade-Offs Within the CSF Framework

Implementing CSF also creates trade-offs among CSF objectives. Reducing ecosystem vulnerability (adaptation) may conflict with increasing carbon sequestration (mitigation). Historic fire suppression increased carbon stocks, but these dense, fuel-rich stands are also more prone to high-severity fires under a warmer, drier climate. Adaptation-oriented measures such as thinning, prescribed or cultural burning, and using less flammable, drought-tolerant species reduce this risk but often lower stand-level carbon in the short term. CSF treats these conflicting outcomes as planned carbon trade-offs, where deliberate reductions in stored carbon may reduce larger, unplanned losses over the long term.

Trade-offs may also arise between adaptation and social components. Managing for high timber yields through shorter rotations (social) could limit the development of mature forest stages and the provision of late-seral habitat (adaptation). Adaptation strategies such as mixed-species stands, longer rotation, and structural retention can improve resilience to climate-related disturbances but reduce short-term harvest and economic returns. CSF addresses this by balancing stand-level adaptation actions with landscape-level arrangements that still meet fibre and social objectives.

Trade-offs can also occur between the mitigation and social components. For example, increasing set-asides or extending rotations to increase carbon storage (mitigation) can reduce available timber in the short term (social). However, when the carbon stored in harvested wood products and the substitution benefits of wood in construction are accounted for, harvesting can still contribute to climate mitigation while long-lived products and landfills can retain a substantial portion of harvested carbon over decades (NCASI 2026).

6.0 Barriers and Opportunities for CSF in Canada

Despite growing interest, CSF adoption in Canada is still constrained by policy, capacity, and knowledge barriers. Fragmented jurisdictional responsibilities, rigid tenure arrangements, and misaligned incentives limit the flexibility needed for widespread adaptive management and innovation (Williamson et al. 2017). Resource and capacity limitations also play a major role. Implementing climate-informed current and new silviculture systems often requires up-front investment and specialized expertise. Many organizations face constraints related to staff capacity, contractor availability, and uncertain markets for emerging products. Data gaps, especially for long-term monitoring of ecosystem service indicators, make it difficult to evaluate CSF outcomes or to justify changes to established practices. Educational and engagement gaps further slow adoption. Traditional forestry training has emphasized sustained yield and short- to medium-term timber targets with less emphasis on climate risk, ecosystem service interactions, and Indigenous knowledge systems. Although broader public engagement and targeted training could improve CSF support, disparities in climate literacy among stakeholders and data accessibility persist.

Several developments are reducing uncertainty and creating opportunities:

- **Improved modelling and scenario analysis:** Tools for climate-informed species selection, growth and yield, and carbon accounting allow comparison of adaptation, mitigation, and economic outcomes across scenarios.
- **High-precision monitoring and SmartForests:** Networks such as SmartForests Canada (Pappas et al. 2022) provide high-resolution data on forest responses to climate and management.
- **Remote sensing and new technologies:** Hyperspectral imaging, LiDAR, and other tools enable more accurate and timely assessment of forest condition and disturbance risk.

Together, these advances support more transparent evidence-based CSF planning and help reduce the perceived risk of changing established practices.

7.0 Summary

Climate change is placing increasing pressure on Canada's forests and revealing the limits of traditional SFM as a vehicle for managing climate risk. CSF offers an approach that integrates climate change adaptation, mitigation, and social benefits to support resilient, multifunctional forests using a combination of new and existing tools and practices. CSF provides an organizing lens to explicitly plan, align, and evaluate current and future SFM practices with respect to climate adaptation, mitigation, and social goals. However, the application of CSF still presents challenges. Managing ecosystem services trade-offs (i.e., balancing carbon storage, timber harvesting, habitat provision, and other values) remains complex with limited research on how these interactions unfold under the CSF framework. Planning the delivery of ecosystem services at the landscape scale and leveraging decision-support tools and monitoring networks provides an avenue to balance trade-offs and distribute management objectives. Other barriers to implementation include regulatory constraints, high costs, and gaps in data and knowledge. Continued investment in data acquisition, modelling, and monitoring tools, along with strengthened partnerships among stakeholders, including Indigenous communities, will support the effective application of CSF in the future. Overall, CSF offers Canada a pragmatic, science-informed path to navigate climate uncertainty while sustaining the diverse ecosystem services and cultural values forests provide.

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