



Adapting Sustainable Forest Management to Climate Change: Criteria and Indicators in a Changing Climate



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Adapting Sustainable Forest Management to Climate Change: Criteria and Indicators in a Changing Climate

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Climate Change Task Force**

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Climate Change Task Force

“Consideration of climate change and future climatic variability is needed in all aspects of sustainable forest management”

A vision for Canada’s forests: 2008 and beyond

(CCFM 2008)

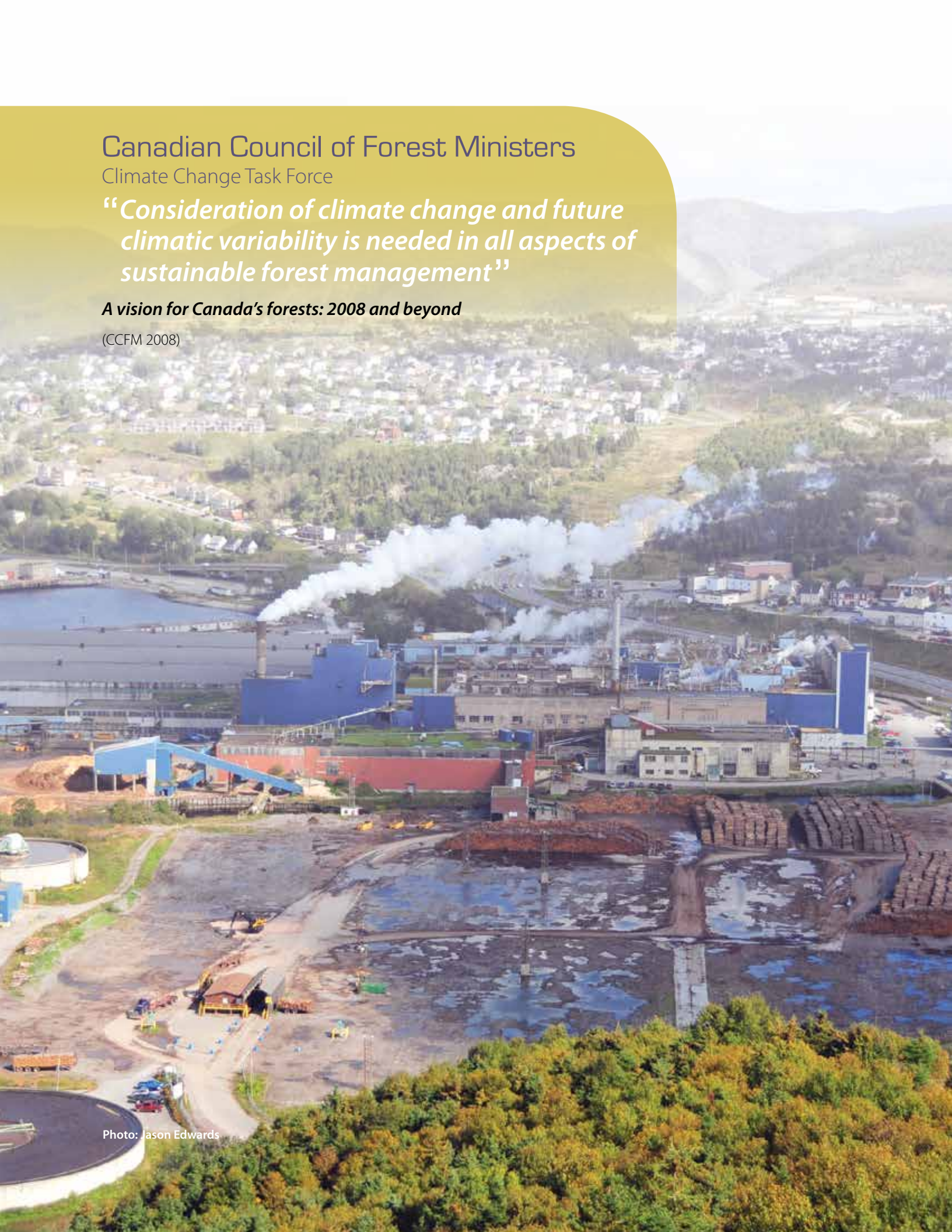


Photo: Jason Edwards



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FOREWORD

Canada has 397 million hectares of forests and other woodlands, representing 10% of the world's forest cover. Our forests constitute a world-class natural treasure providing ecological, economic, social, and cultural benefits to all Canadians, regardless of whether they live in small northern communities or large urban centres. Canada is committed to sustainable forest management, which aims to maintain and enhance the long-term health of forested ecosystems while providing ecological, economic, cultural, and social opportunities for present and future generations.

One of several factors that pose both opportunities and challenges in terms of effectively and efficiently meeting our sustainable forest management goals is climate change and its inherent uncertainties. The Canadian Council of Forest Ministers (CCFM) identified climate change as one of two priority issues for Canada's forest sector. In its *Vision for Canada's Forests: 2008 and Beyond*, the CCFM stated, "Consideration of climate change and future climatic variability is needed in all aspects of sustainable forest management." In addition, to minimize the risks and maximize the benefits associated with a changing climate, Canada's provincial and territorial premiers asked their Ministers responsible for forest management to collaborate with the federal government on adaptation in forestry through the CCFM's Climate Change Task Force. Phase 1 of this work, completed in 2010, involved a comprehensive assessment of the vulnerability of various tree species and identified management options for adaptation. Phase 2 has gone beyond the level of trees to look at climate change adaptation within forest ecosystems and the broader forest sector. The goal of phase 2 was to equip members of the forest sector with a suite of tools and state-of-the-art information to enable them to make better decisions about the need for adaptation and the types of measures that may be most beneficial.

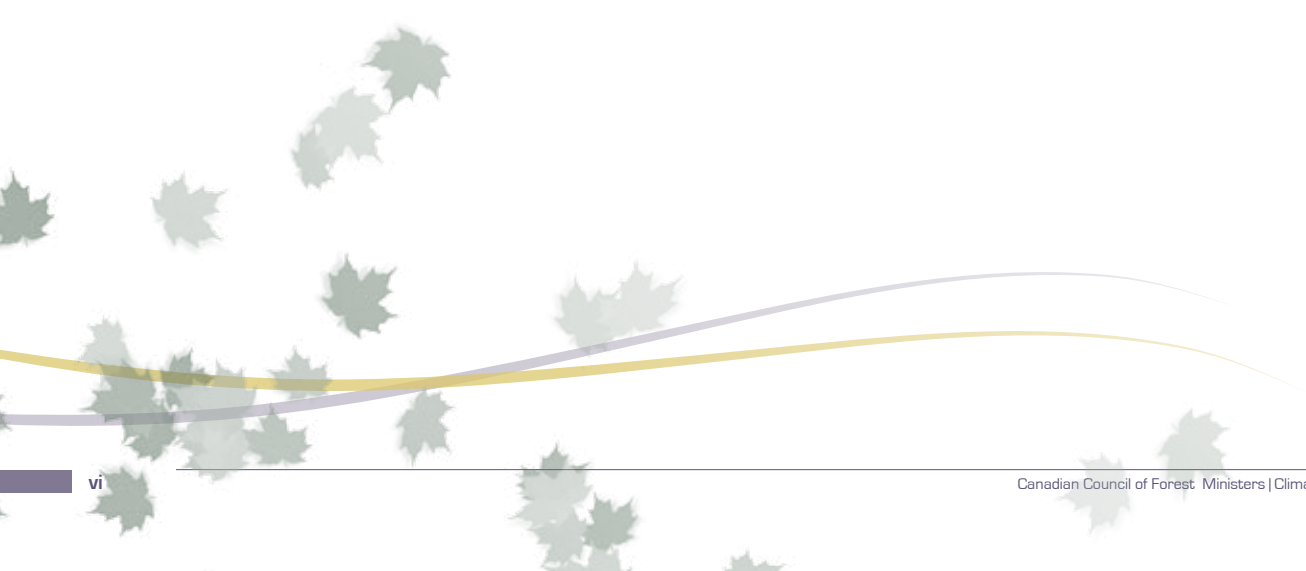
Over a period of two years, nearly one hundred individuals from a wide range of organizations have contributed to achieving this goal. The fruits of their labour have been captured in the CCFM's Climate Change Adaptation series, which comprises several technical reports and review papers. It is our sincere hope that these documents, which will be used in conjunction with workshops, seminars, and presentations, will benefit forest practitioners from coast to coast to coast as they seek innovative ways to adapt sustainable forest management policies and practices for a changing climate.

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ABSTRACT

Canada was an early adopter of the principles of sustainable forest management (SFM). One of the earliest steps was the establishment of a framework of criteria and indicators (C&I) for defining and assessing progress toward the achievement of SFM. However, this framework was developed before the potential consequences of climate change for forests and forest management were well understood. The current C&I assume a relatively stable climate. It is now known, however, that the climate of the future will be different from past and current climate. This change poses unprecedented challenges to forest management and may reduce the effectiveness of current C&I in defining and reporting on progress toward SFM. Decisions about how the existing C&I can be updated to account for climate change seem warranted. However, incorporating climate change into the C&I framework is not straightforward. Efforts to do so will ultimately require broad discussion and consultation at multiple scales on how progress toward SFM is to be defined and measured under a changing climate. This paper considers ways in which the C&I for SFM developed by the Canadian Council of Forest Ministers might be affected by climate change and examines options for updating them to account for climate change.

Key words: climate change, sustainable forest management, criteria and indicators, climate change impacts, adaptation, adaptive capacity, prospective indicators

RÉSUMÉ

Le Canada a été parmi les premiers pays à adopter les principes de l'aménagement forestier durable (AFD). L'une des premières étapes a été de définir un cadre de critères et d'indicateurs (C et I) pour l'évaluation de la progression en AFD. Cependant, ce cadre a été élaboré avant que soient bien comprises les conséquences potentielles des changements climatiques sur les forêts et leur aménagement. Le cadre actuel de C et I suppose la stabilité relative du climat. Or, il est maintenant connu que le climat futur différera du climat actuel et passé. Un tel changement pose des défis sans précédent à l'aménagement des forêts et peut réduire l'efficacité des C et I actuels à définir l'AFD et à en évaluer les progrès. Il semble maintenant y avoir consensus sur la prise de décisions concernant la façon d'actualiser les C et I en fonction des changements climatiques. Cependant, l'intégration de la dimension climatique dans le cadre des C et I de l'AFD n'est pas si simple. Cette question d'intégration exigera la tenue de discussions et de consultations à différentes échelles sur la façon dont on définira et mesurera la progression de l'AFD sous l'influence de cette nouvelle réalité climatique. Dans ce document, nous examinons comment les C et I de l'AFD élaborés par le Conseil canadien des ministres des forêts pourraient être affectés par les changements climatiques et comment ils pourraient être mis à jour.

Mots clés : changement climatique, aménagement forestier durable, critères et indicateurs, impacts des changements climatiques, adaptation, capacité d'adaptation, indicateurs potentiels

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INTRODUCTION

This discussion paper provides a basis for further dialogue within the Canadian forest management community about climate change and its implications for the future development and use of the criteria and indicators (C&I) of sustainable forest management (SFM). It should be acknowledged at the outset that climate change is not the only external factor affecting Canada's forests and SFM values. Other factors include technological change, restructuring of global markets, resource development, land-use change, air pollution, and changes in the values that society associates with forests. However, the analysis presented here focuses on climate change, because climate is a

fundamental determinant of the state and condition of Canada's forests. In addition, climatic change is and will continue to be unprecedented in Canadian forest management experience and thus may have important implications for core SFM values and objectives (as described below, in the section on the "impacts of climate change on criteria and indicators of sustainable forest management").

Recent research has identified specific areas where SFM C&I will be affected by climate change (Ogden and Innes 2007; Eddington et al. 2009; Steenberg et al. 2011, 2013). This paper combines the insights of that research with

the expert views of the Canadian Council of Forest Ministers (CCFM) Climate Change Task Force to provide a high-level evaluation of the effects of climate change on SFM C&I. The paper also identifies potential options for incorporating climate change considerations into SFM C&I.

What is sustainable forest management?

Sustainable forest management (SFM) maintains and enhances the long-term health of forest ecosystems for the benefit of all living things, while providing ecological, economic, cultural, and social opportunities for present and future generations (CCFM 2008). The Canadian Council of Forest Ministers (2006) has defined the following criteria to aid in achieving and monitoring SFM in practice:

1. Biological diversity
2. Ecosystem condition and productivity
3. Soil and water
4. Role in global ecological cycles
5. Economic and social benefits
6. Society's responsibility



Photo: Kelvin Hirsch

SUSTAINABLE FOREST MANAGEMENT IN CANADA

Canada was an early adopter of sustainability in forestry, beginning with the 1992 CCFM national forest strategy (CCFM 1992). One of the earliest steps was to establish a framework of C&I for defining and assessing progress toward SFM. The framework is presented in two earlier CCFM publications (CCFM 2003, 2006), and the C&I themselves are listed in the Appendix.

The SFM C&I developed by the CCFM “provide a science-based framework to define and measure Canada’s progress in the sustainable management of its forests. The criteria represent forest values that Canadians want to enhance or sustain, while the indicators identify scientific factors to assess the state of the forests and measure progress over time” (CCFM 2003). Together, they provide a mechanism for reporting on forest condition, forest values, and forest management actions, with the aim of assessing the extent to which forest management is

preserving and protecting, for both current and future generations, the values that Canadians associate with forests.

Canada’s SFM C&I are based on important forest values and forest management objectives. Similar values (or indicators of values) are organized into criteria (as listed in the box entitled “What is sustainable forest management?”). The indicators in each criterion are then objectively measured to assess either the state of an important aspect of the values associated with a particular sustainability criterion or the actions that would contribute to a forest management goal associated with sustainability.

In its vision document, the CCFM (2008) noted that “consideration of climate change and future climate variability is needed in all aspects of sustainable forest management.” Subsequently, the CCFM’s Climate Change Task Force initiated a number of studies to look at how this can be done (see Edwards and Hirsch 2012). One of the identified areas of work was a consideration of how climate change might affect the ability of current SFM C&I to signal achievement of or progress in SFM.

HOW COULD THE SFM C&I ADD VALUE TO DECISION MAKING AND POLICY?

The concept of SFM is now an integral part of Canadian forest management and policy. Forest legislation in many jurisdictions across Canada includes SFM objectives, and the CCFM's C&I are used to guide forest management decision and policy making. For example, the Canadian Standard Association's certification standard for forest management is based on the CCFM SFM criteria (CSA

2008). The CCFM's C&I also form the basis for many local-level SFM indicator frameworks, and they provide a structure for reporting on the state of Canada's forests. The CCFM's work on SFM C&I at the national level has also supported the country's participation in and contributions toward the development of international C&I by the Montréal Process Working Group (Montréal Process 2009b). Taking steps to ensure that SFM C&I better reflect the implications of climate change would enhance forest management decision making and policy in Canada. For example, two ways that a modified C&I framework would enhance decision making are to monitor forest conditions under a changing climate and to help identify adaptation options.

GENERAL EFFECTS OF CLIMATE CHANGE ON CANADA'S FORESTS

Canada's forests are vulnerable to climate change because of the expected magnitude of anticipated changes, the sensitivity of forest ecosystems to small changes in climatic conditions, and the long growing cycle of trees (Williamson et al. 2009). Johnston et al. (2009) noted that Canada's tree species are particularly vulnerable to climate change, commenting that "climate change will create changes in microclimates, local site conditions, disturbances (e.g., fire, insects, disease, drought, extreme storms), phenology (i.e., the timing of biological activity

over a year in relation to climate), and the distribution, abundance, and ecosystem interactions of invasive species, all of which could lead to increased tree mortality and changes in competitive interrelationships. ... The general effects of climate change on tree species include changes in:

- regeneration success
- forest health ...
- productivity (positive in some places, negative in other places)
- amount of growing stock ...
- species ranges, species composition, age class distribution, and forest structure at any given location, over time."



Photo: Jason Edwards

IMPACTS OF CLIMATE CHANGE ON CRITERIA AND INDICATORS OF SUSTAINABLE FOREST MANAGEMENT

The CCFM's current C&I were developed before the specific impacts of climate change were recognized as a serious issue for SFM in Canada. As noted above, it is now evident that climate change poses increasing challenges for SFM in Canada (Ogden and Innes 2007; Johnston et al. 2009; Williamson et al. 2009).

The remainder of this document considers some of the potential implications of climate change on SFM C&I and identifies preliminary options for incorporating climate change considerations into the C&I. The assessment is based in part on recent technical analyses on the subject of climate change and SFM indicators, including those by Ogden and Innes (2007), Eddington et al. (2009), and Steenberg et al. (2011, 2013).

The assessment is also based on the expert views of the membership of the CCFM's Climate Change Task Force and its Technical Analysis Group. The perspectives of members of both these bodies were obtained through a combination of written reviews of drafts and discussion at a face-to-face meeting.

One aspect of the current SFM C&I is that they assume a stable and relatively constant climate over time (Ogden and Innes 2007; Eddington et al. 2009; Steenberg et al. 2011). The reality facing forest management, however, is that future climate will differ from past and current climate. The effectiveness of reporting systems that do not account for this new reality (such as the current SFM C&I) may be reduced (Ogden and Innes 2007; Steenberg et al. 2011). The extent to which the effectiveness may be reduced depends on how climate change affects the ability of current indicators to report on progress toward SFM in robust and defensible ways. It also depends on whether current indicators are relevant under a changing

climate. In other words, does the reality of climate change mean that some current indicators will no longer be effective or that new indicators are called for, as suggested by Steenberg et al. (2011)?

The remaining discussion in this section considers how climate change can be expected to affect the current SFM C&I at the broad criterion level (see Appendix for the full list of SFM C&I). Ogden and Innes (2007), Eddington et al. (2009), and Steenberg et al. (2011, 2013) provide more detailed technical analyses of the impacts and implications of climate change on SFM C&I.

Criterion 1: Biological diversity – Criterion 1 indicators track the biological diversity of Canada's forests from the perspectives of ecosystem, species, and genetic diversity. They measure forest area (by type and age class within and outside of protected areas), the populations of forest species (including both species at risk and species not at risk), the presence of exotic and invasive species, the genetic diversity of reforestation seed lots, and the status of efforts to conserve native tree species in Canada. Climate change will have a measurable influence on many of these indicators. For example, Steenberg et al. (2011) found that 87% of the indicators within this criterion will decline in predictability, responsiveness, or relevance as a result of climate change. Over time, climate change will influence the distribution of forest-associated species, forest types, and age classes. Climate change may make it difficult to demonstrate successful conservation of forest biodiversity (Scott and Lemieux 2005). For example, climate change may contribute to declines in the populations of certain forest-based species at risk, such as woodland caribou (Thompson et al. 1998). The overall effect may be that the current suite of biological diversity indicators will become less effective for measuring progress in forest management because of changes in forest biodiversity resulting from stressors unrelated to forest management, such as climate change. Moreover, the current SFM C&I do not incorporate actions that may be needed to reduce the negative impacts and take advantage of the positive impacts of climate change.

Criterion 2: Ecosystem condition and productivity –

Criterion 2 indicators track growing stock, additions and removals of forest area by cause, area disturbed (by wildfire, insects, disease, and timber harvest), area affected by ozone and acid rain, and timber harvest area successfully regenerated. These indicators are sensitive to climate and will likely be affected by climate change. Climate change has the potential to affect the resources required by trees (e.g., water, nutrients, and carbon dioxide), as well as site conditions (e.g., through changes in moisture level, melting of permafrost, and effects on nutrient cycling), landscape-scale disturbance processes (such as drought, extreme weather, wildfire, and insect outbreaks), and tree physiology (e.g., phenology, respiration, photosynthesis, metabolism, growth, mortality, and reproduction). Changes in climate over the medium (e.g., 2050s) to long (e.g., 2080s) term may have impacts on ecosystem condition and productivity indicators, including changes in forest land (with losses in some areas and gains in other areas), in the proportion of forest land that is sufficiently stocked with desired species following harvest or disturbance, in forest yield and inventory, and in forest health. Similar to the findings for criterion 1, the overall anticipated effect for criterion 2 indicators is that they will become less effective as measures of forest management progress because changes observed might be the result of forestry-related activities, climate change, or other factors, and it may not be possible to distinguish among these causes. For example, Steenberg et al. (2011) found that all of the indicators within this criterion would be directly or indirectly influenced by climate change.

Criterion 3: Soil and water – Criterion 3 indicators are used to monitor both compliance with environmental standards to protect soil and water resources and the extent of stand-replacing disturbances in watersheds. Under a changing climate, the period of frozen ground conditions will become shorter, which will reduce winter harvest opportunities. Moreover, the magnitude and incidence of extreme precipitation and runoff events could increase. It is possible, therefore, that compliance

with environmental standards could become more costly and more difficult to achieve. In addition, it is probable that the frequency and magnitude of stand-replacing disturbances, such as wildfire and blowdown, will increase in some of Canada's forested watersheds.

Criterion 4: Role in global ecological cycles – The role of forests and the forest sector in global ecological cycles is represented by indicators that track periodic changes in forest ecosystem carbon, forest products carbon, and forest sector carbon emissions. Steenberg et al. (2011) found that all of the indicators for this criterion would be directly or indirectly influenced by climate change. This influence will be manifested in various ways. The indicators may increase in importance because of the amount of carbon that is currently stored in Canada's forests and the potential role of Canadian forest management in increasing forest ecosystem carbon. However, the capacity of Canada's forests to store carbon may be negatively affected. As the climate changes, stocks and flows of forest carbon will be affected by changes in the growth rate of trees, disturbances, and the decomposition rates of dead organic matter.

Criterion 5: Economic and social benefits – Criterion 5 indicators represent measures of harvest sustainability and utilization, industrial competitiveness, production and income generation, and employment from primary and secondary manufacturing of forest resources and from the nontimber forest products sector. Steenberg et al. (2011) suggested that 77% of the indicators for this criterion would be directly or indirectly influenced by climate change. The biophysical impacts of climate change could have a number of direct implications for the economic and social benefits that Canadians realize from forest resources, including the following:

- changes in the supply of timber (positive in some areas and negative in others)
- changes in the supply of nontimber goods and services (positive in some areas and negative in others)

- reductions in opportunities for winter harvest
- increases in the costs of delivered wood
- changes in industrial production, employment, and income
- increases in the costs of forest management (e.g., forest protection and reforestation)
- increases or decreases in opportunities for outdoor recreation in summer and winter

Climate change, therefore, is a new driver of change for the social and economic benefits obtained from forests. As such, it will have important social and economic consequences that are not solely the result of forest management activity.

Criterion 6: Society's responsibility – Criterion 6 indicators relate to people and to fair and effective resource management choices. This criterion “addresses

the effectiveness of institutions in managing resources in ways that accurately reflect social values, the responsiveness of institutions to change as social values change, how we deal with the special and unique needs of particular cultural and/or socio-economic communities, and the extent to which the allocation of our scarce resources can be considered to be fair and balanced” (CCFM 2003). Many of its indicators could be affected by climate change because climate change will alter the context for SFM decision making. The biophysical and socio-economic impacts of climate change mentioned above could also affect the well-being and resilience of forest-based communities. How well SFM decision-making processes and expectations about forest values incorporate knowledge about climate change and the ability of decision-making organizations to adapt to the impacts of climate change could increase in importance.



Photo: EMEND Project, University of Alberta

OPTIONS FOR INCORPORATING CLIMATE CHANGE CONSIDERATIONS INTO CRITERIA AND INDICATORS

The analysis in the previous section suggests that climate change may have fundamental implications for definitions of SFM and for how progress toward SFM is measured. The pace of change in climate and therefore in forested ecosystems is expected to be unprecedented. This new reality requires recognition of current and potential future impacts and a national discourse on whether we will be able to achieve SFM as currently defined. In fact, on the basis of what is known about climate change, the current C&I may no longer be representative of SFM. This possibility raises a number of questions about Canada's national C&I for SFM:

- Does climate change require a rethinking of the purpose or intent of these C&I?
- Does climate change imply a need for modifications to existing indicators or possibly the addition of new indicators?
- Is there a need to add forward-looking (i.e., prospective) indicators to help forest managers ensure forest sustainability under both present climate conditions and future (changed) climate conditions?

Revisiting the purpose of C&I under a changing climate – Given that climate change will reduce the effectiveness of certain SFM C&I as currently defined, changes in the C&I may be appropriate. For example, a broader discussion of the need to modify the purpose of SFM C&I may be needed.

One possible new role for the SFM C&I would be in reporting on progress toward SFM under a changing climate. If the purpose or intent of SFM C&I shifts in this way, then it may be necessary to modify or augment state and action indicators in ways that account for the impacts

of climate change on SFM objectives and allow reporting on activities consistent with the sustainable management of forests under a changing climate. Furthermore, it may be necessary to recognize that forest management in combination with climate change (as well as other factors) will affect the state of Canada's forests over time. In other words, a new role for a modified SFM C&I framework could be monitoring (or projecting) the state of the forests for the purposes of identifying needs for adaptation and adaptation options.

Modifications of and additions to indicators –

Discussion is also required about the structure of the current SFM C&I framework. For example, addition to, deletion from, or modification of the current suite of SFM indicators may be required as a result of climate change. Various new indicators specific to climate change could be considered (see Eddington et al. 2009; Steenberg et al. 2011), such as indicators reflecting recent or future changes in key climate variables of importance to forest ecosystems and forest management (e.g., seasonal maximum and minimum temperature and precipitation, soil moisture values, and length of the growing season). Indicators of current and potential impacts of climate change and action indicators demonstrating the ways in which forest managers are adapting to climate change might also be considered.

Another topic of discussion could be the potential addition or enhancement of indicators of the adaptive capacity of SFM systems. Adaptive capacity is defined as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2001, p. 6). This definition applies to both the ecological and human components of SFM systems. Forest managers are continuously adapting to changes in technology, markets, social expectations and values, and natural capital values, as well as to changes in social, economic, and forest conditions. Under climate change, adaptability becomes even more important. The need for higher levels of

adaptability in the context of climate change means that indicators of the adaptive capacity of SFM systems might be warranted (see Williamson and Isaac 2013).

Prospective indicators – To date, the assessment of SFM has been based on indicators that assess changes in SFM criteria. This approach often relies on comparing the current value of particular indicators to their historical values (i.e., trend analysis). This back-casting type of approach is appropriate for assessing SFM under constant climate conditions; however, a potential implication of climate change is the requirement for a complementary, forward-looking approach to C&I assessment (Steenberg et al. 2011). A prospective approach of this type would involve developing outlooks or multiple scenarios of the future potential value of SFM indicators. The use and development of scenarios for SFM has been described by Price and Isaac (2012).

International SFM C&I – Canada is 1 of 12 national signatories to the Montréal Process. The Montréal Process

Working Group on C&I, which was formed in 1994, has produced four editions of its SFM C&I framework, the most recent released in 2009 (see Montréal Process 2009b) In 2008, the Montréal Process Working Group developed a strategic plan (Montréal Process 2009a) that included the following actions:

- To explore approaches to identifying and monitoring trends in forest degradation to support an increasing focus on the impacts of climate change and the adaptation needs of member countries.
- To develop approaches that will allow member countries to use C&I as a forward-looking planning or strategic tool, as well as a reporting framework.

Work performed at the national level on incorporating climate change into SFM C&I would position Canada to play a leading role in international initiatives to include climate change in international frameworks.

SUMMARY AND CONCLUSIONS

Forest managers in Canada are committed to SFM, but climate change has important implications for SFM in this country. The effectiveness of current C&I as a mechanism

to define and measure progress toward SFM could be affected by climate change. Modifying or adapting current C&I to account for climate change is one logical step. However, incorporating climate change in the C&I poses a number of challenges. Efforts to do so will ultimately require broad discussion and consultation at multiple scales about what Canadians value about the country's forests and how SFM is measured and defined and how forests are managed under a changing climate.

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GLOSSARY

Adaptation | “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (Parry et al. 2007).

Climate | “Climate in a narrow sense is usually defined as the ‘average weather’, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO)” (Parry et al. 2007).

Climate change | “Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines ‘climate change’ as: ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods’” (Parry et al. 2007).

Criteria | Criteria represent forest values that Canadians want to enhance or sustain (CCFM 2006).

Ecosystem | “The interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales and can comprise the entire globe, biomes at the continental scale or small, well-circumscribed systems such as a small pond” (Parry et al. 2007).

Ecozone (ecoprovince, ecoregion, ecodistrict) | A broad, ecologically distinctive area delineated at the subcontinental level and defined by its interaction of human, vegetative, wildlife, climatic, geologic, and physiographic factors. Canada’s ecological land classification framework comprises 15 terrestrial ecozones that are further divided into subdivisions comprised of 53 ecoprovinces, 194 ecoregions, and 1020 ecodistricts (CCFM 2006).

Indicator | Factors that assess the state of forests, the economic and social benefits obtained from forests and society’s performance in managing forests sustainably (CCFM 2006).

Scenario(s) | “A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined within a ‘narrative storyline’” (Parry et al. 2007). Scenarios are not predictions, and they typically do not include prediction errors or likelihoods.

Sensitivity | “The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)” (Parry et al. 2007).

Sustainable forest management | “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” (CCFM 2008). According to the Canadian Council of Forest Ministers, the criteria for defining and monitoring sustainable forest management in Canada are biodiversity, ecosystem condition and productivity, soil and water, role of the forests in global ecological cycles, economic and social benefits, and society’s responsibility.

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APPENDIX

Current Criteria and Indicators of Sustainable Forest Management, as defined by the Canadian Council of Forest Ministers

Criterion 1: Biological diversity

- 1.1 Ecosystem diversity
 - 1.1.1 Area of forest by type and age class, and wetlands in each ecozone
 - 1.1.2 Area of forest by type and age class, wetlands, soil types, and geomorphological features in protected areas in each ecozone
- 1.2 Species diversity
 - 1.2.1 The status of forest-associated species at risk
 - 1.2.2 Population levels of selected forest-associated species
 - 1.2.3 Distribution of selected forest-associated species
 - 1.2.4 Number of invasive, exotic forest-associated species
- 1.3 Genetic diversity
 - 1.3.1 Genetic diversity of reforestation seed-lots
 - 1.3.2 Status of *in situ* and *ex situ* conservation efforts of native tree species within each ecozone

Criterion 2: Ecosystem condition and productivity

- 2.1 Total growing stock of both merchantable and non-merchantable tree species on forest land
- 2.2 Additions and deletions of forest area, by cause
- 2.3 Area of forest disturbed by fire, insects, disease, and timber harvest.
- 2.4 Area of forest with impaired function due to ozone and acid rain

- 2.5 Proportion of timber harvest area successfully regenerated

Criterion 3: Soil and water

- 3.1 Rate of compliance with locally applicable soil disturbance standards
- 3.2 Rate of compliance with locally applicable road construction, stream crossing, and riparian zone management standards
- 3.3 Proportion of watersheds with substantial stand-replacing disturbance in the last 20 years

Criterion 4: Role in global ecological cycles

- 4.1 Carbon cycle
 - 4.1.1 Net change in forest ecosystem carbon
 - 4.1.2 Forest ecosystem carbon storage by forest type and age class
 - 4.1.3 Net change in forest products carbon
 - 4.1.4 Forest sector carbon emissions

Criterion 5: Economic and social benefits

- 5.1 Economic benefits
 - 5.1.1 Contribution of timber products to the gross domestic product
 - 5.1.2 Value of secondary manufacturing of timber products per volume harvested
 - 5.1.3 Production, consumption, imports, and exports of timber products
 - 5.1.4 Contribution of non-timber forest products and forest-based services to the gross domestic product
 - 5.1.5 Value of unmarketed non-timber forest products and forest-based services
- 5.2 Distribution of benefits
 - 5.2.1 Forest area by timber tenure

- 5.2.2 Distribution of financial benefits from the timber products industry
- 5.3 Sustainability of benefits
 - 5.3.1 Annual harvest of timber relative to the level of harvest deemed to be sustainable
 - 5.3.2 Annual harvest of non-timber forest products relative to the levels of harvest deemed to be sustainable
 - 5.3.3 Return on capital employed
 - 5.3.4 Productivity index
 - 5.3.5 Direct, indirect, and induced employment
 - 5.3.6 Average income in major employment categories

Criterion 6: Society's responsibility

- 6.1 Aboriginal and treaty rights
 - 6.1.1 Extent of consultation with Aboriginals in forest management planning and in the development of policies and legislation related to forest management
 - 6.1.2 Area of forest land owned by Aboriginal peoples
- 6.2 Aboriginal traditional land use and forest-based ecological knowledge
 - 6.2.1 Area of forested Crown land with traditional land use studies
- 6.3 Forest community well-being and resilience
 - 6.3.1 Economic diversity index of forest-based communities

- 6.3.2 Education attainment levels in forest-based communities
- 6.3.3 Employment rate in forest-based communities
- 6.3.4 Incidence of low income in forest-based communities
- 6.4 Fair and effective decision-making
 - 6.4.1 Proportion of participants who are satisfied with public involvement processes in forest management in Canada
 - 6.4.2 Rate of compliance with sustainable forest management laws and regulations
- 6.5 Informed decision-making
 - 6.5.1 Coverage, attributes, frequency, and statistical reliability of forest inventories
 - 6.5.2 Availability of forest inventory information to the public
 - 6.5.3 Investment in forest research, timber products industry research and development, and education
 - 6.5.4 Status of new or updated forest management guidelines and standards related to ecological issues

Source: Canadian Council of Forest Ministers. 2003. Defining sustainable forest management in Canada: criteria and indicators 2003. Ottawa, ON. Also available from <<http://www.cfs.nrcan.gc.ca/pubwarehouse/pdfs/23636.pdf>>

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