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Climate Change and Sustainable Forest Management in Canada:

A Guidebook for Assessing Vulnerability and Mainstreaming Adaptation into Decision Making

This report is a product of the Climate Change Task Force of the Canadian Council of Forest Ministers.

Copies of this report in French and English can be found online at ccfm.org or by contacting the Canadian Council of Forest Ministers.

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A Guidebook for Assessing Vulnerability and Mainstreaming Adaptation into Decision Making

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CONTENTS

Worksheet Tables

Chapter 1

Chapter 2

Chapter 3

Chapter 4

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 *A 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 2 years, nearly 100 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. This current workbook draws upon information from all the previously published papers and reports in this series. It is a highly practical and user-oriented workbook that will enable forestry professionals to conduct evaluations of climate change vulnerability and potential adaptation options in a comprehensive and structured manner as a means of making informed investment and management decisions.

It is our sincere hope that these documents, which will be used in conjunction with workshops, seminars, and presentations, will benefit Canadian 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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0.1 Adapting to Climate Change: The Need and the Challenge

Depending on the region, climate change may result in productivity changes, maladaptation of trees, changes in forest land cover or species composition, increases in the frequency and intensity of biotic and abiotic disturbances, and a host of other biophysical effects. In some cases forest productivity will be enhanced by climate change. However, it is expected that the overall net effect of climate change on Canada's forest will be negative, particularly in the absence of early adaptation (Johnston et al. 2009).

The potential effects of climate change on forests will likely have important implications for Canada's ability to achieve sustainable forest management (SFM) objectives and goals as currently defined. Consequently, climate change was identified as one of two strategic issues of national importance for Canadian forest management, and the Canadian Council of Forest Ministers (CCFM) has recommended that consideration of both climate change and future climatic variability is needed in all aspects of SFM (CCFM 2008).

The CCFM has identified six defining criteria that must be met for forests in Canada to be considered as being managed sustainably (see sidebar **What is Sustainable Forest Management?**). SFM is a moving target to which many managers aspire but which they often find difficult to achieve because of dynamic environmental, economic, cultural, and social conditions. As a consequence, SFM demands continuous monitoring, improvement, and adjustment. With the additional stresses and pressures caused by changing climate conditions, it is now widely acknowledged that forest managers may face unprecedented challenges in reaching this common goal of sustainability.

Currently, SFM policies and practices are often based on an assumption that future environmental processes and conditions shaping forests will be within the range of variability that shaped the current forest. Under a changing climate, however, this assumption may no longer be valid. Recognition that future climate (and hence growing conditions, the rate and severity of natural disturbances, conditions for forest harvest operations, etc.) will be different from the climate of the recent past and that of the present calls for a fundamental rethinking about approaches and assumptions used in forest management. Failure to acknowledge the new reality of climate change may result in widespread impacts, many of which could be reduced or avoided if appropriate adaptation actions were identified, planned, and implemented today. Information about the vulnerability of forest management systems is needed to determine how best to incorporate climate change considerations into definitions of SFM and into the norms, standards, practices, and policies that are used to implement and monitor SFM.

Adaptation offers a path forward for forestry practitioners to meet the demands of the forest sector within the context of complex socioecological systems and a rapidly changing climate. Adaptation seeks to ensure that the breadth of ecosystem services provided by forests and underpinning the competitiveness of Canada's forest sector is maintained under future climates. In other words, the purpose of adaptation is to identify

and implement the measures necessary to reduce vulnerability to climate change and thus to increase the likelihood that SFM objectives will be achieved. Therefore, the fundamental goals of adaptation and SFM are the same.

Adaptation is often implemented at a local or regional scale, and it can be enabled by institutions and policies that support adaptation actions. The need for adaptation within forest management varies across ecosystems and is related to the vulnerability of SFM systems relative to their ability to achieve SFM objectives under a changing climate. Tools and knowledge that allow forest resource professionals operating at various scales to understand climate change and to effectively and efficiently adapt to potential impacts are required. The CCFM has addressed this need, in part, through its "Adapting Sustainable Forest Management to Climate Change" report series (see Edwards and Hirsch 2012), which outlines a comprehensive approach to understanding and adapting SFM to climate change. The current guidebook is part of the series and provides a "how to" tool for applying the CCFM adaptation framework described by Williamson et al. (2012).

What is Sustainable Forest Management?

Forests provide significant ecological, economic, social, and cultural benefits to Canadians. As development pressures on forest resources have mounted over time, the need for a concept of forest management that ensures conservation of healthy forests for future generations, while allowing for a balanced, equitable, and efficient flow of ecological, economic, social, and cultural benefits for current generations, has become apparent. The concept of sustainable forest management (SFM) was developed in response to this need. SFM has now been embraced by forest managers across Canada. Furthermore, demonstrating adherence to the principles of SFM has become an international requirement, both through international agreements, such as the Montréal Process (see www.montrealprocess.org), and through various forest management processes, such as certification.

To implement SFM and to ascertain whether it was being achieved, a clear definition of the concept and a mechanism or tool to monitor and measure progress toward it were required. The Canadian Council of Forest Ministers (CCFM) therefore developed a national framework of criteria and indicators to meet these dual requirements (CCFM 2006). This framework sets out six criteria for achieving SFM:

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

Managing forests according to these six criteria is far from the largely timber-focused management approach of the past. Instead, SFM works to address and balance a wide range of ecological, economic, social, and cultural considerations so that the needs and expectations of all forest users may be met today and in the future. This comprehensive approach requires more than just dealing with the immediate challenges of the day; it also requires working to predict long-term trends so that Canadians can plan how best to maintain the health and well-being of the country's forests and forest economy.

0.2 Overview of the CCFM Framework for Assessing Vulnerability and Mainstreaming Climate Change into SFM

The CCFM has developed an SFM adaptation approach that can be used by forest resource professionals across Canada to identify how best to incorporate climate change considerations into their SFM policies, plans, and practices. At the center of the CCFM SFM adaptation approach, and the foundation for this guidebook, is a framework for identifying sources of vulnerability to climate change that are important to sustainability and developing adaptation options to reduce these vulnerabilities.

The framework, which provides a structured decision-making approach to adapting SFM to climate change, is explained in detail in the CCFM report "Adapting Sustainable Forest Management to Climate Change: A Framework for Assessing Vulnerability and Mainstreaming Adaptation into Decision Making" (Williamson et al. 2012). The framework outlines the following four stages for adaptation, which in turn encompass six components (or steps) (see Figure 0.1):

Stage 1 – Organizational readiness: The aim of stage 1 is to explore the organization's readiness to undertake an SFM vulnerability and adaptation assessment (see Gray 2012). This guidebook assumes that this stage has been completed and that the organization is prepared to initiate an SFM vulnerability assessment and potentially to change SFM policies and practices if required.

Stage 2 – Pre-vulnerability analysis: The aim of stage 2 is to develop the context of the assessment, describe the current climate and climate–forest relationships, and develop future climate and forest impact scenarios.

Stage 3 – Detailed vulnerability analysis: The aim of stage 3 is to identify where SFM is vulnerable to climate change (and therefore where adaptation is needed) and where opportunities or positive effects could occur (which could be enhanced by adaptation).

Stage 4 – Identify, implement, and monitor adaptation: The aim of stage 4 is to evaluate, implement, monitor, and mainstream adaptation measures into SFM decision making.

The adaptation framework is somewhat general in nature and nonprescriptive in terms of concrete steps required for adaptation of SFM. This guidebook provides an approach to moving the framework from general theory into practice.

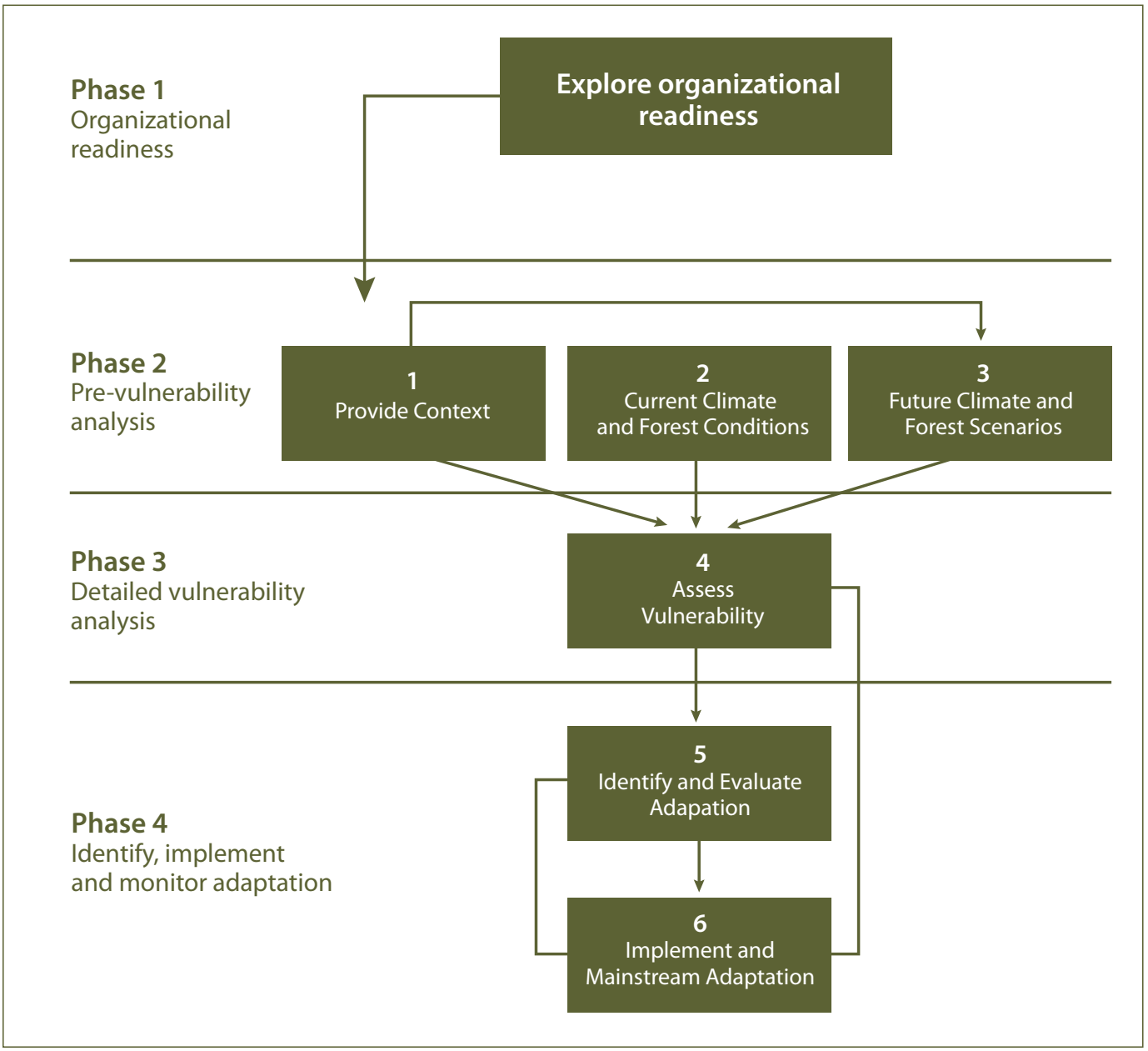

Figure 0.1. The four stages and six components (indicated by green boxes) of adaptation to climate change in the context of sustainable forest management (adapted from Williamson et al. 2012).

0.3 About this Guidebook

Goal and Objectives

The intent of this guidebook is to provide practical guidance to forest resource professionals (practitioners and policy makers) who are applying the CCFM approach to vulnerability assessment and adaptation planning for SFM. This guidebook has the following attributes:

- primarily targets forestry practitioners (at the operational and planning levels) but also recognizes the importance of supporting policy makers in mainstreaming climate change adaptation (see sidebar **Definitions**)
- focuses on how to assess the vulnerability of SFM objectives to climate change and identify options for mainstreaming adaptation into decision making
- is relevant to both practice and policy but is not prescriptive
- recognizes that there is no single best method for implementing the framework that will be suitable in all situations, given that capacity, resource availability, management, and climate change impacts all differ widely from region to region within Canada
- shares key findings and lessons learned from early attempts at forestry-related vulnerability assessments in Canada (case studies)
- provides a structured decision-making process for acquiring climate impact knowledge to help guide SFM adaptation decisions and actions
- provides a framework for maintaining a record of decision making, prompting users to document the reasoning behind changes to management policies and practices.

Overview

Each chapter in the guidebook corresponds to one of the components of the CCFM framework for assessing vulnerability and mainstreaming adaptation, as described in Williamson et al. (2012) and illustrated in Figure 0.1 (referred to as the framework). The framework is a general approach that can be used by forest resource professionals across Canada to identify how best to incorporate climate change considerations into SFM policies and plans. Each chapter is structured around a series of worksheets (presented in chapter 7) that are designed to assist users through the methodologies presented herein and to help them document the results and discussions of each assessment stage. A glossary is included to ensure common understanding of the terms used throughout this guidebook (see Appendix 1).

Each chapter contains the following elements:

- **Purpose and expected outcomes**
- **Worksheets:**
  - *Theory* – provides background, based on the literature and practitioners' experience, and theory for the guidance being provided

Definitions

Forestry practitioners: Forestry practitioners are those responsible for operational activities and for developing forest management plans to achieve directions set at the strategic level.

Policy makers: Policy makers are those responsible for high-level or strategic-level plans to develop policies and programs that both facilitate and guide the work of forest practitioners.

- *Practice* – provides practical guidance for completing the worksheets, along with suggested alternative methods (a basic approach and a more comprehensive approach) for tailoring the guidance provided to each project's unique circumstances

- **Case studies** to demonstrate how some of the vulnerability assessment concepts have been put into practice across Canada
- **Strategic and operational considerations** for implementing methodologies described herein, drawn from the literature and practitioner's experiences

The purpose of each chapter and its associated worksheets are described in Table 0.1.

Although a sequential approach is recommended, it is not essential, and an iterative process may be required as the assessment project unfolds. In addition, not all worksheets will be useful for all projects, and it will be up to each assessment team to determine which will be the most helpful for their project and to identify the best available method for completing them, given the resources available.

Throughout the guidebook several methodological approaches, ranging from basic to more comprehensive, are provided to help the user understand how to approach the framework steps and worksheets. The approach selected will often depend on the assessment resources available and the scope and scale of the assessment.

Users of the guidebook should seek to understand and investigate the trade-offs inherent in selecting one approach over another.

For example, selecting a basic approach may provide an easier and quicker route to the next step in the vulnerability assessment process but may mean that critical aspects of the SFM system are not considered. Conversely, a more comprehensive approach may mean that more information and more aspects of the SFM system are considered, but more resources and time may be required to gather the data, information, and knowledge required to complete the assessment stage.

The steps in the CCFM adaptation framework, and the guidance presented within this guidebook, are based on principles of structured decision making (identify objectives, define problem, identify and assess options against objectives; see sidebar **Structured Decision Making**), principles of adaptive management (plan, act, monitor, evaluate, adjust), and decision making under uncertainty (e.g., employ scenarios to explore possible futures).

Users are encouraged to treat every step of this guidebook as an ongoing and iterative process, and to understand that each step can be revisited once new knowledge is gained.

Also, although the worksheets provided represent a suggested approach to applying the framework, users of this guidebook are encouraged to adapt them as required. However, users should try to adhere to the concepts within the framework even if such adjustments are made.

Structured Decision Making

A process to plan for climate change adaptation may benefit from the application of concepts developed for decision analysis. A structured decision-making approach represents a useful way to guide the development, evaluation, implementation, monitoring, and mainstreaming of adaptation recommendations and strategies. Structured decision making provides a useful framework to assess when and where a particular adaptation option may be suitable. In relation to adaptation to climate change, structured decision making involves establishing management objectives for the future forest; determining the vulnerability of forest ecosystems, forest communities, local economies, and human populations; developing alternative adaptation options; evaluating alternative options against management objectives; implementing desired adaptation policies and practices; monitoring the effectiveness of climate change adaptation efforts in achieving management objectives; and modifying management practices when adaptation efforts are unsuccessful in meeting management objectives (e.g., adaptive management). Articulating specific objectives may increase the success of planning processes in addressing long-term concerns within short-term decisions. This approach is consistent with the approach adopted in the CCFM report "Adapting Sustainable Forest Management to Climate Change: A Framework for Assessing Vulnerability and Mainstreaming Adaptation" (Williamson et al. 2012).

Structured decision making has many similarities to the adaptation policy framework process suggested by the United Nations Development Programme. Both involve assessing current vulnerability, formulating adaptation strategies, and then implementing, monitoring, and improving the initiatives launched. Structured decision making places more emphasis on the articulation of management objectives and the evaluation of alternative options and strategies against these objectives. The adaptation policy framework process places more emphasis on who is involved in making the evaluation (strong stakeholder engagement), on the careful scoping of a project to ensure that it is well integrated into a policy and planning process (to foster implementation of results), and on enhancing adaptive capacity. Neither approach requires high-quality data or extensive modeling expertise, and both approaches encourage thoughtful assessment and a structured process.

The following sources provide helpful information on structured decision making: Lim and Spanger Siegfried (2005); Ogden and Innes (2007); Ohlson et al. (2005); Williamson et al. (2012).

Table 0.1. Summary of each chapter within the guidebook and its associated worksheets[a]

Chapter	Description	Worksheets
1. Provide context for vulnerability assessment	This chapter provides guidance for how to begin assessing vulnerability to climate change and mainstreaming adaptation into SFM[b]. The focus is to develop an understanding of the need to address climate change and thus undertake an SFM vulnerability assessment, and to clearly define the goals of the assessment.	**Worksheet 1.1.** Define the problem or challenge **Worksheet 1.2.** Describe the SFM system and define the scope of the vulnerability assessment **Worksheet 1.3.** Confirm the scope of the assessment
2. Current climate and forest conditions	This chapter provides guidance on describing and documenting how climate has shaped current forest conditions and management practices in the user's SFM area. It also provides guidance on documenting any current adaptations to climate change that the user may already be practicing.	**Worksheet 2.1.** Describe climatic conditions and trends **Worksheet 2.2.** Describe the relationships among climate, forest conditions, and forest management practices **Worksheet 2.3.** Describe how recent climate trends or changes in forest conditions have led to changes in current management practices **Worksheet 2.4.** Identify uncertainties and knowledge gaps
3. Future climate and forest impact scenarios	This chapter provides guidance on developing and describing future climate and forest impact scenarios.	**Worksheet 3.1.** Develop and describe future climate scenarios **Worksheet 3.2.** Develop and describe forest impact scenarios
4. Assess vulnerability	This chapter provides guidance on evaluating and documenting SFM vulnerability to current climate and the range of future climate change scenarios.	**Worksheet 4.1.** Assess current and future impacts on SFM **Worksheet 4.2.** Evaluate adaptive capacity of the SFM system **Worksheet 4.3.** Assess current and future vulnerability **Worksheet 4.4.** Assess overall SFM system vulnerability **Worksheet 4.5.** Decision point: Is adaptation required?
5. Adaptation options	This chapter provides guidance on developing climate change adaptation options for SFM.	**Worksheet 5.1.** Develop potential adaptation options for SFM objectives **Worksheet 5.2.** Develop potential adaptation options for the overall SFM system of interest
6. Implementation and mainstreaming of adaptation	This chapter provides guidance on implementing and mainstreaming adaptation for SFM.	**Worksheet 6.1.** Prioritize adaptation options **Worksheet 6.2.** Recommend priority adaptation options for implementation **Worksheet 6.3.** Implement (mainstream) recommended adaptations **Worksheet 6.4.** Evaluate adaptation performance

[a]Each chapter corresponds to one of the six components of adaptation framework for adaptation to climate change, as presented in Figure 2 in Williamson et al. (2012).
[b] SFM = sustainable forest management.

0.4 Learning from Others: The Forestry Adaptation Community of Practice

Adapting forest management policies and practices within a complex system, such as SFM, can be challenging. Fortunately, many "early adapters" have completed forestry-related vulnerability assessments (e.g., CCFM case studies summary report by Johnston and Edwards 2013), and the lessons learned and good practices are available to others via an online community of practice (https://www.ccadaptation.ca/en/facop). The Forestry Adaptation Community of Practice (also known as FACoP) is hosted by the Ontario Centre for Climate Impacts and Adaptation Resources. It is a subcommunity within a broader online climate change adaptation community of practice (http://www.ccadaptation.ca). Everyone is welcome to join, and users of this guidebook are encouraged to use this forum to share lessons learned and methods used to assess the vulnerability of their SFM policies, plans, and practices.

0.5 Tools and Resources for Vulnerability Assessment

An ever-increasing number of vulnerability assessment examples and climate change adaptation tools are being documented and published. Many of these examples have been related to assessing the vulnerability of forested ecosystems and developing adaptation options to reduce these vulnerabilities.

This guidebook adds to the toolbox by going beyond the assessment of forest ecosystems to assessing the vulnerability of SFM goals and objectives.

Forestry-Related Vulnerability Assessment Examples

- The CCFM vulnerability assessment case studies report (Johnston and Edwards 2013) highlights 10 forestry-related vulnerability assessments from across Canada: http://www.ccfm.org/pdf/ENG_CaseStudy_prf10.pdf.
- Many projects undertaken by the Future Forest Ecosystem Scientific Council of British Columbia involved the conduct of ecosystem vulnerability assessments: http://www.for.gov.bc.ca/hfp/future_forests/council/index.htm.
- The U.S. Department of Agriculture Forest Service has published information about its ecosystem vulnerability assessment in northern Wisconsin (Swanston et al. 2011): http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs82.pdf.
- The U.S. Department of Agriculture Forest Service has also published information about its vulnerability assessment of the Olympic National Forest (Halofsky et al. 2011b): http://www.fs.fed.us/pnw/pubs/pnw_gtr844.pdf.

Vulnerability Assessment Guidance

- The United Nations Environment Programme's Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (also known as PROVIA) recently published detailed guidance on conducting vulnerability assessment (Hinkel et al. 2013). This excellent, highly recommended resource highlights and suggests methods, approaches, and decision trees appropriate at various points in the assessment process: http://www.unep.org/provia/RESOURCES/Publications/PROVIAGuidancereport/tabid/130752/Default.aspx.
- "A Practitioner's Guide to Climate Change Adaptation in Ontario's Ecosystems" (Gleeson et al. 2011) provides vulnerability and risk assessment guidance for natural resources managers in Ontario. The Ontario guide is based on a draft version of the current guidebook: https://www.ontario.ca/environment-and-energy/practitioners-guide-climate-change-adaptation-ontarios-ecosystems-ver-1-2011.
- U.S. Department of Agriculture Forest Service recently produced two adaptation guidance documents that target forest managers in the United States – "Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers" (Swanston and Janowiak 2012): http://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs87.pdf, and "Responding to Climate Change in National Forests: A Guidebook for Developing Adaptation Options" (Peterson et al. 2011): http://www.fs.fed.us/pnw/pubs/pnw_gtr855.pdf.
- "Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment" (Glick et al. 2011) provides good background on vulnerability assessment methodology for conservation resource professionals: http://www.nwf.org/vulnerabilityguide.
- The use of workshops is one of the most widely used approaches to conducting impact, vulnerability, and adaptation assessments. Halofsky et al. (2011a) have documented a workshop approach for developing climate change adaptation and action strategies for natural resource managers: http://www.fs.fed.us/psw/publications/millar/psw_2011_millar001(halofsky).pdf.
  A workshop approach is also highlighted by Janowiak et al. (2011): http://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs81.pdf.

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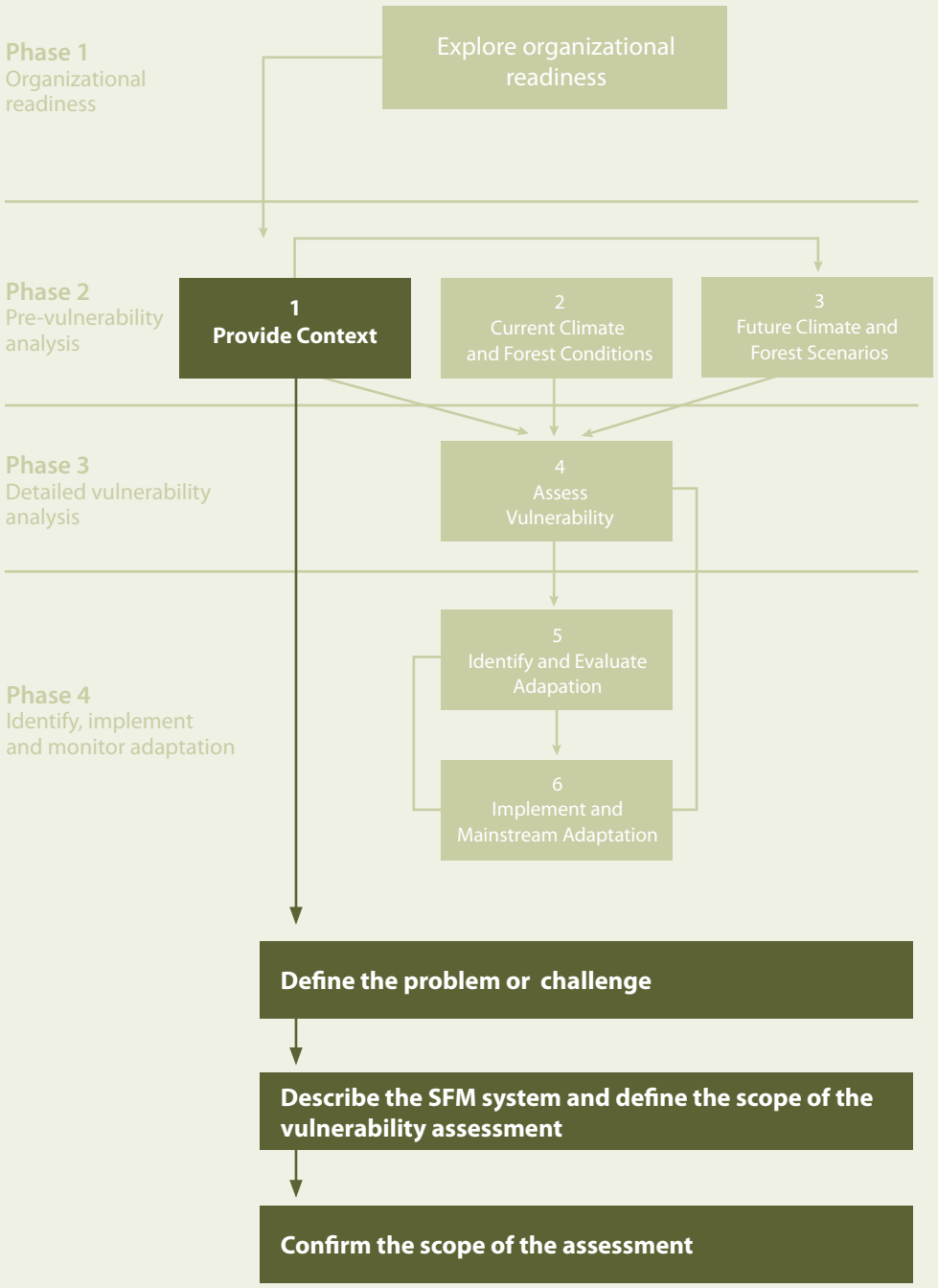
CHAPTER 1 PROVIDE CONTEXT FOR VULNERABILITY ASSESSMENT



Before you begin:

It is recommended that you read *Adapting sustainable forest management to climate change: a systematic approach for exploring organizational readiness* by Gray (2012) and *Adapting sustainable forest management to climate change: a framework for assessing vulnerability and mainstreaming adaptation into decision making* by Williamson et al. (2012).

It is also assumed that you and your organization are prepared to initiate an SFM vulnerability assessment (see Gray 2012).

1.1 Overview

This chapter provides guidance on how to begin assessing vulnerability to climate change and mainstreaming adaptation into SFM. The focus is to develop an understanding of the need to address climate change and thus undertake an SFM vulnerability assessment, and to clearly define the goals of the assessment.

This chapter also helps users of the guidebook to define the SFM system of interest by describing the spatial extent and scope of the assessment, identifying the actors and decision makers, understanding both the decision-making context (e.g., governance) and the policy context, and determining if the required resources are available to conduct the assessment as defined. Taking appropriate time at the beginning of the assessment to clearly define the system of interest is important to success.

This chapter is structured around three worksheets that are designed to facilitate an SFM vulnerability assessment:

Worksheet 1.1. Define the problem or challenge

Worksheet 1.2. Describe the SFM system and define the scope of the vulnerability assessment

Worksheet 1.3. Confirm the scope of the assessment

From the assessment framework…

"A description of the context is needed for three reasons. First, it ensures that the goals and design of the assessment are consistent with the management system and the management context for which it will be used. Second, it ensures a clear and direct link between the vulnerability and adaptation segments of the assessment. Third, it confirms that the organization has the necessary capacity to complete the assessment."

—Williamson et al. (2012)

Purpose of "providing the context"	Outcomes
To initiate your SFM vulnerability assessment by defining both the SFM system of interest and the scope of the assessment	• An understanding of the reasons for undertaking an assessment • A description of the SFM system that will be assessed • A list of potential partners and interested groups/individuals • Confirmation of the scope of the assessment

1.2 Define the Problem or Challenge

1.2.1 The Theory

Ohlson et al. (2005) stated that "clearly formulating and specifying the management problem is perhaps the most important and least appreciated step in the development and evaluation of adaptation strategies." They advocated for a direct statement of the problem and the decision context for solving the problem before an assessment is undertaken. Although the impacts of climate change are usually negative and can be best

described as problems, in some situations in Canadian forests, climate change may create opportunities, with corresponding challenges for SFM to embrace the opportunities.

Certain factors, or triggers, often influence the desire to initiate an SFM vulnerability assessment and adaptation planning process (see Appendix 2), including the following:

- past extreme weather and/or weather-related events (e.g., insect infestation, fire, flood, wind) that caused damage to forest resources or infrastructure
- anticipated changes in climatic variability (e.g., increased frequency or magnitude of extreme weather-related events, changes to forestry operation seasons)
- identified vulnerabilities (e.g., results of a scientific study or anecdotal evidence)
- desire to adopt "best management practices" or to be an "early-adopter"
- funding opportunities for climate change vulnerability assessment or adaptation
- desire to realize concurrent benefits (e.g., job creation, community sustainability)
- pressure from interest groups or the public to account for climate change in plans
- professional ethics
- investor or insurance demands
- risk perceptions and concerns of forest managers and the public.

Brainstorming how climate and climate change affect the system being assessed is an effective way to better understand the problems and challenges that might need to be considered (ICLEI 2010). The scoping step can be strengthened by explicitly considering the question, "What might be the consequences of not undertaking a vulnerability assessment and not adapting proactively to climate change?" (Williamson et al. 2012). This type of localized information can also provide concrete examples of why a climate change vulnerability assessment is needed. These examples can be valuable when seeking resources and commitment for the assessment.

If clear factors have prompted a vulnerability assessment of SFM and some benefits of an assessment have been defined, it may also be useful to clearly define why you wish to proceed with the assessment and what you hope to achieve. Developing well-defined purpose and outcome statements at this early stage can help focus the scope and participation level of the assessment.

The outcome of defining the problem or challenge should be a direct statement that specifies the problem to be addressed, the purpose of the vulnerability assessment, and the expected outcomes of the assessment.

1.2.2 The Practice

Although defining the climate change problem or challenge is crucial at the initiation of an effective climate change vulnerability assessment, this step is often not taken seriously. As a result, the focus for the assessment may be unclear, and relevant decision makers or interested parties may be omitted from the process. Lack of clear problem definition may also lead to an ever-expanding assessment, which may in turn result in a fatigue of resources, in terms of both financial support and participants' attention.

Worksheet 1.1 (Define the problem or challenge) guides you in preparing the statements of purpose and expected outcome after identification of the factors that have triggered the assessment and exploration of the anticipated benefits of a vulnerability assessment or the potential consequences of not doing so.

A basic approach	Bring together your colleagues to brainstorm and complete **Worksheet 1.1 (Define the problem or challenge)**. If possible, include one key decision maker.
A comprehensive approach	Invite representatives from all departments in your organization, as well as from other organizations and agencies with SFM roles for your area. Work together to explore possible triggers and affected decisions and decision-makers, keeping an open mind to the diversity of views. Try to avoid seeking consensus at this stage and instead simply record the diversity of views, as this reflects the reality that you will likely encounter during the assessment.
Operational considerations	Be mindful of the possible implications of triggers on operational factors such as length of the harvest season or the need for unexpected salvage harvesting. Consider which decisions are actually made by operations personnel, including contractors and forest workers.
Strategic considerations	At the strategic scale, challenges related to climate change can affect several decisions. For example, an increase in the area burned by wildfires can necessitate increased salvage harvesting, change reforestation success, shift timber supply, and alter wildlife habitats, all of which may affect strategic decisions.

1.3 Define the SFM System of Interest

1.3.1 The Theory

The concept of vulnerability (see sidebar **Vulnerability**) that has been adopted in the assessment framework (Williamson et al. 2012) focuses on a defined climate-sensitive "system." SFM is carried out through a complex, integrated socioecological system, with elements that are more or less sensitive to climate.

Defining the SFM system of interest entails choosing and describing an appropriate geographic (spatial) scale for the vulnerability assessment, listing the actors (i.e., those involved in making decisions and those affected by the decisions), and describing the larger decision-making context (e.g., policies and regulations) within which the system resides. Clearly defining the SFM system of interest early in the vulnerability assessment and adaptation process can help reduce barriers to adaptation later on (Moser and Ekstrom 2010).

Canadian SFM systems encompass a defined land area and include two types of elements:

- natural biophysical elements (e.g., ecosystems, forest types, streams, wildlife)
- human elements (e.g., individuals and organizations, institutions, built infrastructure such as roads).

The SFM system also includes management objectives, which define the outcomes desired from the system, and indicators used to measure achievement of these objectives. Climate change is likely only one of several factors influencing the SFM system. Other key

Vulnerability

"The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity."

—(Parry et al. 2007)

factors of change, such as local land-use trends and global economic trends, should also be included in your description of the SFM system.

Explicitly describing your SFM system ensures that the vulnerability assessment addresses all the climate-sensitive dimensions of the system and takes into account the nonclimatic factors that may exacerbate or lessen climate vulnerabilities. The following sections provide background information on describing your SFM system.

A lesson learned from forestry vulnerability assessment case studies (Johnston and Edwards 2013):

Defining the SFM system of interest, the scale, the scope, and the level of participation are the most critical steps in a vulnerability assessment. An assessment that is well matched to available resources and has the appropriate level of engagement from interested parties is likely to be more successful in implementing adaptation options and reducing barriers to new approaches and practices.

Defining the Spatial Scale

The factors prompting a vulnerability assessment and adaptation planning project can aid in defining your assessment area, as they may indicate the spatial scale at which the issue is best examined. The appropriate spatial scale is often related to the decision context (or contexts) within which the issue is best addressed. Generally, the greater the scale of the issue, the more complex the assessment (with more stakeholders [interested parties], more policy linkages, etc.). Many climate change issues operate across multiple scales, a consideration that should be taken into account within any vulnerability assessment and adaptation planning project. For more information, see Theme 1: Spatial and Temporal Context in Gray (2012).

Local area – A smaller area provides the opportunity to explore vulnerability and adaptation to climate change in a very specific biogeographic and political context (e.g., a community forest or woodlot). Such assessments tend to be more operational in nature and the local management objectives may be more clearly defined compared with regional or national scales (see "Case study – Local area: Site prescriptions for fuel abatement and biodiversity conservation in Jasper National Park").

Case Study – Local area: Site prescriptions for fuel abatement and biodiversity conservation in Jasper National Park	For communities located at the wildland–urban interface, climate change may be of increasing concern because of anticipated changes in the forest fire regime. The FireSmart manual (Partners in Protection 2003), developed by the Partners in Protection program to support fuel abatement around communities, has been adopted and implemented by many communities across Canada, including Jasper National Park. Consistent with the principles of SFM, Jasper National Park has successfully integrated the management of other values, such as biodiversity and visual esthetics, into its site prescriptions for fuel abatement. While this example does not explicitly deal with climate change, it is an example of the operational nature of local risk and vulnerability assessments. Source: Westhaver (2007).

Regional area – Regional assessments (e.g., for a watershed, timber supply area, or forest district) represent a level of complexity above that of local studies. Assessments at this scale tend to demand more integration between different decision-making contexts, involve a larger number of stakeholders (or interested parties), and require more careful examination of trade-offs in the exploration of adaptation options. Regional assessments often address both strategic and operational considerations. Examples of regional area vulnerability assessments are highlighted in Johnston and Edwards (2013), and one example is summarized in "Case study – Regional area: Southwest Yukon."

Case Study – Regional area: Southwest Yukon	The southwest Yukon has provided an ideal location for examining climate change vulnerability and adaptation. Accumulating evidence suggests that the Champagne and Aishihik First Nations (CAFN) Traditional Territory (CATT) in southwest Yukon is already experiencing the impacts of climate change. Warmer winters and warmer, drier summers beginning in the early 1990s have contributed to a severe spruce beetle outbreak affecting almost 400 000 ha of white spruce forest (of an estimated 600 000 ha) in the CATT. This is the largest and most intense recorded outbreak of spruce beetle in Canada. Climate change played a critical role in increasing the population of beetles to epidemic levels, a phenomenon exacerbated by the large tracts of mature white spruce characterizing the forests in this region. Also, since the mid-1990s, the spruce beetle outbreak has been driving forest management and planning efforts in the affected region. In December 2004, a Strategic Forest Management Plan (SFMP) for the CATT was jointly approved by the CAFN and the Government of Yukon. The plan identifies reduction of fire hazard, renewal of beetle-killed forests, provision of economic benefits, and preservation of wildlife habitat as priorities. In April 2006, the CAFN and the Government of Yukon jointly set a salvage harvest level for this zone of up to 1 million cubic meters of beetle-affected timber over 10 years. Climate change impacts are likely to affect whether the community-directed SFMP goals, which include having functioning forest ecosystems and providing community sustainability and benefits, can be achieved. Although planning has been driven by a climatically induced outbreak, climate change adaptation was not an explicit consideration in the planning process. To explore the possibilities for such adaptation further, 30 local forest practitioners engaged in a participatory process to identify climate change vulnerabilities and evaluate alternative adaptation options. A structured decision-making approach was used to frame the assessment. The existence of regional management objectives greatly facilitated the evaluation of over 80 adaptation options. Practitioners identified 24 of these adaptation options as being important to implement to achieve the regional goals and objectives of sustainable forest management in light of climate change. Source: Ogden and Innes (2009).

National or provincial/territorial area – Not all issues lend themselves to assessment locally or regionally, and some climate change vulnerabilities and opportunities are best addressed at a larger scale. An example of a larger-scale project is the assessment examining the risk of the mountain pine beetle spreading beyond British Columbia to eastern pine forests. The National Forest Pest Strategy facilitated this assessment, with input being required from jurisdictions in both western and central Canada (see "Case study – National area: National Forest Pest Strategy"). The outcome of a provincial, territorial, or national assessment may include the establishment of broad policies providing guidance and support for adaptation planning at regional and local scales. These studies tend to be more strategic in nature.

In many cases, successful adaptation processes combine policy making with proactive risk management. In this way, key adaptation priorities are identified and addressed at the appropriate level.

Case Study – National area: National Forest Pest Strategy	The provinces, territories, and federal government agreed to collaborate on developing the National Forest Pest Strategy (NFPS), which would enable forest managers across the country to manage forest pests in a more proactive, integrated way through more efficient use of knowledge and technology. In 2007, forest managers and scientists tested the risk assessment approach of the NFPS on a real-world question: Would the mountain pine beetle outbreak, already spreading beyond British Columbia, present a threat to Canada's boreal and eastern pine forests? Combining biological evidence, climate change trends, and computer simulations, the researchers concluded that the beetle does pose a real risk to the boreal forest. This assessment has led to calls for attempts to slow the beetle's spread eastward, to give resource industries and governments time to address the susceptibility of their forests. Sources: Canadian Council of Forest Minsters Forest Pest Working Group: http://www.ccfm.org/english/coreproducts-forestpests.asp Natural Resources Canada National Forest Pest Strategy: http://www.nrcan.gc.ca/forests/insects-diseases/13409

Biophysical Elements of the SFM Area

The natural biophysical elements of SFM vulnerability assessments most often focus on forested ecosystems. A detailed description of forest ecosystems and their existing natural drivers of change (e.g., fire dynamics, forest pest dynamics) is a useful starting point for a vulnerability assessment. Nonforested ecosystems (e.g., wetlands, grasslands) may also be included, as climate change is likely to affect these ecosystems and may influence SFM practices and adaptation options.

Human Elements of the SFM System

SFM systems include a variety of human elements (e.g. individuals, organizations, governance structures, institutions) that influence how decisions are made and implemented. It is essential to account for these human elements in an SFM vulnerability assessment. For example, it may be useful to consider individuals, agencies, organizations, or governments with the following characteristics:

- involved in overall land management or partnered in the management of the area
- involved in reviewing or approving plans or in regulatory compliance or enforcement
- holding land-use tenures
- in a position to affect decisions for the area
- in a position to be affected by decisions for the area.

Individuals within the SFM system will include personnel from these organizations, including managers and professional and operational staff, as well as individuals who are not affiliated with any particular organization but who are interested in the area for other values, such as recreation users and the general public.

SFM Management Objectives

Defining management objectives is a key task within the SFM vulnerability assessment framework, as it is these objectives that form the basis of the assessment.

> *The central question of an SFM vulnerability assessment is whether SFM objectives can be met with current policies and practices, given the current climate and a range of potential future climates.*

Most forest management plans in Canada include clearly stated management objectives that define the desired future forest conditions or economic and societal outcomes of management actions, with criteria and measurable indicators to report progress toward meeting those objectives (see sidebar **Canadian Council of Forest Ministers' Criteria and Indicators Framework**). For many forest management plans with third-party certification, these objectives and indicators may already be well defined.

Key Nonclimatic SFM Factors

Climate change vulnerability assessments should not be conducted in isolation from other key management factors that already have influenced SFM (or may influence SFM over time). Today, many Canadian forest-sector operations must contend with competition for workers, an aging workforce, severe financial pressures, and shifts in land use and public values. Climate change is a cross-cutting issue that should be considered along with other factors of change. The impacts of climate change may inhibit or enhance the effects of these other factors. Likewise, these other factors may affect the ability to successfully implement adaptation options.

Canadian Council of Forest Ministers Criteria and Indicators Framework

The Canadian Criteria and Indicators Framework of the Canadian Council of Forest Ministers (CCFM) is a science-based framework used to define and measure Canada's progress in SFM. The criteria represent forest values that Canadians want to enhance or sustain, with the indicators identifying scientific factors that can be used to assess the state of the forests and measure progress over time (see Appendix 3 for the list of current CCFM SFM Criteria and Indictors).

The framework was created in 1995 and was most recently updated in 2003 (CCFM 2003). A national status report was prepared in 2005 (CCFM 2006).

For additional information on the CCFM Criteria and Indicators see http://www.ccfm.org/english/coreproducts-criteria_in.asp.

1.3.2 The Practice

In practice, a number of issues may drive adaptation, thus influencing the aspects of the SFM system that should be assessed. Consider the problems or challenges that you identified in Worksheet 1.1 as having prompted this assessment, to aid in defining the scale, boundaries, and elements of the SFM system to be considered in the assessment. Describe the SFM system in enough detail to give all assessment participants a good understanding of the biophysical aspects (i.e., the forest ecosystems) within the defined geographic scale, the benefits and values derived from the forests within this area, and the decision contexts and the stakeholders or interested parties within the defined assessment scope.

Worksheet 1.2 (Describe the SFM system and define the scope of the vulnerability assessment) provides guidance on describing the SFM system of interest and defining the scope of the SFM vulnerability assessment.

HINT

You may want to build a team work plan and a team charter to outline each member's commitments and tasks for the vulnerability assessment. You may also wish to consider a communications plan that defines the key participants and interested parties and how you plan to involve them in the assessment process and communicate to them the progress and results of the assessment.

A basic approach	A local-level, single-driver assessment tends to be the simplest approach. You may wish to constrain the boundaries of your assessment to something at this scale, particularly if you have limited resources and/or a desire to gain some experience in vulnerability assessment and adaptation planning before taking on a more complex and challenging assessment at a broader level.
A comprehensive approach	A more comprehensive approach depends on your unique situation. Scoping the most appropriate SFM area to address your needs, given available resources, is the ideal approach. Also, no matter the scale at which your SFM area is defined, it is essential to pay attention to cross-scale issues and considerations.
Operational considerations	Keeping your decision-making context in mind may help in determining the SFM system for the assessment. Matching your SFM system to the decisions that you wish to inform may help to enhance the uptake of the vulnerability assessment and its relevance to the decision-making process.
Strategic considerations	Is your vulnerability assessment and adaptation planning process being driven by a single issue or vulnerability? Or is there a desire to perform a comprehensive assessment that examines all potential vulnerabilities? Consider these questions as you decide upon the SFM system for the assessment. Having a clear notion of your SFM system will help you to target your assessment and information-gathering process and to more clearly define the interested parties, stakeholder groups, and/or assessment partners. Also, keep in mind that climate change may interact with other drivers of change, such as changes in markets conditions or workforce availability and new technologies.

1.4 Confirm the Scope of the Assessment

1.4.1 The Theory

At this early stage, vulnerability assessments can be complex and time-consuming. They can also be frustrating and unproductive if the scope does not match the resources available, leading to the withdrawal of participants from the climate change adaptation process. One important rule of thumb is to start with the simplest representation of the problem, increasing the complexity only as required (Ohlson et al. 2005).

Scaling an assessment to realistically match the resources available is essential at this early stage of climate change adaptation. Effectively exploring one aspect of the identified problem that leads to proactive adaptation and ongoing learning may be much more desirable than not initiating assessment and adaptation at all. Other aspects of the identified problems and challenges can then be assessed over time as part of an adaptive management approach, keeping in mind that the adaptation process is ideally an ongoing and iterative process (i.e., it is mainstreamed into day-to-day decision making).

A lesson learned from forestry vulnerability assessment case studies (Johnston and Edwards 2013)

Identifying a strong champion of the vulnerability assessment is one key aspect to success.

Achieving buy-in and support from all organizations and interested parties involved in the SFM system of interest is important for the success of the vulnerability assessment. Identifying a strong champion is another key aspect of success (Johnston and Edwards 2013).

1.4.2 The Practice

Worksheet 1.3 (Confirm the scope of the assessment) guides you in examining the resources required to undertake the assessment as defined. If you are unable to secure all of the necessary resources, you may need to prioritize and focus on specific aspects of the problem identified in **Worksheet 1.1**. If the scope changes, a new purpose and outcome statement should be prepared.

It may be necessary to garner further support, both financial and political, to conduct the vulnerability assessment as defined. Creating a short, clear summary of the vulnerability assessment project may be useful for presenting the assessment concepts to decision makers and other interested parties in efforts to gain support.

A basic approach	If you are doing a quick or cursory assessment that involves only in-house resources, focus the scope by identifying and securing those resources that are available in-house, and keep the spatial scale of the assessment small.
A comprehensive approach	Develop an inventory of internal and external resources that is as comprehensive as possible. The scope and complexity of an assessment is often dictated by the resources available, so be as thorough as possible in preparing your inventory.
Operational considerations	Regularly revisit your inventory of available resources. The availability of resources may change over time, so review resource requirements regularly and be on the lookout for opportunities to take advantage of additional resources.
Strategic considerations	If resources are limited, do not be dismayed. Although having more resources may increase the information available to serve as a basis for the assessment, there will remain many irreducible uncertainties related to climate change. Focusing available resources into a "smart" process may pay more dividends than throwing a lot of resources at an ill-conceived process. Resource constraints can help to focus efforts, prioritize activities, and stimulate the development of innovative methods for assessing vulnerability and adaptation options.

Chapter 1 Completion Check-in

Has the assessment team:

- ☐ Understood the reasons for doing an SFM vulnerability assessment?
- ☐ Developed a clear statement of purpose for the assessment and a statement of expected outcomes?
- ☐ Described the spatial extent and forest structure of the area of interest?
- ☐ Described the decision-making scope and actors within the SFM system of interest?
- ☐ Assessed whether the available resources match the purpose and expected outcomes?
- ☐ Confirmed the scope of the assessment?
- ☐ Made an explicit decision to go forward with the vulnerability assessment and adaptation process?

The assessment team may also wish to:

- ☐ Develop a team charter and work plan detailing responsibilities and timelines for individuals and organizations participating in the assessment
- ☐ Develop a communications plan to ensure that decision makers and other interested parties (e.g., stakeholders) are kept informed of the purpose and progress of the assessment

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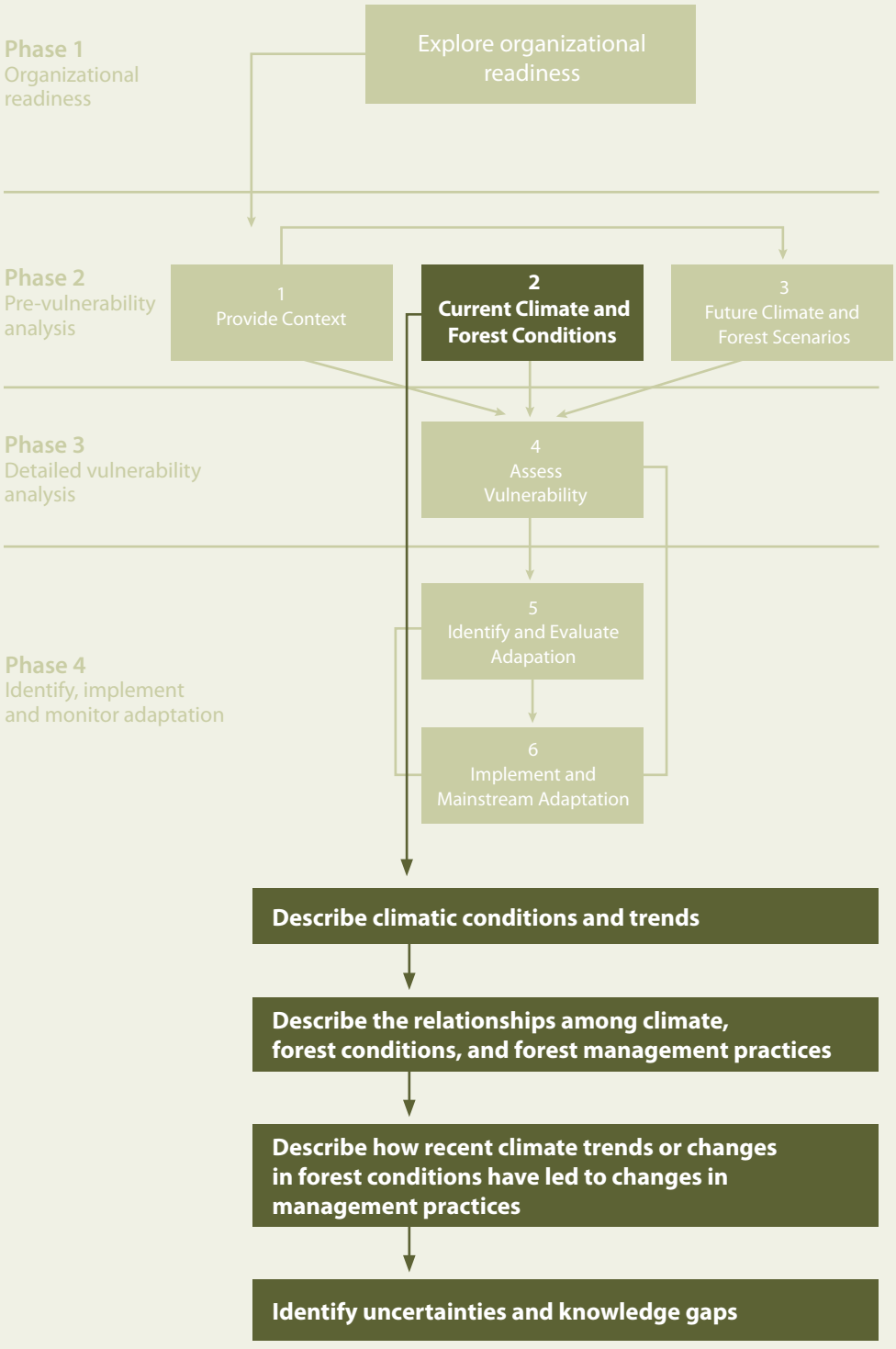
Phase 1
Organizational readiness
Explore organizational readiness
Phase 2
Pre-vulnerability analysis
1
Provide Context
2
Current Climate and Forest Conditions
3
Future Climate and Forest Scenarios
Phase 3
Detailed vulnerability analysis
4
Assess Vulnerability
Phase 4
Identify, implement and monitor adaptation
5
Identify and Evaluate Adapation
6
Implement and Mainstream Adaptation
Describe climatic conditions and trends
Describe the relationships among climate, forest conditions, and forest management practices
Describe how recent climate trends or changes in forest conditions have led to changes in management practices
Identify uncertainties and knowledge gaps

2.1 Overview

This chapter provides guidance on describing and documenting how climate has shaped current forest conditions and management practices in your SFM area. It also provides guidance on documenting any current adaptations to climate change that you may already be practicing. The chapter is structured around four worksheets that are designed to facilitate the gathering of climate information; the identification of relationships among climate, forest conditions, and current forest management policies and practices; and the recording of uncertainties and knowledge gaps:

Worksheet 2.1. Describe climatic conditions and trends

Worksheet 2.2. Describe the relationships among climate, forest conditions, and forest management practices

Worksheet 2.3. Describe how recent climate trends or changes in forest conditions have led to changes in current forest management practices

Worksheet 2.4. Identify uncertainties and knowledge gaps

From the assessment framework…

"Determining and describing how forests are being affected by, and how forest managers have adapted to, current climate, clarifies relationships among climate, forests, and current management."

—Williamson et al. (2012)

Purpose of "describing current climate and forest conditions"	Outcomes
• To document and understand how climate has shaped current forest conditions and management practices • To identify any recent changes in climate trends and variability • To document how current forest management practices have changed as a result of changes in climate	• Description of current climate and forest conditions • Improved understanding of the relationships among climate, forest conditions, and forest management • Identification of any recent changes in climate that have resulted in changes to forest management practices • A list of uncertainties and knowledge gaps

HINT

Understanding current climate and how any recent changes in climate trends or variability have affected your forest management practices can make assessing future vulnerabilities less daunting.

2.2 Describe Climate Normals, Trends, and Variations

2.2.1 The Theory

Across Canada, the climate has already started to change (Lemmen et al. 2008). However, SFM in Canada has, until recently, been based on the assumption that climate in a local area is relatively stable, within a known range of historical variability. As such, changes in climate have not been considered as a major factor affecting long-term decisions (see sidebar **Climate terms**).

The climate measures that are important to document are those that might affect the SFM system. Although measures of annual climate conditions are helpful, the climate across Canada varies with the season, so seasonal measures are also important.

Climate Terms

Weather – The day-to-day and hour-to-hour atmospheric conditions at a given location.

Extreme weather event – An event that is rare within the weather conditions at a particular place.

Climate – The "average weather" described in terms of the mean and variability of features such as temperature, precipitation, and wind over a period ranging from months to thousands or millions of years. The usual period for describing climate in Canada is 30 years.

Climate variability – The highs and lows of climate conditions over a long period.

Climate change – A statistically significant change in either the average (mean) state of the climate or in its variability, measured over an extended period, usually at least 30 years.

Climate trends – Data providing a picture of how much change has occurred in the past, for example, over a period of 50 to 100 years. Climate trends are derived from statistical analysis of historical climate data.

HINT

It can also be helpful to collect climate measures for recent extreme weather events (e.g., heavy rain or snow, drought, windstorm). Recent global analyses by Field et al. (2012) provide accepted methodologies for describing the frequency and severity of these events.

2.2.2 The Practice

In most places in Canada, the climate has changed during recent decades. A national assessment of climate change impacts reported by Lemmen et al. (2008) provided national- and regional-scale information about historical climate changes, known as "trends" (see section for national information in Information Resources box, below). More detailed regional or local information may be available for specific areas from national or regional climate information centers (see sections for western and eastern Canada in Information Resources box, below).

The climate information that has been collected by the Meteorological Service of Canada at weather stations across the country has been analyzed to generate "climate normals" for these station locations. Climate normals describe the average conditions over a 30-year period. Normals are available for three overlapping 30-year periods from 1961–1990 up to the most recent period of 1981–2010 (1961–1990, 1971–2000, 1981–2010). Comparing selected climate variables for the three climate normal periods may help to illustrate changes in climate.

In addition, detailed historical climate data can be downloaded and analyzed for individual stations across Canada. Graphs of annual mean temperature and precipitation are helpful to illustrate local climate variability and trends. Analysis of these data should be conducted with the advice of a climate specialist.

Observations by individuals who have spent a lot of time (e.g., several decades) in your SFM area are also valuable for describing changes in local climate conditions or extreme weather-related events (see sidebar **How important are local observations?**). These individuals are likely to have observed effects of climate change or extreme weather events that may not be obvious from analysis of climate data. Human memory is not always reliable, however, so climate data should be sought to corroborate any changes that are thought to have created significant ecological, economic, cultural, or social impacts. This sharing and linking of local, traditional, and scientific knowledge can foster ongoing exchanges, facilitate continuous learning, and provide momentum for effective and practical adaptation responses (Gray 2012).

How Important are Local Observations?

People who work day-to-day in climate-sensitive resource industries (e.g., forestry or agriculture) tend to have an intimate understanding of their local surroundings and of how the current local climate affects their respective management systems. They often understand the local climate and have some sense of their vulnerability to climate and climate variability.

For example, forest managers will likely know when the most recent severe fire years occurred and will recall what combination of high-temperature days and periods without rainfall contributed to them. When such relationships are established, it becomes easier to answer questions such as, What would happen if conditions become hotter and drier? What would happen if the hot and dry conditions that contributed to a severe fire year become "normal" conditions at some point in the future?

Long-time residents from the SFM area who spend much of their time on the land (e.g., hunters, backcountry recreationists, First Nations people) can also provide valuable observations of climate and environmental changes. Efforts to combine these observations with climate data through events such as workshops can often lead to rewarding discussions between local residents, forest managers, and researchers.

Worksheet 2.1 (Describe climatic conditions and trends) provides a format for recording climate trends, climate normals, and sources of information about climate variability.

A basic approach	At the Government of Canada climate website (http://climate.weather.gc.ca/climate_normals/index_e.html), find climate data for at least one location that is near your SFM system of interest. Interpolated climate data for any geographic location in Canada can also be downloaded from the Canadian Forest Service's regional, national, and international climate modeling website (http://cfs.nrcan.gc.ca/projects/3/6) (see Information resources box below).
A comprehensive approach	Include on the team a climate scientist who can analyze historical climate data and prepare future projections. Analysis of data from local climate stations can provide information about change and variability for a number of relevant climate measures.
Operational considerations	Examples of climate measures that are important for day-to-day operations include changes in the number of frost-free days, the number of high and extreme fire hazard days, and the winter access season.

Information resources	**National** • The Government of Canada's Climate website provides historical hourly, daily, and monthly weather data as well as 30-year climate normals for many weather stations across Canada (http://www.climate.weather.gc.ca). • Natural Resources Canada, Canadian Forest Service: regional, national, and international climate modeling (http://cfs.nrcan.gc.ca/projects/3/6), specifically the web application for obtaining climate estimates for your location (http://gmaps.nrcan.gc.ca/cl_p/climatepoints.php). **Western Canada** • ClimateWNA (Western North America) is a program to generate high resolution climate data for western North America. See http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/#ClimateWNA for details. **Eastern Canada** • Ouranos is a consortium that brings together 400 scientists and professionals from different disciplines. Based in Quebec, Ouranos focuses on two main themes: "climate sciences and vulnerabilities" and "impacts and adaptation" (http://www.ouranos.ca).

2.3 Determine Relationship of Climate to Current Forest Conditions and Forest Ecosystem Processes

From the assessment framework…

"Assessing current climate and forest conditions is an important step in the vulnerability assessment framework because it allows managers to describe what they know with some certainty."

—Williamson et al. (2012)

2.3.1 The Theory

Climate is a fundamental driver of forest ecosystems and therefore influences many forest management activities. Understanding how climate influences current forest conditions (e.g., species composition and productivity) and ecosystem processes (e.g., fire and insect disturbances, regeneration, nutrient cycling) is critical to forest management planning and operations (see "Case study – Canadian Forest Service Forest Change Initiative"). Exploring these relationships at this stage of the vulnerability assessment can help create an understanding about why current forest management practices have been established or current policies instituted and how these policies and practices may have changed in response to recent changes in climate and weather. Additionally, highlighting key linkages between climate and forest conditions can assist in the development of future forest impact scenarios (chapter 3).

2.3.2 The Practice

Take a close look at your current forest management policies and practices to see how climate has influenced the decisions made during implementation of these policies and practices (e.g., growth and yield projections, seasonal operation plans, silvicultural operations). You may also draw on the knowledge of forest practitioners, local residents, or academic researchers to help identify the relationships of climate to current forest conditions and processes. Use **Worksheet 2.2 (Describe the relationships among climate, forest conditions, and forest management practices)** to list the relationships of climate to forest conditions and of forest conditions to management practices (see Appendix 4 for examples of forest conditions and ecosystems processes to consider).

Case Study – Canadian Forest Service "Forest Change" initiative	Forest Change is a new Canadian Forest Service initiative for enhancing forest-sector competitiveness in a changing climate. The initiative has three main deliverables: • a tracking system to report indicators of climate change impacts on forests and the forest sector in Canada • an adaptation toolkit for SFM under a changing climate • an integrated assessment of the implications of climate change for Canada's forests and forest sector, to inform policies and investment by the public and private sectors. These deliverables aim to generate the most current knowledge about climate change impacts on Canada's forests and to make this knowledge available to practitioners in usable and accessible formats. Source: Nelson (2012).

2.4 Identify Changes to Forest Management Practices Due to Recent Changes in Climate

2.4.1 The Theory

SFM systems in Canada are inherently adaptable (Williamson et al. 2009). The forest sector has adapted to recent changes in markets by innovating new products for market, increasing efficiency of operations, and developing new forest management practices in response to new societal values (e.g., biodiversity). Given this inherent adaptability of forest management systems in Canada, it is likely they have already adapted to any recent changes in the climate (i.e., over the past decade or two) and any impacts these changes may have had on forests or forest operations, and it may be helpful to identify any such adaptations. For example, have forest policies or practices been adapted in response to outbreaks of mountain pine beetle or other pests associated with changes in climate? Have any changes been made to duration of winter harvest because of changes in frozen soil conditions or lake ice-in conditions (i.e., for winter roads)? Have there been any changes to the wildfire season (e.g., earlier start dates or later end dates) that have increased the length of time that wildfire crews are required on active duty? See "Case study –'Climate change and Canada's Forests'" for additional ways climate change is already affecting Canada's forests.

2.4.2 The Practice

Examine your current SFM policies and practices and see if you can identify any changes (i.e., adaptations) that have been made as a result of recent changes to climate or climate variability. This activity can be done by a smaller assessment team or by engaging a broader audience in a workshop setting to gather tacit knowledge of changes that might not be well documented. You may want to start by identifying a recent unanticipated event (e.g., a large wildfire or insect outbreak, an extreme precipitation event, a market downturn) and then describing how that event affected your ability to manage forests sustainably and what changes to management practices or policies were made to account for the impacts of this event.

Record these observations in **Worksheet 2.3 (Describe how recent climate trends or changes in forest conditions have led to changes in forest management practices)**.

Case Study – "Climate Change and Canada's Forests"	This document, a compilation of contributions from the authors of the forestry sections in the Canadian national assessment (Lemmen et al. 2008) states that "Climate change is already affecting Canada's forests." They list the following recent changes in Canada's forests that are related in some way to recent climate change: • longer growing seasons, earlier bud burst and flowering in some species, and upward expansion of treelines to encroach upon alpine ecosystems • nationwide drought in 2001–2003, which was unprecedented in terms of its duration, geographic extent, and (in some locations) severity and which resulted in aspen dieback in some parts of the prairies and devastating fire seasons in British Columbia and Yukon • more frequent occurrence of extreme wildfire seasons, with severe burning conditions at times of the year when they have not previously occurred • epidemic of mountain pine beetle in western Canada, resulting from large areas of mature lodgepole pine and an unprecedented number of abnormally warm winters in consecutive years • the largest outbreak of spruce bark beetle ever recorded in Yukon • epidemic of Dothistroma needle blight in young and mature lodgepole pine in northwest British Columbia. These changes illustrate that impacts are often the result of interacting factors (e.g., mountain pine beetle epidemic due to large areas of mature pine and warm winters). As well, climate change has the potential to cause multiple, interacting impacts that occur simultaneously. For example, changes in the risks of drought, fire, insect and disease disturbance, and extreme weather, as well as changes in growth and yield, may all occur at the same time. As a result, foresters must be able to recognize, understand, and adapt to the cumulative impacts of climate change. Source: Williamson et al. (2009). For the full report go to: http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/29616.pdf.

2.5 Key Uncertainties and Knowledge Gaps

2.5.1 The Theory

Climate change is characterized by substantial uncertainty. You will likely encounter a number of knowledge gaps and uncertainties (e.g., concerning the relationship between forest conditions and climate) while completing the previous worksheets on climate and forest conditions. Key knowledge gaps and uncertainties are often a barrier to successful adaptation, as they can cause the vulnerability assessment process to stall or stop. The point of recording them here is simply to acknowledge their existence. This list will be a great starting point to adaptation option planning (chapter 5).

2.5.2. The Practice

Use **Worksheet 2.4 (Identify uncertainties and knowledge gaps)** to record any uncertainties and knowledge gaps that arise as you work through the vulnerability assessment and adaptation planning process. This worksheet can be used as a "parking lot" for issues and ideas that could be relevant at later stages in the assessment process.

The point is to record them here for potential use when you are identifying adaptation options (chapter 5). At this stage of the process, don't dwell on these uncertainties; simply acknowledge that they exist and move on. Later in the process, you may want to refer back to this list as a starting point for developing adaptation options, since increasing awareness and addressing knowledge gaps are two possible options for adapting to climate change.

Chapter 2 Completion Check-in

Has the assessment team:

- ☐ Gathered information and data on climate and forest conditions and trends?
- ☐ Developed an understanding of how climate has shaped current forests and forest management practices?
- ☐ Identified any recent changes or trends in climate and the effects these changes have had on current forest management practices?
- ☐ Started a list of key uncertainties and knowledge gaps related to climate and forest conditions?

2.6 Literature Cited

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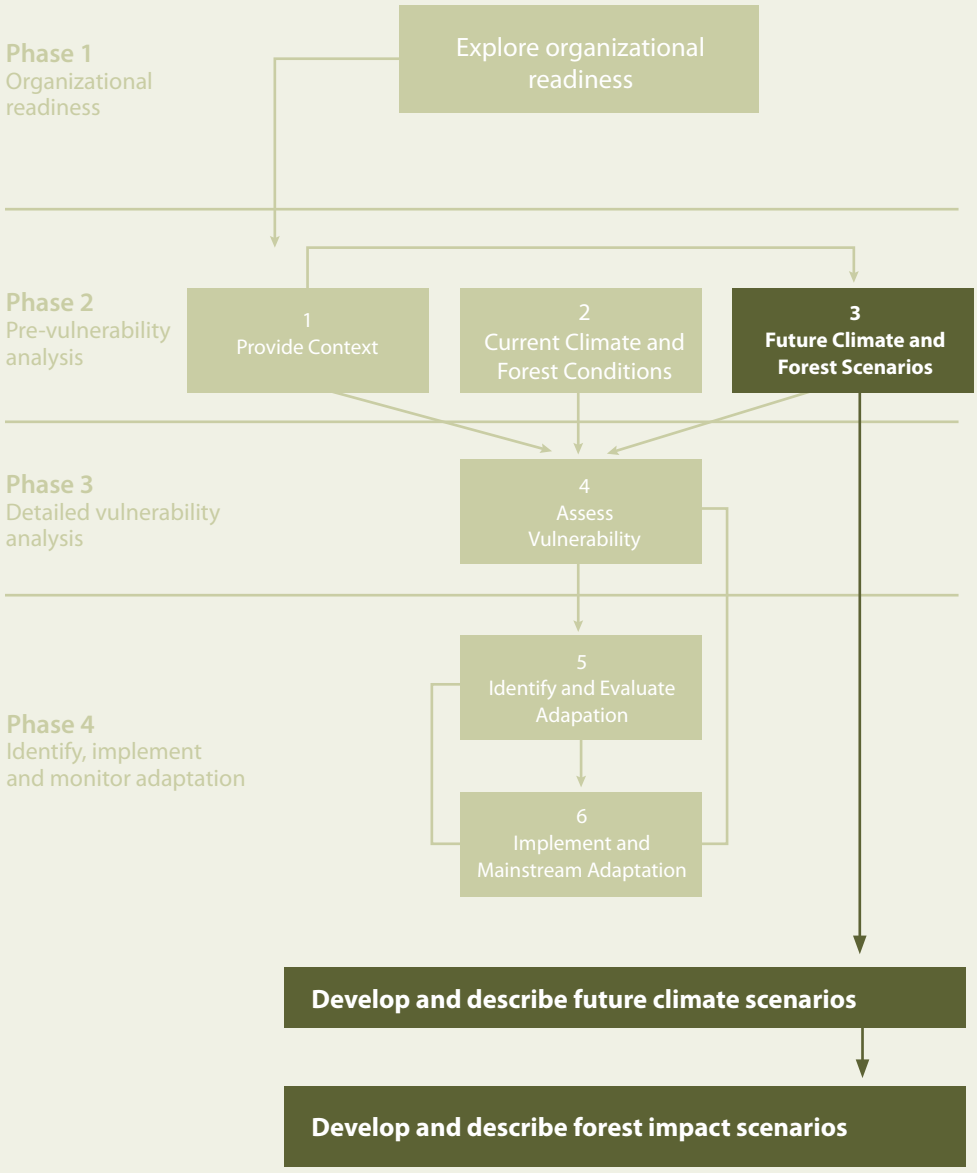
CHAPTER 3 FUTURE CLIMATE AND FOREST IMPACT SCENARIOS



Before you begin:

It is recommended that you read *Adapting sustainable forest management to climate change: scenarios for vulnerability assessment* by Price and Isaac (2012), which provides the background and theory for this chapter.

3.1 Overview

This chapter provides guidance on developing and describing future climate and forest impact scenarios. It is structured around two worksheets that are designed to characterize a range of possible future climate scenarios and associated forest impact scenarios:

Worksheet 3.1. Develop and describe future climate scenarios

Worksheet 3.2. Develop and describe forest impact scenarios

Purpose of "developing scenarios"	Outcomes
Develop and characterize scenarios that encompass the range of potential future climate and the related impacts on forest ecosystems	• Selection and description of climate change scenarios • Creation of forest impact scenarios • Updated list of uncertainties and knowledge gaps related to future climate change and forest impact scenarios

From the assessment framework…

"Forest management is inherently a long-term undertaking, and assessing SFM vulnerability therefore requires estimation of the potential future positive and negative impacts of climate change on forests. However, the potential impacts of future climate change on forests are uncertain. The third component of the vulnerability assessment framework therefore involves the development of scenarios of future climate and forest conditions."

—Williamson et al. (2012)

Scenarios for an Uncertain Future

Many aspects of the SFM system are weather-sensitive, and therefore SFM vulnerability and adaptation assessment should be based on expectations about what the future effects of climate change may be on the natural biophysical and human elements of the SFM system (see definitions in section 1.3.1). Weather and climate conditions affect growing conditions and tree, stand, and landscape processes, as well as infrastructure stability (e.g., roads and bridges) and human activities. Climatic change will modify future weather conditions and therefore can be expected to modify forest structure, species distribution, productivity, and disturbance patterns. Climate change will also affect physical attributes of the landscape such as permafrost, soil stability, and water regimes. Such modifications have important implications for the ability to achieve SFM objectives in the long run and for decision making today.

The Need for Scenarios

Future climate change and the effects that such change may have on forest ecosystems are highly uncertain, in part because of limited, though ever-growing, knowledge of climate systems and forest ecosystems, but also because of the impossibility of predicting future human behaviors and values. In this situation of uncertainty, one option is to create a single prediction or forecast for the future (e.g., "this is what will happen"), using information generated by models or based on scientific knowledge and inference, and then to use this prediction to make decisions. Exclusively relying on this option, however, has a number of limitations, including the fact that model results are subject to assumptions and inherent uncertainty, especially over the time scales relevant to forest management planning. In fact, it is not possible currently, and may never be possible, to create a single accurate prediction of climate and SFM impacts for decades into the future, especially at time scales relevant to operational decision making.

Inability to predict future impacts with confidence can be a significant barrier to vulnerability and adaptation assessment. An alternative approach is to develop a number of plausible scenarios (e.g., "this is what might happen") describing a range of possible futures and to use these scenarios as a foundation to guide the exploration of climate change impacts and the implications of adaptation decisions (see "Case study – Forest Futures project").

Scenarios Defined

The creation of scenarios is a well-developed technique for planning under uncertainty (see sidebar **The Power of Scenarios in Climate Change Adaptation**). A scenario is not a single prediction or forecast, which would imply that a particular outcome is likely to occur. Rather, a scenario represents one of any number of possible futures. As such, scenarios are constructed stories about conditions that could occur in the future. It is essential that scenarios be logical, internally consistent, and believable portrayals of possible future conditions.

Berkhout et al. (2002) described approaches for scenario development in the context of climate change assessment with four underlying principles for scenario analysis:

(1) recognizing that past trends do not provide a basis for projecting the future

(2) accepting that the future cannot be predicted with certainty but that "exploring" possible futures can inform decision making

(3) accepting uncertainty and recognizing that any one of a number of different futures could occur

(4) acknowledging that local knowledge is fundamentally important for successful scenario development.

The Power of Scenarios in Climate Change Adaptation

By illustrating possible future settings, scenarios can be used as a tool for long-term planning and decision making in the present. They shift the analytical focus away from estimating the most likely path, which is unknown in a changing climate, toward determining the range of consequences of potential changes and the most appropriate adaptations across these different situations (i.e., robust adaptation options). For this reason, Berkhout et al. (2002) referred to scenarios as "learning machines." A scenario does not imply "This is what will happen, and this is what you should do about it." Rather, a set of well-constructed scenarios indicate "This is what could happen in the future" and ask the question "What would you do about it now if this were to happen?"

Case Study – Forest Futures project	A recent example of an exercise involving integrated scenario development in forestry is the Forest Futures project completed by the Sustainable Forest Management Network, led by Dr. Peter Duinker (Dalhousie University). The Forest Futures project used a structured process to develop scenarios for "plausible" futures across a range of uncertain conditions, including climate change, and to explore the implications of those scenarios for the many benefits that Canadians derive from forested lands. Central to the project were a series of national and regional workshops used to identify the drivers of future change, to define plausible scenarios, and to analyze those futures from various perspectives. The process was designed to involve a large number of people from many forest stakeholder groups and to integrate their expertise and insight into the project's outcomes. The overall objective of the Forest Futures project was to produce a set of documents that inform the scenarios and analyses, which can in turn be used to inform decision making by industry, governments, and other groups interested in Canadian forests. The products of the Forest Futures project—scenario descriptions, research papers describing drivers, workshop proceedings, and analysis documents—are available online at: http://www.sfmn.ales.ualberta.ca/en/Research/ForestFutures/ForestFuturesDocuments.aspx.

3.2 Develop and Describe Future Climate Scenarios

3.2.1 The Theory

Climate change scenarios are derived from climate models, which are in turn driven by projections of changes in atmospheric greenhouse gases (primarily carbon dioxide) resulting from alternative scenarios of future socioeconomic development. There are many plausible future climate scenarios because there are a number of different climate models and many possible scenarios of socioeconomic development.

The resolution of most global climate models is too coarse for use in vulnerability assessments of SFM. Methods such as downscaling can be used to produce climate scenarios at a scale more useful for assessing SFM vulnerability. Price et al. (2011) presented a series of high-resolution interpolations of climate scenarios for Canada. Many regional climate centers (e.g., Pacific Climate Impacts Consortium, Ouranos) are excellent sources of climate information and scenarios. Additionally, Price and Isaac (2012) have presented a summary of scenario development processes for SFM.

From the assessment framework…

"The first step in developing these forest impact scenarios ... is to select climate scenarios representing a range of plausible climate futures for the region of interest. Each climate scenario necessarily includes projections of selected climatic variables that affect forest ecosystems."

—Williamson et al. (2012)

3.2.2 The Practice

The first step in developing scenarios is to decide on a small number of climate change scenarios (e.g., two to four) representing a range of plausible climate futures for your SFM system. There are several ways to create climate change scenarios for the SFM system:

- Use "off-the-shelf" climate projections for the area encompassing the SFM unit, which are available from research centers such as the Pacific Climate Impacts Consortium and Ouranos. The Canadian Forest Service and some provincial and territorial forest services have significant resources available to project climate changes and impacts on forests (see the description of the Canadian Forest Service's Forest Change initiative, in section 2.3.2).
- Involve analysts who can work with the available datasets of climate change projections to create information for the SFM area.
- Include climate experts on the assessment project team to explore and expand on the available data.

Efforts should be made to align the timeframes for reporting within the climate change scenarios with the timeframes for assessing SFM impacts. The following two approaches have been used in practice:

(1) Assess a short-term and a long-term timeframe (e.g., 20 years, using the climate change results for the 2020s, and the end of the century, using results for the 2080s).

(2) Assess at one midterm timeframe, often the 2050s (i.e., 2041–2070), which is consistent with the timescale used for reporting midrange climate change projection results.

Confidence and Uncertainty

Uncertainties have always been a factor in forest management decisions in Canada, in part because of the long lifespan of the country's common tree species. The pace and scale of climate change simply increases the scope and implications of these uncertainties.

The Intergovernmental Panel on Climate Change (Parry et al. 2007) defined uncertainty as "an expression of the degree to which a value (e.g., the future state of the climate system) is unknown." Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty is a reality in vulnerability assessments, given that no one knows exactly how the climate may change or how ecological, infrastructure, or human systems will respond to change in a particular location (Glick et al. 2011).

Vulnerability assessments aim to understand and manage, rather than overcome, as much of the full range of uncertainty related to climate change as is practicable. At the end of the assessment, uncertainty may appear to have expanded, but this impression may relate largely to a better understanding of the underlying factors (Parry et al. 2007). In the case of vulnerability assessment of SFM, it is likely that the nature of the SFM system—its components and the types of interactions among them—will be better understood.

Explicitly characterizing the level of confidence in a specific information source and in assessment outcomes clarifies where uncertainties are greatest. However, when it comes to future climate change scenarios, remember that "all models are wrong" and that the "outlier" may be the most accurate.

Despite uncertainties about the timing and magnitude of climate change, several authors (Lemmen et al. 2008; Glick et al. 2011; Peterson et al. 2011) have concluded that sufficient information exists to begin to adapt—we need not be paralyzed by lingering uncertainties. Opportunity now exists to explore these uncertainties in a structured manner, such as suggested within this guidebook, and to proactively mainstream adaptation into forest management plans, practices, and institutions.

For more information on uncertainty and vulnerability assessment, see chapter V, "Addressing uncertainty in vulnerability assessments," in Glick et al. (2011).

Worksheet 3.1 (Develop and describe future climate scenarios) provides a template for describing important climate conditions for three scenarios. You might select more scenarios, but as a general rule the analysis should have a minimum of three scenarios, one of which might be current climate (as a "status quo" scenario).

It is suggested that scenarios be described by simple names, such as low, moderate, and high change to represent an exploration of differences in the rate of change (e.g., the change in mean annual temperature). You may choose to explore differences in combinations of temperature and precipitation change (such as warmer and wetter, warmer and drier) or combinations reflecting different rates of change in temperature and precipitation (such as faster warming over time; slower warming over time).

A basic approach	Use the practitioner and local knowledge existing within your assessment team to describe a range of possible climate scenarios for the future. You may want to focus on the same change in climate (e.g., warmer and drier) over time, with variation in the degree or rate of change over time (e.g., minor change, moderate change, large change). Alternatively, you may want to look at a range of potential changes in climate (e.g., warmer and drier, warmer and wetter). The scenarios you choose should be relevant to your local or regional area. The idea is not to be predictive in your estimates of change but to describe a range of future climates. You will assess the sensitivity of SFM objectives to these changes in chapter 4.
A comprehensive approach	Include a climate expert on the project team, who will prepare locally focused climate change projections and information. Expand the climate variables in the projections beyond temperature and precipitation to include factors that participants identify as being important to SFM, such as wind speed, frequency of freeze–thaw cycles, changes in seasonal temperature and precipitation, fire weather index (FWI[a]) values, and climate moisture index (CMI[b]).
Operational considerations	Seasonal conditions are crucial to operational decisions, making it important to report seasonal as well as annual projections. If possible, include in the climate scenarios seasonal climate variables that affect operational decisions.
Strategic considerations	It is essential to encourage reasonable expectations about the certainty of future climate change projections. Some participants may expect to receive detailed projections for localized situations (e.g., a community forest area) and others may be discouraged by what they perceive as large uncertainties in the projections. In either case, it is important to remind participants that the purpose of the assessment is to explore what could happen if any of the projected range of climates were to occur in the future.

[a]For information on the Fire Weather Index (FWI) see http://cwfis.cfs.nrcan.gc.ca/background/summary/fwi. Many provincial and territorial departments responsible for wildfires maintain FWI data records.

[b]The Climate Moisture Index (CMI) was originally described by Hogg (1994, 1997) as a method for assessing differences in moisture regimes using simple climate data (temperature and precipitation).

3.3 Develop and Describe Forest Impact Scenarios

3.3.1 The Theory

Forest ecosystems are sensitive to climate and will be affected, both directly and indirectly, by changes in temperature, precipitation, and frequency of extreme weather and weather-related events (e.g., droughts, floods, wildfires, pest outbreaks, tree diseases). Potential forest impacts will depend on the extent of climate change (i.e., exposure) and the sensitivity of the forest to such change. Additionally, forest ecosystems are complex and consist of many interactions and feedbacks that make it difficult to predict the impacts of future climate change, particularly given the uncertainty in the rate and amount of future climate change. One approach to dealing with this uncertainty is to develop a range of potential forest impacts based on multiple future climate scenarios (see sidebar **Confidence and Uncertainty**).

Williamson et al. (2008) summarized the potential impacts of climate change on Canada's forests and forest ecosystems at a broad scale. However, for many SFM vulnerability assessments, a finer-scale analysis of climate change impacts on forests may be required. The scientific literature is rich with information about the impacts of climate change on forest ecosystems. Also, numerous modeling approaches and tools are available that can be used to estimate climate change impacts on forests.

Many of the vulnerability assessment case studies highlighted by Johnston and Edwards (2013) used both detailed modeling efforts and forest impact scenarios generated by local forest practitioners to develop a range of potential impacts to different future climates. Halofsky et al. (2011) and Swanston et al. (2011) have also provided relevant examples of how to develop forest ecosystem impact scenarios for use in vulnerability assessment.

From the assessment framework…

"The second step in developing forest impact scenarios is to evaluate the response of forests and forest ecosystems to each climate scenario (i.e., the climate change impacts). This response (i.e., the effects on the forest) will be a function of the magnitude of the change in climate under a particular scenario (i.e., exposure) combined with the degree to which the forests are able to tolerate or adapt to the degree of change in climate under a particular scenario (i.e., sensitivity)."

—Williamson et al. (2012)

3.3.2. The Practice

Use **Worksheet 3.2 (Develop and describe forest impact scenarios)** to record the range of potential impacts on forests, given the climate scenarios developed in **Worksheet 3.1 (Develop and describe future climate scenarios)**.

Potential forest impacts will depend on the extent of climate change (i.e., exposure) and the sensitivity of the forest that is affected by climate change. Williamson et al. (2008, Figure 2) outlined a method to map the potential impacts of climate change on forests. Additionally, the Canadian Forest Service's Forest Change initiative (described in section 2.3.2) is producing knowledge products and tools related to forest impacts from climate change across Canada. These knowledge products and tools are being developed with forest practitioners in mind, with the goal of assisting them in developing forest impact scenarios. Many provincial forest services, climate consortiums (e.g., Pacific Climate Impacts Consortium, Ouranos, ClimateWNA), and universities also have forest impact modeling resources available for forest practitioners to use when considering climate change. Use these products in conjunction with practitioner knowledge and expert opinion to develop scenarios of forest impacts. You may also wish to consult or partner with academic researchers to investigate potential climate change–related forest impacts.

Several technical aspects should be considered in the creation of forest impact scenarios. The amount of scientific analysis and modeling required will often depend on how much information (data) exists for the SFM area of interest, the availability of resources to model forest ecosystems and their responses to changes in climate, and the degree of "evidence" required for making decisions. Keep in mind that scenarios are not predictions, but possible futures; therefore, possible future forest impact scenarios can be developed simply through discussion with colleagues, detailed models, or a combination of the two.

The forest impact scenarios developed here will be used in the next step of the assessment to assess the consequences of these impacts on the ability to achieve SFM objectives.

A basic approach	Use the practitioner and local knowledge existing within your assessment team to describe a range of possible forest impact scenarios based on the climate scenarios developed in chapter 2. The scenarios you choose should be relevant to your local or regional area. The idea is not to be predictive in your estimates of change but rather to describe a range of possible futures.
A comprehensive approach	A more comprehensive approach would be to include on the vulnerability assessment team a number of forest resource and modeling experts who can examine a range of potential climate change impacts on the forests within the SFM area of interest and beyond. The use of multiple forest impact models combined with tacit or expert knowledge is a useful method for exploring potential future forest conditions.
Operational considerations	The impacts of climate change on forests may have implications for forestry operations. Such implications may include reduced access to forest resources (e.g., shorter winter road conditions), increased salvage operations, reduced timber or fiber quality for mills, or reduced tree-regeneration success. Consider forest planning, harvesting, and regeneration practices when developing forest impact scenarios.
Strategic considerations	Keep in mind that no model or expert can accurately predict the future climate and forest conditions in that climate. Exploring a range of possible futures is a method for developing management options that are robust across a range of future forest conditions. Changes to forests and forest conditions in the future may present new opportunities for the SFM system of interest. It is therefore important to consider potential positive impacts of climate change as well.

Chapter 3 Completion Check-in

Has the assessment team:

- ☐ Selected and described future climate scenarios?
- ☐ Created forest impact scenarios and an overall forest impact ranking for each scenario?
- ☐ Added to the list of uncertainties and knowledge gaps?
- ☐ Documented all information sources?

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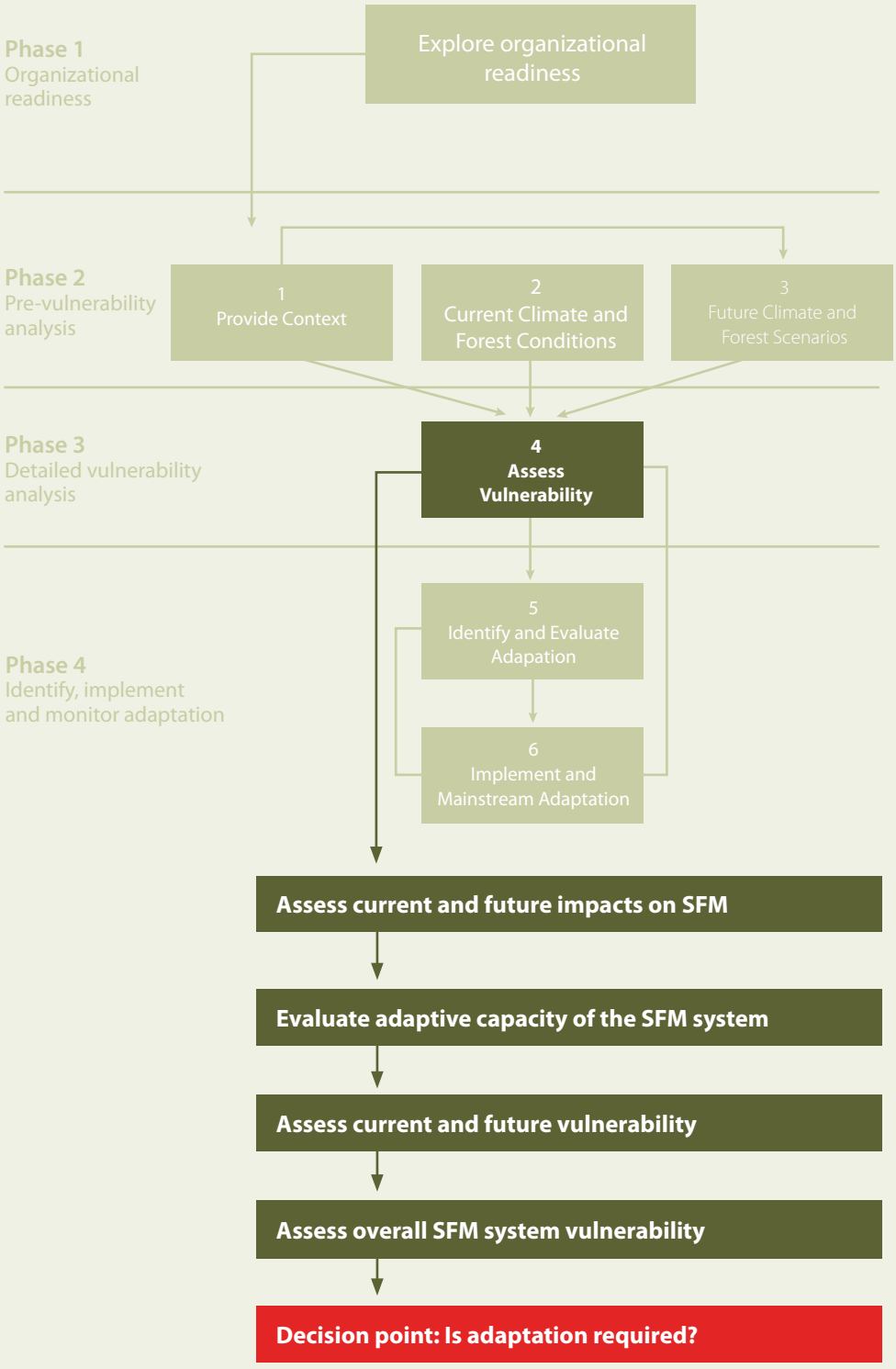


Before you begin:

It will be helpful to revisit the general assessment process and definitions of terms used in vulnerability assessments; see the sidebar **SFM Climate Change Vulnerability Assessment**.

Also, it is recommended that you read Williamson and Isaac (2013), which provides additional background and theory for the adaptive capacity section of this chapter.

4.1 Overview

From the assessment framework…

"The first part of assessing the vulnerability of SFM to current and future climate is to consider how the analysis of current climate and forest conditions ... and the forest impact scenarios ... might affect each of the SFM criteria [and objectives]. The impacts on SFM criteria [and objectives] should be assessed for current climate and for each of the future climate and forest impact scenarios... The second part of assessing SFM vulnerability is to determine the current adaptive capacity of the forest management organizations of interest or the SFM system."

—Williamson et al. (2012)

This chapter provides guidance on evaluating and documenting SFM vulnerability to current climate (and climate variability) and the range of future climate change scenarios. Vulnerability is "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (Parry et al. 2007). This chapter is structured around five worksheets that are designed to facilitate a detailed assessment of both current and future vulnerability of the SFM system:

Worksheet 4.1. Assess current and future impacts on SFM

Worksheet 4.2. Evaluate adaptive capacity of the SFM system

Worksheet 4.3. Assess current and future vulnerability

Worksheet 4.4. Assess overall SFM system vulnerability

Worksheet 4.5. Decision point: Is adaptation required?

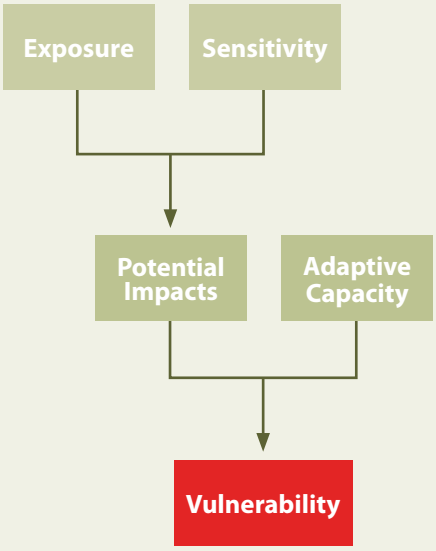
Purpose of "assessing vulnerability"	Outcomes
To evaluate and document vulnerability to current climate conditions and a range of future forest impact scenarios	• Description of the current impacts and the range of potential future forest impacts on achievement of SFM objectives • Improved understanding of the degree to which the biophysical and human elements of your SFM system may be susceptible to, or unable to cope with, potential future effects of climate change • Improved understanding and updated list of the uncertainties and knowledge gaps related to vulnerability of the SFM system to future climate

4.2 Assess Impacts on SFM

4.2.1 The Theory

Impacts on forest conditions and processes due to climate change will likely affect forest managers' abilities to achieve SFM objectives as currently defined (Ogden and Innes 2007). Understanding how SFM objectives might be affected by these changes is critical in assessing the vulnerability of the objectives to climate change. Therefore, the ability of the SFM system to adapt to current and potential climate change impacts should be assessed.

SFM Climate Change Vulnerability Assessment



Definitions

Exposure – The degree to which the SFM system is exposed to significant climatic variations, and the nature of that exposure, including both physical climate changes (e.g., temperature and precipitation) and resulting climate conditions (e.g., droughts, altered fire regimes, freeze–thaw cycles).

Sensitivity – The degree to which all elements of the SFM system are affected, either adversely or beneficially, by climate-related stimuli. Sensitivity may depend on innate physiological or biological variables, physical or ecological factors, or the existence and extent of other stressors (e.g., habitat fragmentation or economic downturn).

Potential impacts – The effects of climate change on the ability to achieve SFM objectives.

Adaptive capacity – The ability of the human elements of the SFM system to adjust to climate change (including climate variability and extremes) to moderate potential effects, to take advantage of opportunities, or to cope with the consequences.

Vulnerability – The degree to which the SFM system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes, resulting in challenges to achieving SFM objectives.

4.2.2 The Practice

The ability to achieve SFM objectives in the future will be affected by the projected impacts of climate change on forest ecosystems. Using the forest impact scenarios developed using **Worksheet 3.2 (Develop and describe forest impact scenarios)** and the best available information (studies, expert judgments, datasets, model outputs, etc.), assess the expected impact of climate and climate change on the ability to achieve SFM objectives. Record your assessments in **Worksheet 4.1 (Assess current and future impacts on SFM)**. Impacts on the SFM objectives will depend on the degree of projected forest change and the sensitivity of the objectives to this change (e.g., the ability to maintain rare habitat on a land base is quite sensitive to changes in forest conditions resulting from climate change).

A basic approach	Brainstorm with your colleagues to complete the worksheets. If possible, have a forestry climate change specialist review your findings.
A comprehensive approach	For each SFM objective, or for logical groupings of objectives (e.g., biological diversity and ecosystem function and productivity), organize focus groups of scientists, technical specialists, practitioners, and policy specialists with expertise related to the objective. Facilitate a workshop with each group to complete the worksheet, based largely on the findings in **Worksheet 3.2 (Develop and describe forest impact scenarios)**. Summarize the findings for review by all participants, particularly those who will be responsible for future decision making and/or implementation.
Operational considerations	Involve forest practitioners in the assessment process to gain an "on-the-ground" perspective about how changes in climate and forest conditions may affect the ability to achieve SFM objectives.
Strategic considerations	When assessing climate change impacts, it is essential to consider nonclimatic factors, such as markets, jobs, and societal values. These are often strategic-scale factors that should be brought into the assessment. Refer to the driver papers from the Future Forests Project (http://www.sfmn.ales.ualberta.ca/en/Research/ForestFutures/ForestFuturesDocuments.aspx) for factors that you might consider in your assessment.

Climate Change Adaptation and Adaptive Capacity

In a climate change vulnerability assessment, adaptive capacity and adaptation are not equivalent.

Adaptation describes the action taken to reduce negative impacts related to climate change and to increase the magnitude and likelihood of positive impacts (e.g., research and training to learn more about climate change).

Adaptive capacity is the condition of the system being assessed (e.g., low awareness of climate change or limited financial resources).

4.3 Evaluate Adaptive Capacity of the SFM System

4.3.1 The Theory

Definition of Adaptive Capacity

Adaptive capacity has been 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" (Parry et al. 2007) (see sidebar **Climate change adaptation and adaptive capacity**). Adaptive capacity can moderate impacts to reduce the vulnerability of a system to climate change.

Adaptive capacity is a crucial element of climate change vulnerability assessment. A system with high adaptive capacity can identify adaptation requirements and implement adaptation actions to reduce its vulnerability to climate change and to nonclimatic stressors and to take action on opportunities.

Assessment of Adaptive Capacity

Assessment of adaptive capacity remains one of the more challenging aspects of vulnerability analysis. The measurement and analysis of adaptive capacity is a relatively new and evolving area of study in general and a new area of consideration in forestry-related assessments. The relevance of "adaptive capacity" in the day-to-day operations of Canadian SFM systems is increasing, in part because management environments are becoming more complex, uncertainty is increasing, and the pace of changes

affecting forest management seems to be rising (see Case Study – "National assessment of adaptive capacity and sustainable forest management"). The combined effect is increasing recognition of the need to be adaptive and to understand and develop the system's inherent capacity to adapt. Adaptive capacity can be assessed a number of ways. Williamson and Isaac (2013) summarized the current literature on adaptive capacity relevant to SFM and presented a framework of the dimensions of adaptive capacity along with relevant assessment approaches.

Case Study - National assessment of adaptive capacity and sustainable forest management	Based largely on insights from extensive discussions and interviews with Canadian forest managers and other practitioners, Johnston et al. (2010) reported the following key findings: • **Awareness of the issue and perception of urgency** – Awareness of climate change as an important issue for forest management is increasing in Canada, although site-specific impacts and adaptation options are not yet well understood. • **Range of technological options available to decision makers** – The availability of technological options for adaptation is variable, and cost is often a limiting factor. • **Economic resources** – Investment in innovation in the Canadian forest sector is generally low, which limits the ability to develop innovative solutions to address climate change impacts. In addition, resources are often lacking to support vulnerability assessments and adaptation planning. • **Institutional factors** (e.g., design and structure, flexibility, ability to efficiently allocate resources to adaptation, degree of autonomy in making adaptation choices) – Institutional barriers are an important limitation to implementing adaptation options. Analyses of current policy could help in identifying features likely to hinder adaptation. Canadian forest management has a number of institutions that increase adaptive capacity (e.g., Forest Products Association of Canada, the model forest network, forest certification programs, the national forest strategy, and professional associations). • **Human and social capital of adaptors** (e.g., skills, education, experience, networks) – Although the adaptive capacity of the forestry profession is generally high, a lack of scientific capacity is an important constraint to planning for climate change. In some locations, the lack of human capacity is seen as a constraint. • **Knowledge and access to information** – Research capacity related to forest management is high in Canada, but to date researchers have not addressed climate change comprehensively. Also, there is a lack of scientific capacity relative to understanding and dealing with climate change in the Canadian forest sector, and a lack of information at spatial and temporal scales relevant to forest management planning and decision making. New modeling tools will assist in developing a better understanding of the impacts of climate change and the role of potential management interventions in adaptation activities. • **Ability to manage risk** – Forestry companies, like any other type of business, engage in risk management as part of normal business practice. However, some aspects of forest management, such as long-term commitments favoring certain tree species during reforestation, make risk management more difficult.

Case Study - Kamloops Future Forest Strategy	The Kamloops Future Forest Strategy emphasized "management adaptive capacity" in a vulnerability assessment for a forest area of 2.7 million hectares in central British Columbia. Management adaptive capacity was defined as encompassing current legislation, policies, administrative structures, and other factors that shape the way forest management functions in the area, including its influence on the management actions that forest managers are willing and/or able to implement. Following the identification of possible management actions to reduce the sensitivity of ecosystems, adaptive capacity was considered by evaluating barriers to implementation. The following five broad themes or general barriers emerged: (1) lack of a comprehensive strategic planning process (2) more costly reforestation (3) more costly or break-even harvesting (4) need for ongoing stand management (e.g., beyond free growing) (5) requirement for government to take on increased management risk. Source: Details on the Kamloops Future Forest Strategy can be found at http://k2project.files.wordpress.com/2010/01/kamloops-future-forest-strategy-june25-09.pdf

4.3.2 The Practice

Adaptive capacity assessments rely largely on interviews, discussions, and surveys during which individual practitioners and policy specialists share their views about their individual and collective adaptive capacity, based on a list of assets or determinants taken from the literature. Assessment of adaptive capacity is highly contextual and details of the assessment will vary depending on the focus of the assessment (see "Case study – Kamloops Future Forest Strategy").

Worksheet 4.2 (Evaluate adaptive capacity of the SFM system) provides guidance on assessing adaptive capacity characteristics, based on the framework proposed by Williamson and Isaac (2013). The worksheet consists of a series of questions that users can ask themselves and their organizations to help understand their capacity to adapt both generally and specifically in relation to climate change.

4.4 Assess Current and Future SFM Vulnerability

4.4.1 The Theory

According to the IPCC, vulnerability "is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Parry et al. 2007). Systems that experience relatively low level of impacts, either because they are not exposed to significant climate changes or variability or because they are insensitive to these changes (or a combination of these factors) have low vulnerability. Where there is potential for large impacts on a system because of high exposure or high sensitivity (or both), high adaptive capacity can reduce the degree to which the system is vulnerable. However, in cases where an impact critically affects the ability to meet

objectives and there is no potential adaptive capacity, the system has high vulnerability. A high level of vulnerability may lead to significant adverse effects on natural and human systems.

The outcomes of a vulnerability assessment consist of relative vulnerability rankings and a documented understanding of the specific factors contributing to this vulnerability. Glick et al. (2011) emphasized that a vulnerability assessment is not an end point; rather, it is a source of information to be incorporated into planning and decision making. They described vulnerability rankings as an intermediate step, used in setting management and planning priorities and crafting adaptation options, including monitoring and allocating scarce resources.

4.4.2 The Practice

Assessing the vulnerability of SFM objectives is a subjective practice based on the best available information and knowledge of potential impacts on the objectives and the assessment of general adaptive capacity. There is no exact science for this process, and it is best to work in a group or to conduct a workshop to estimate the vulnerability of your SFM objectives.

Worksheet 4.3 (Assess current and future vulnerability) combines the impacts on SFM objectives determined in **Worksheet 4.1 (Assess current and future impacts on SFM)** and the assessment of adaptive capacity from **Worksheet 4.2 (Evaluate adaptive capacity of the SFM system)** to determine the vulnerability of SFM objectives under current forest conditions and future forest impact scenarios. For example, if the impacts of climate change on achieving a specific SFM objective are ranked as high and the adaptive capacity of the system for this objective is ranked as low, vulnerability would be ranked as high.

It is also useful to step back from the level of individual SFM objectives and examine the SFM system as a whole, considering the question, "Under current forest conditions and the range of potential future climate and forest impacts, is the SFM system vulnerable to climate change?" Use **Worksheet 4.4 (Assess overall SFM system vulnerability)** to summarize your conclusions.

4.5 Decision Point: Is Adaptation Required?

At this stage, the detailed vulnerability assessment is now complete. You should have a good indication of what aspects of the SFM system and its objectives are vulnerable to climate change. If vulnerabilities exist, it is now time to identify adaptation options (chapter 5) and put those options into practice (chapter 6). Conversely, if the SFM system is sound and no vulnerabilities have been identified, you should continue to monitor the system and reassess vulnerability as new knowledge, learning, or insights are gained (see figure 4 in Williamson et al. [2012]). Use **Worksheet 4.5 (Decision point: Is adaptation required?)** to record your determination of whether adaptation is required on the basis of the vulnerability assessment.

Chapter 4 Completion Check-in

Has the assessment team:

- ☐ Assessed the effects of current and potential future forest impacts on the ability to achieve the SFM objectives?
- ☐ Assessed the adaptive capacity of the SFM system?
- ☐ Assessed current and future vulnerability according to SFM impacts and adaptive capacity?
- ☐ Updated the list of uncertainties and knowledge gaps?
- ☐ Documented all information sources?

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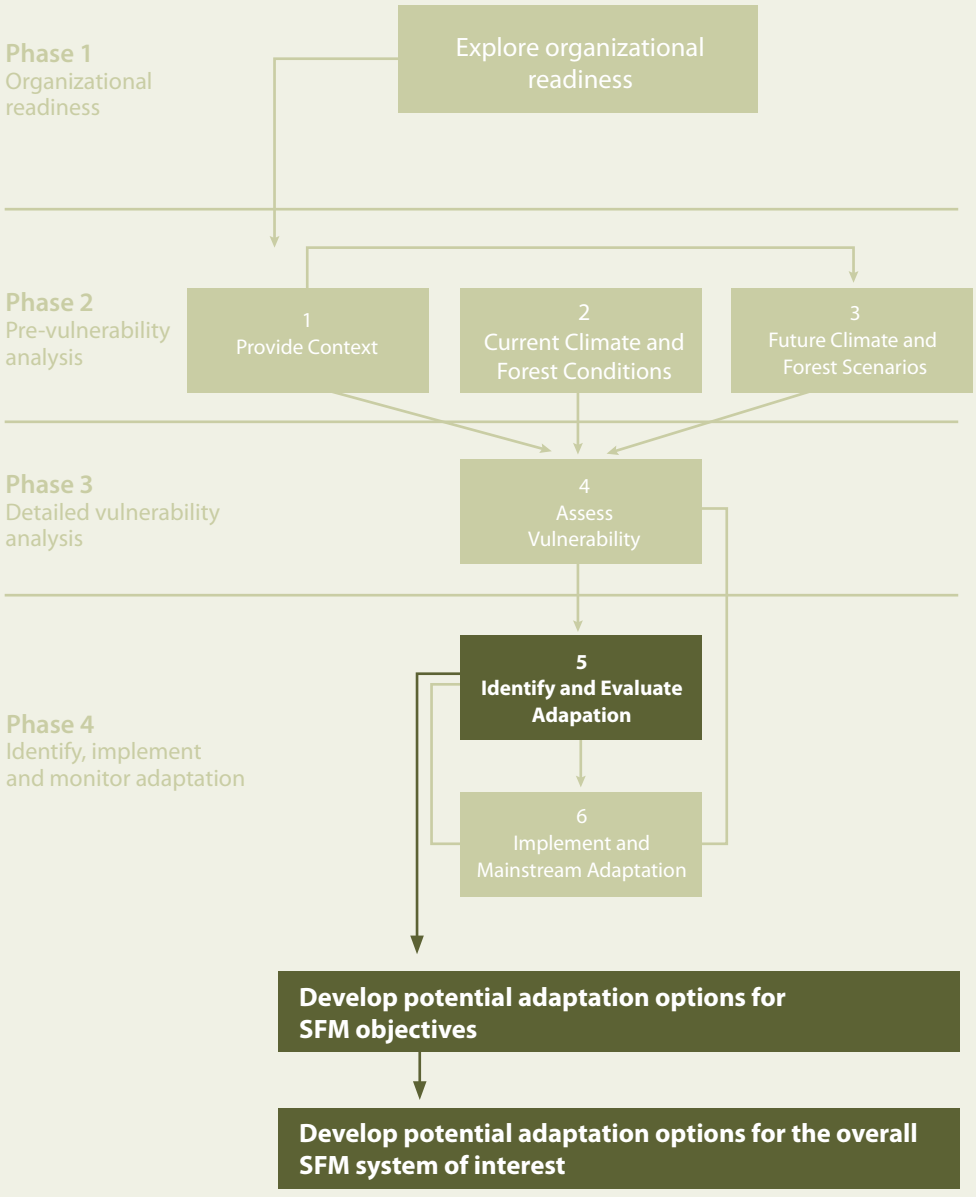
Phase 1
Organizational readiness
Explore organizational readiness
Phase 2
Pre-vulnerability analysis
1
Provide Context
2
Current Climate and Forest Conditions
3
Future Climate and Forest Scenarios
Phase 3
Detailed vulnerability analysis
4
Assess Vulnerability
Phase 4
Identify, implement and monitor adaptation
5
Identify and Evaluate Adapation
6
Implement and Mainstream Adaptation
Develop potential adaptation options for SFM objectives
Develop potential adaptation options for the overall SFM system of interest

5.1 Overview

From the assessment framework…

"If it is determined that adaptation is required, it is then necessary to identify options. The identification of these options or their subsequent modification will depend on the types and magnitudes of SFM vulnerability identified in [chapter] 4. Some adaptation options will reduce the potential negative impacts or increase the potential positive impacts, whereas others will enhance adaptive capacity or reduce adaptive capacity deficits."

—Williamson et al. (2012)

This chapter provides guidance on developing climate change adaptation options for SFM. It includes two worksheets designed to facilitate this assessment:

Worksheet 5.1. Develop potential adaptation options for SFM objectives

Worksheet 5.2. Develop potential adaptation options for the overall SFM system of interest

Purpose of "assessing vulnerability"	Outcomes
To develop a suite of adaptation options for the SFM system of interest and to assess the importance of each option for achieving SFM objectives	• A list of possible adaptation options for each of the CCFM SFM criteria and for the overall SFM system of interest or, if you are reassessing adaptation options, a list of modified adaptation options • An assessment of the importance of adaptation options for achieving SFM objectives and for the overall SFM system of interest under the range of climate change scenarios that you have defined

5.2 Develop Potential Adaptation Options

5.2.1 The Theory

Once key current and future vulnerabilities have been identified, the next step is to formulate a list of adaptation options. There is little theory available on the development of adaptation options (see "Case study –Capabilities approach to identifying adaptation options" for one approach). The key is to develop as wide a range of options as possible, given the scenarios developed earlier in the vulnerability assessment process. The adaptation options can focus on a range of policy, practice, or capacity changes. The options will be prioritized and the feasibility of implementing them assessed in chapter 6.

5.2.2 The Practice

An inventory of adaptation options was compiled to aid in the development of this guidebook (see Appendix 5). This inventory was based on a review of the literature (drawn largely from Ogden and Innes 2007 and Innes et al. 2009) to identify adaptation options previously suggested by researchers as ways of incorporating climate change considerations into forest management and planning.

Case Study – Capabilities approach to identifying adaptation options	Alberta's Climate Change Adaptation Framework Manual (ESRD 2010) uses a capabilities approach to identify adaptation options. The premise behind this approach is that an organization's capabilities for adaptation depend on options in four critical areas, each of which should be considered when developing a list of potential adaptation options: • **Governance** – These options address management, policies, and processes to direct the organization's activities and cover policy, resource decisions, and facilitation of cross-organization relationships. • **People** – These options improve the capacity and capabilities of individuals within the organization and also look beyond the organization to external stakeholders through training, recruitment and retention strategies, updated job descriptions, and performance management. • **Technology** – These options involve the application of science for adaptation to the environment, such as climate modeling software, geographic information systems, field equipment, monitoring equipment, and infrastructure. • **Process** – These options address how work is done within the organization. Processes for climate change adaptation include developing and deploying strategies, identifying and assessing risks, responding to risks, designing and testing measures, monitoring and re-evaluating progress, and continuous improvement.

The field of forest management adaptation is rapidly evolving, and this inventory of adaptation options should therefore not be considered definitive or comprehensive; rather, it should be revised and updated as new knowledge is gained or as innovative ideas are proposed. The inventory of potential adaptation options and the worksheets associated with this step are categorized according to relevant CCFM SFM criteria.

In addition to these suggestions and any that have been collected during the vulnerability assessment process, the assessment team should also explicitly consider options to strengthen adaptive capacity to achieve each of the SFM objectives. The team should revisit the adaptive capacity assessment **(Worksheet 4.2. Evaluate adaptive capacity of the SFM system)** and identify adaptive capacity deficits that are specific to achieving individual SFM objectives. For example, a knowledge deficit that can be filled by ongoing support from a climate specialist through analysis of future extreme rainfall to understand potential impacts on soil erosion could be recorded as an adaptation option under your SFM objective related to maintaining soil productivity. Referring back to the key uncertainties and knowledge gaps identified throughout the vulnerability assessment process **(Worksheet 2.4. Identify uncertainties and knowledge gaps)** can also be a great starting point for generating adaptation options.

Worksheet 5.1 (Develop potential adaptation options for SFM objectives) involves identifying all potential adaptation options for your SFM system of interest. At this stage, adaptation options should not be evaluated; rather, efforts should be directed toward identifying all possible options.

Some of the identified impacts may be cross-cutting, influencing several or all of the SFM objectives (e.g., lack of awareness of climate change impacts among senior managers is likely to affect many objectives). A separate worksheet **(Worksheet 5.2. Develop potential adaptation options for the overall SFM system of interest)** is provided to develop and assess options with a view to reducing cross-cutting impacts on the SFM system.

Changing current policies, practices, and strategies (i.e., adapting) to reduce climate change vulnerabilities can focus on many areas of forest management. Two good places to start are developing options to address potential impacts on forests and to increase adaptive capacity.

A basic approach	Gather a group of interested parties to review the adaptation options listed in Appendix 5 (the inventory of potential adaptation options) and to brainstorm additional options to add to the list. You may also use the knowledge gaps and uncertainties identified throughout the vulnerability assessment as a starting point. Engaging with others who are working on vulnerability assessment of SFM may also be useful; for example, see the Forestry Adaptation Community of Practice <http://www.ccadaptation.ca/facop>.
A comprehensive approach	A more comprehensive approach might include a review of the relevant literature, keeping in mind that adaptation is a "local" activity and that adaptations identified in the literature may not fit with the specific ecological or institutional context of your assessment area. Another approach to eliciting adaptation options is to conduct the first round of a Policy Delphi process (see, for example, http://www.climateontario.ca/LakeSimcoeDelphi.php).
Operational considerations	What options exist for adapting forest management policies and practices to reduce vulnerability to climate change? When identifying potential adaptation options, keep the following guidance in mind • Be creative and innovative. Climate change adaptation is a newly expanding area, and not all options are on the table yet. • Encourage the identification of new approaches to adaptation by brainstorming. Don't evaluate options at this stage, because doing so can limit creativity. • Engage a variety of perspectives in this process, and consider a broad range of potential management intensities and viewpoints.
Strategic considerations	Keep in mind that the ultimate goal of adaptation planning is to reduce vulnerability to climate change and thereby increase the likelihood that management objectives will be achieved. Because of the profound uncertainties associated with many of the adaptation options, it may be important to build flexibility and "learning by doing" into your list of adaptation options.

5.3 Identify Important Options for Achieving SFM

5.3.1 The Theory

Once a suite of potential adaptation options has been identified, the next step is to assess and select those adaptations that have the greatest benefits for SFM or that offer the greatest promise in terms of achieving SFM objectives. It is essential to focus on the importance of implementing adaptation options at this stage in the adaptation process and not on the feasibility of implementing the adaptations. Assessing feasibility and ecological and social suitability will be addressed in chapter 6.

Options that support achievement of SFM objectives across the range of possible future scenarios are known as "robust" options. Other categories of important options are "no-regret," "win–win," and "must-do" options. No-regret options make sense today and for all potential futures. For example, increasing awareness of climate change and climate change impacts within your organization is likely to be a no-regret option, and very little will be lost if the projected climate change and impacts do not materialize. Win–win options are those that can reduce vulnerability to climate change while improving or positively affecting other priorities. For example, the use of assisted migration to incorporate new tree species may present the opportunity to use tree species that are more productive, which could (hypothetically) lead to increased carbon capture. Must-do options are those that ought to be undertaken immediately to achieve SFM objectives under current climate conditions and regardless of projected future climates.

5.3.2 The Practice

Guidance for completing the option assessment steps in **Worksheet 5.1 (Develop potential adaptation options for SFM objectives)** and **Worksheet 5.2 (Develop potential adaptation options for the overall SFM system of interest)** is provided below.

Importance of implementing adaption option to achieve management objectives – A good starting point for climate change adaptation in the forest sector is to proactively identify management policies and practices with a higher likelihood of achieving SFM objectives across a wide range of potential climate futures (see "Case study – Southwest Yukon"). Considering climate change vulnerabilities, how important (or beneficial) is it to implement each of the adaptation options to achieve management objectives in your area? Perform this assessment both for current climate conditions and for each of the scenarios you have described.

"Important" adaptation options – Determine which adaptation options can be considered robust, no-regret, win–win, and/or must-do (i.e., options that are important to implement across all scenarios to achieve management objectives in your area and thus most beneficial for SFM). In identifying these "important" adaptation options, look for any that are considered by a diverse group of practitioners or stakeholders as important to

From the assessment framework…

"Once a suite of potential adaptations has been identified, the next step is to assess them and select those that have the greatest potential benefit for SFM or that offer the greatest promise in terms of achieving SFM (however it is defined for the management system of interest), given the realities of climate change."

—Williamson et al. (2012)

implement across a wide range of possible future scenarios. Also identify any options that could enhance flexibility in policies and practices given an uncertain future. These could also be considered important options.

"Not-important" adaptation options – Some options may not be ranked as important for achieving SFM objectives under a changing climate. Although you may not wish to consider these options for the remaining assessment steps, it is wise to keep them on your list of potential adaptation options for use as a starting point for future reassessment of vulnerability. In addition, although these options may not be ranked as important for addressing climate change, they may represent important views and opinions of interested parties that can be addressed through other planning processes.

Case Study – Southwest Yukon	A good starting point for climate change adaptation in the forest sector is to proactively identify policies and practices with a higher likelihood of achieving management objectives across a wide range of potential climate futures. This step should be followed by implementation of these options and monitoring of their success in achieving objectives within an adaptive management context. A study in southwest Yukon identified locally appropriate adaptation options by tapping into the experiential knowledge base of local forest practitioners while concurrently building capacity within this community to implement the options. Thirty forest practitioners involved with implementation of a regional forest management plan were engaged in identifying climate change vulnerabilities and evaluating alternative adaptation options. A structured decision-making approach was used to frame the assessment. Practitioners identified 24 adaptation options that they considered important to implement for achieving the regional goals and objectives of SFM in light of climate change. Source: Ogden and Innes (2009).

A basic approach	Evaluate adaptation options using best available information (studies, expert judgment, datasets, model outputs, etc.). Instead of seeking consensus on a single ranking, you may wish to provide a range of rankings from various sources.
A comprehensive approach	Gather a diverse group, including planners, individuals responsible for implementing adaptation actions, representatives of interest groups, and policy makers, to evaluate the list of adaptation options.
Operational considerations	Given that every forest area has its own unique combination of ecological, economic, social, and cultural conditions, there is no single right approach to adaptation. Instead, options should be evaluated for specific areas and timeframes, to determine when and where various adaptation options should be implemented.
Strategic considerations	Don't become overwhelmed by a lack of data or by low confidence in the information available for many of these decisions. Use the information that is available, but also plan to rely on expert judgments and/or the informed judgments of local forest practitioners (see sidebar **Informed judgements**). Do your best to identify "important" adaptations that are likely to do reasonably well over a wide range of potential future conditions.

Informed Judgements

Public perceptions of climate change have been widely documented and have been the focus of considerable research in recent years. In addition, expert judgments (generally defined as those of well-recognized researchers) have been used to forecast and assess probabilities and risks and have provided useful insights for decision makers, particularly in situations characterized by complexity and deep uncertainty. Although some efforts have been made to document the judgments of members of the professional and practitioner communities on matters related to climate change, research in this area has received considerably less attention. A notable gap is research to document the informed judgments of forest practitioners on priorities and mechanisms for adaptation.

It may be useful for forest managers to gain experience in developing and evaluating alternative adaptation options. Integrating considerations related to climate change adaptation into existing decision-making processes is called "mainstreaming" and can lead to "win–win" policies, i.e., those that reduce vulnerability to climatic change while simultaneously addressing other priorities. It is also important for key local actors and institutions to be involved in mainstreaming, because they play significant roles in knowledge transfer and policy development. Interventions will be more successful if they are identified and developed by local actors, as they (the interventions) are more likely to be consistent with local priorities, goals, norms, and institutions. Conversely, a recommendation developed without consultation with local communities and/or government institutions is far less likely to be adopted.

Forest practitioners play a critical role in adaptation planning. They are involved with the planning and management of forest-based resources and frequently collaborate with ecological, economic, social, and cultural experts, as well as holders of local, traditional, and/or scientific knowledge of forest-based resources. Practitioners are well-informed, highly knowledgeable individuals whose employment or livelihood is tied to the forest sector and who are typically employed by key decision-making agencies; alternatively, they may be stakeholders who are instrumental in driving forestry decision making. Documenting the informed judgments of practitioners could therefore provide useful insights into the state of knowledge and practice on climate adaptation and the readiness of practitioners to engage in adaptive strategies. The applied knowledge held by forest practitioners can also provide useful insights for decision makers while research to produce more definitive results is in progress, particularly in situations characterized by complexity and deep uncertainty (see Walker et al. [2013] for more on adaptation under deep uncertainty).

Forest practitioners work at the confluence of government, scientific, and community knowledge and priorities and as such are experts in the local context. They also play an important role in developing, implementing, and/or reviewing operational forest management plans to ensure that community-directed goals and objectives of forest management are achieved. Within the experiential knowledge base of local practitioners rests an applied understanding of local priorities, goals, norms, and institutions. There are many trade-offs involved in forest management decision making, trade-offs that are well understood by those who are experts in the local context. This expertise is incredibly useful to an assessment of climate change vulnerabilities and the regional appropriateness of adaptation options and strategies. An exploration of practitioners' viewpoints on adaptation measures in a local context also creates the opportunity to build a collective understanding of locally appropriate measures that might be taken to adapt to climate change. In addition, raising awareness of the range of alternative adaptation options within this community can facilitate changes in policy and practice. In this way, exposing practitioners to adaptation-related questions might help to build the necessary foundation for their incorporation into longer-term forest management and planning-related decisions.

Sources: Ogden and Innes (2007); Ogden and Innes (2009); Walker et al. (2013).

Chapter 5 Completion Check-in

Has the assessment team:

- ☐ Developed a list of possible adaptation options for each of the CCFM SFM criteria and for the overall SFM system of interest or, if you are reassessing adaptation options, a list of modified options?
- ☐ Conducted an assessment of the importance of adaptation options for achieving SFM objectives and for the overall SFM system of interest under the range of climate change scenarios that you have defined?

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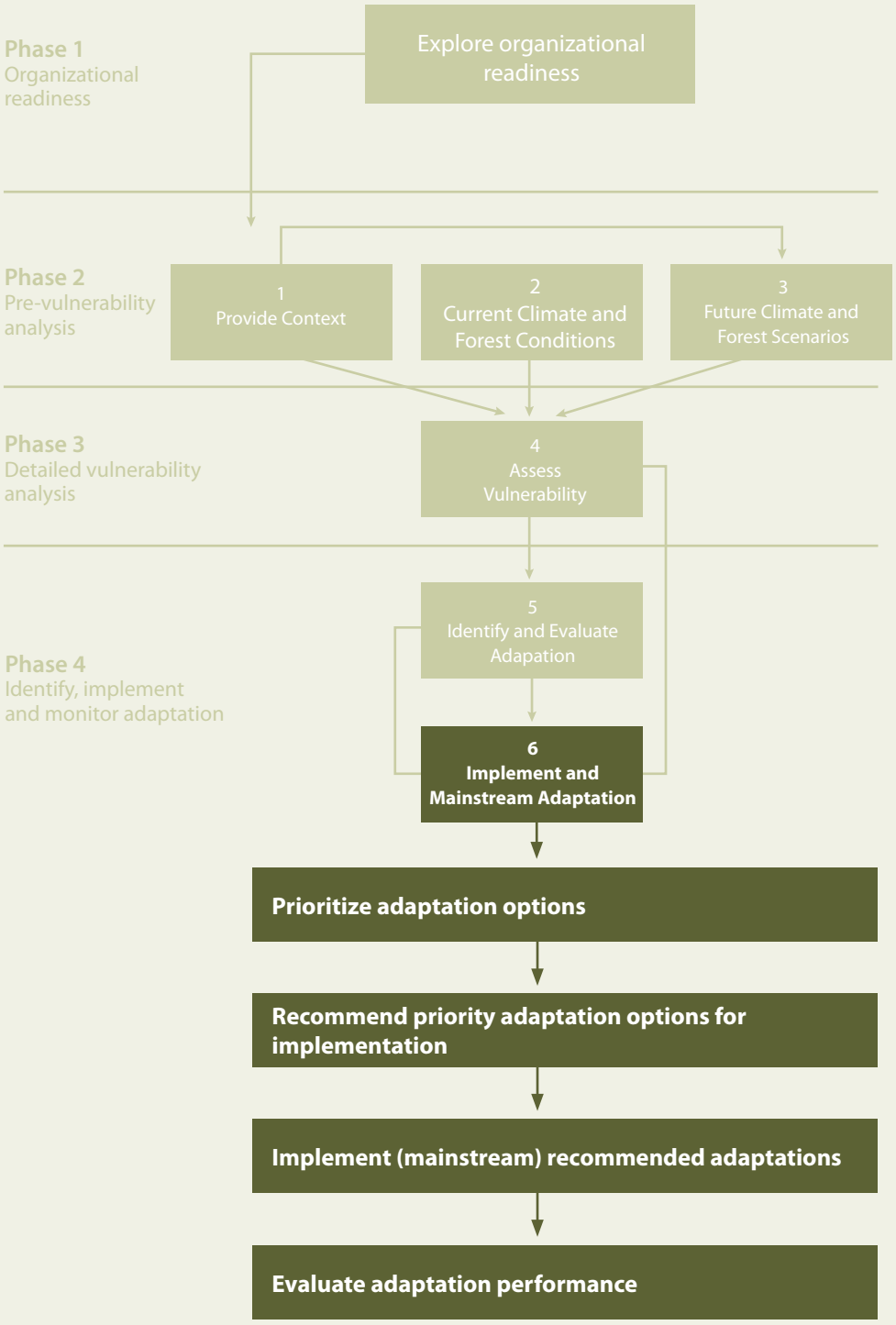
CHAPTER 6 IMPLEMENTATION AND MAINSTREAMING OF ADAPTATION



Before you begin:

It is recommended that you read the report *Adapting sustainable forest management to climate change: a review of assisted tree migration and its potential role in adapting sustainable forest management to climate change* by Ste-Marie (2014). It explores the various ecological, social, and technological facets to consider when implementing assisted migration as an adaption option, and more generally serves as an example of factors to consider before implementing any adaptation option for SFM.

6.1 Overview

This chapter provides guidance on implementing and mainstreaming adaptation for SFM. It is structured around four worksheets that are designed to facilitate mainstreaming of adaptation into SFM planning and practice:

Worksheet 6.1. Prioritize adaptation options

Worksheet 6.2. Recommend priority adaptation options for implementation

Worksheet 6.3. Implement (mainstream) recommended adaptations

Worksheet 6.4. Evaluate adaptation performance

Purpose of "implementing and mainstreaming adaptation"	Outcomes
To support efficient and successful implementation of adaptation priorities by mainstreaming selected adaptation options into existing SFM activities as much as possible	• A list of prioritized adaptation options • A list of recommended adaptation options for implementation • Integration of implementation planning into existing SFM processes or creation of an implementation plan outlining the human resources, financial resources, business processes, and partnerships required for successful implementation of your adaptation priorities • A plan for continuous evaluation of the implementation of adaptation actions and for continuous monitoring of the SFM system

From the assessment framework…

"Mainstreaming adaptation into decision making is a continual process whereby

- *adaptations are assessed in terms of the degree to which they are effective;*
- *technical feasibility and costs and benefits are evaluated;*
- *adaptations that are feasible and economically justified are implemented;*
- *the performance of the adaptations is monitored and evaluated;*
- *the adaptation program and/or management objectives are modified, if necessary; and*
- *vulnerability is periodically reassessed as new knowledge, learning, and insights become known."*

—Williamson et al. (2012)

6.2 Prioritize and Recommend Adaptation Options

6.2.1 The Theory

After "important" adaptation options have been identified, they can be prioritized and then rejected, postponed, or selected for implementation. Of the many methods available for prioritizing options, the most useful will depend on the decision-making context of your SFM system and the actors involved in the vulnerability assessment. One method for prioritizing adaptation options is a Policy Delphi process (as described in "Case study – Lake Simcoe" in section 6.2.2), which involves the use of multiple rounds of expert opinion, solicited through an anonymous process, to generate and refine the list of potential adaptation options. Conversely, some prioritization may have already been completed when you assessed the importance of each adaptation option in **Worksheet 5.1 (Develop potential adaptation options for SFM objectives)** and **Worksheet 5.2 (Develop potential adaptation options for the overall SFM system of interest)**.

The main consideration throughout the prioritization and recommendation stages is whether the adaptation helps in achieving SFM objectives across a range of potential futures.

Information Source	Lim and Spanger-Siegfried (2005) identified four main methods for prioritizing adaptation options: 1. **Cost–benefit analysis** – This method uses one criterion—economic efficiency—to assess and provide an absolute measure of the desirability of alternative adaptation options. It can identify optimal options and priorities, albeit based on a single criterion. Cost–benefit analysis has relatively heavy data requirements. 2. **Multicriteria analysis** – This method is suitable when more criteria are thought to be relevant and it is not possible to quantify and evaluate the criteria in monetary terms. It is typically used to rank options. If a "do-nothing option" is one of the alternatives being evaluated, a multicriteria analysis can help to clarify whether the adaptation measure is better than the status quo. Subjective judgment plays an important role in multicriteria analysis, making its outcomes more arbitrary than those of cost–benefit analysis. 3. **Cost-effectiveness analysis** –This method is a form of economic analysis that compares the relative costs and outcomes (effects) of two or more courses of action. It is distinct from cost–benefit analysis, in that it does not assign a monetary value to the measure of effect. Cost-effectiveness analysis lies somewhere between cost–benefit analysis and multicriteria analysis in terms of subjectivity; it is similar to multicriteria analysis in providing only a ranking. 4. **Expert judgment** – Expert judgments have been used to forecast and assess probabilities and risks and have provided useful insights for decision makers, particularly in situations characterized by complexity and deep uncertainty and where limited information is available. See box **Informed Judgments** in chapter 5 for a more detailed discussion of this approach.

Once the prioritization step is complete, the priority adaptation options should be assessed for ecological and social suitability and for feasibility of implementation. If the options are deemed suitable and feasible, the adaptations are "upgraded" from options to recommendations. Ste-Marie (2014) has summarized the facets to consider when assessing assisted migration as an adaptation option, but the points presented in that summary are relevant to any adaptation options being considered.

6.2.2 The Practice

Few forest management adaptation planning processes have reached the stage of prioritizing adaptation options, so limited guidance is available as to what will work in various contexts. One recent experience, the Lake Simcoe Vulnerability Assessment, is described in the case study below.

Case Study – Lake Simcoe	The vulnerability assessment for Lake Simcoe, Ontario, involved a Policy Delphi process to both elicit a wide range of adaptation options and to assess and refine the list of potential options. The original list developed during the assessment process presented over 900 potential adaptation options. Use of the Delphi process allowed participants to reduce the number of options to a more feasible number (see http://www.climateontario.ca/LakeSimcoeDelphi.php).

The first step in **Worksheet 6.1 (Prioritize adaptation options)** is to describe the process that will be used to prioritize the options created in chapter 5. This process will likely depend on the existing decision-making context. The second step is to list the prioritized adaptation options by SFM objective and describe why these adaptation options are priorities for implementation.

Worksheet 6.2 (Recommend priority adaptation options for implementation) provides guidance for assessing and selecting priority adaptation options to be implemented.

Potential barriers and conflicts – For all of the adaptation options selected as having priority, potential conflicts with implementation must be assessed. This process involves considering the ecological suitability, social acceptability, and economic and institutional feasibility of the adaptations. In some cases, feasibility may be limited by identifiable barriers or constraints to adaptation (see Moser and Ekstrom 2010). For example, the uncertainty of adaptation success may be too high to justify implementation without further research. Such constraints should be noted and described, because the preferred adaptation option in such a case might be to remove or reduce the barriers and constraints. Infeasibility could also result from the social unacceptability of a potential adaptation option (e.g., introduction of exotic tree species at a large scale).

If an adaptation option is deemed infeasible, it may be worth determining whether the option can be changed in a way that would make it feasible. If that possibility exists, then the adaptation option can be adjusted; otherwise, the adaptation option is rejected and alternatives should be sought. Priority adaptation options should also be assessed for conflicts with the achievement of other SFM objectives.

Recommended adaptations – Once it has been determined that a particular suite of adaptation options will benefit SFM objectives, yield acceptable outcomes, and be feasible, then the adaptation options can be upgraded from "options" to "recommendations." Keep in mind that adaptation options ranked as very important for achieving an SFM objective in a changing climate may not be the most suitable or the most feasible options. You may need to weigh the importance, or benefit, of implementing the option against the ease or difficulty of implementation.

Timeframe for implementation –Determine the timeframe for implementation of the recommended option. Implementation timeframes may be related to existing opportunities (e.g., the start of a new forest management planning cycle), the status of the option as a "must-do" adaptation, the impending disappearance of a funding source to support the implementation, or other factors. Certain adaptation options may not need to be implemented immediately but can be delayed until the timing is right.

"Achievability" of SFM objectives – Keep in mind that it may not be possible to reach all management objectives through adjustments to forest management policies and practices. Climate change will likely result in some impacts to forests which, regardless of the intensity of forest management efforts, will preclude the achievement of certain objectives. In these cases, the forest management objectives themselves should be revisited by asking the question, "With implementation of the recommended adaptations, do we expect to be able to achieve our SFM objectives?" If the answer is "no," you should consider either identifying additional adaptations or revising your SFM objectives.

A basic approach	Have the vulnerability assessment team assess the options on the basis of their experience and knowledge, with the understanding that the team represents only a small proportion of the interested parties within the SFM system of interest.
A comprehensive approach	Seek participation of and perspectives from a diverse group of interested parties (e.g., stakeholders, public, other government departments) in assessing potential conflicts and prioritizing adaptations.
Operational considerations	Individuals responsible for forest planning, harvesting operations, and mill operations should be included in the assessment of suitability and feasibility. Individuals who work on these tasks daily often know the details required to implement new approaches and techniques. This step in the adaptation process can also be an opportunity for all interested parties to bring forward creative solutions and new opportunities.
Strategic considerations	Don't become overwhelmed by a lack of data or tremendous uncertainties. Use the information that is available, but also plan to rely on expert judgments and/or the informed judgments of local forest practitioners to develop recommendations and priorities. Look for "no-regret" adaptations (i.e., actions that make sense now and in the future, regardless of what the climate might be).

6.3 Mainstream Adaptation Priorities

6.3.1 The Theory

Now that you have developed a list of adaptation priorities, it is time to transform them into actions by incorporating them into the day-to-day operations of relevant organizations. Integrating adaptations into regular business practice is known as "mainstreaming." This process also encourages all members of an organization to become knowledgeable about climate change and its potential impacts.

Fundamentally, adaptation is about doing things differently. Implementation may require a change in ways of doing business, such as alterations in planning, procedures, policies, regulations, legislation, investments, protocols, guidelines, training, and operational methods. The changes may be minor and easily implemented, or they may be more significant and require careful planning and monitoring. Implementation will require mobilization of financial and human resources, as well as ongoing, effective partnerships with agencies and other organizations that may be involved in, or affected by, implementation of the adaptation measures.

If the individuals who will be responsible for and involved in implementing the adaptations have been engaged in the earlier stages of vulnerability assessment, they should already know the reasons why adaptations are needed. If they have not had an opportunity to learn about climate change impacts or how and why specific adaptations were chosen, they will need to be brought up to speed, to facilitate their support and ensure effective implementation of the adaptations. Moser and Ekstrom (2010) have summarized the barriers to implementation of adaptation options and some options for overcoming them.

From the assessment framework…

"Adaptation means a change in the way of doing business. Implementation of an adaptation may therefore require changes in planning, procedures, policies, regulations, legislation, investments, protocols, guidelines, standards, and operational methods. However, implementation does not encompass any change in SFM objectives.""

—Williamson et al. (2012)

6.3.2 The Practice

Mainstreaming adaptation into day-to-day operations requires integrating priority adaptations into ongoing planning and operational procedures. This can be accomplished by developing a mainstreaming plan for each priority adaptation. If appropriate, individual plans can be combined into a comprehensive mainstreaming plan with strategic, operational, and adaptive capacity components. **Worksheet 6.3 (Implement [mainstream] recommended adaptations)** provides a template to aid you in preparing your mainstreaming plans. For each recommended adaptation, the follow actions are suggested:

- Assess the **jurisdiction** within which the adaptation actions fall and the roles and responsibilities of various agencies and individuals in implementation.
- Identify the **actions** required to implement the adaptation (e.g., changes in planning, procedures, policies, regulations, legislation, investments, protocols, guidelines, training, and operational methods).
- Identify **opportunities to mainstream** the adaptation into regular business processes.
- Identify **roles and responsibilities** (i.e., the specific person or department that will lead implementation and other individuals or departments that should be involved). Set deadlines for implementation progress.
- Assess the **internal support** required for implementation to proceed (e.g., operational staff, specialists, senior management, political leaders).
- Assess the **external support** required for implementation to proceed (e.g., involvement or buy-in from other organizations).
- Identify the **human resources** required for implementation to proceed and assess whether these resources are available or if they must be secured.
- Assess **information and/or training needs** that may be required to implement the adaptation.
- Identify the **financial resources** required for implementation to proceed and assess whether these resources are available or if they must be secured.
- Describe what successful implementation would look like (e.g., all planning and operations staff are knowledgeable about climate change impacts and adaptation; silvicultural operations reflect changes in precipitation).
- Identify the **overall schedule**, **the timing of specific events**, and **the milestones** associated with implementation.
- Determine if there is a need to **communicate** with decision makers, other staff, or interested parties about the adaptation and its potential implications.
- Determine if there is an **existing monitoring or tracking plan** into which this adaptation should be incorporated.
- Consider whether the adaptation can help to achieve other non-SFM objectives or goals.

Ideally, the adaptations will be mainstreamed into regular business processes and included in regular business reviews and improvements over time. If not, consider creating a separate implementation plan and a team to monitor implementation and effectiveness. The first tasks of the implementation team should be to review and finalize the implementation plan and to secure the necessary internal and external support from key agencies.

A basic approach	Integrate the adaptations into your existing strategic plans (e.g., strategic forest management plan), operational plans (e.g., annual work plan), and day-to-day decisions. Add the priority adaptations when you update each plan, or undertake a review to identify whether existing plans should be updated immediately.
A comprehensive approach	Effective communications and good working relationships will be extremely important to successful implementation of adaptations. In addition, implementation provides a great opportunity to work cooperatively and collaboratively with land management partners and other interested parties. Work with these stakeholders to secure needed resources, identify business process requirements, prioritize activities, agree on responsibilities, and identify feasible milestones. Working together to mainstream adaptations will help to create buy-in and should result in adaptations that are realistic and achievable.
Operational considerations	To support buy-in and effective implementation, it will be essential to share the reasons for the adaptations with anyone who will be involved in implementing them (e.g., planners, government approvals staff, operations personnel, contactors, and forest workers). Remember that this will take time and resources.
Strategic considerations	Ensure that you have done everything you can to garner support from the various individuals and organizations that may be affected by the adaptation, both internal personnel (such as senior managers) and external interests (such as communities and neighboring land users).

6.4 Evaluate Adaptation Performance

6.4.1 The Theory

Insights and recommendations about management policies and practices gained by working through the worksheets in this guidebook represent a starting point for vulnerability assessment and adaptation. Confidence in the feasibility and effectiveness of some adaptations and in projections for future climate change may be low, so it is essential that individual adaptations and the entire SFM system be closely monitored and refined once recommendations for adaptation options have been made (see Williamson and Edwards 2014). As well, regardless of the acceptability and feasibility of the recommended adaptation actions, some vulnerability is likely to remain after implementation. Therefore, monitoring is an essential part of the vulnerability and adaptation assessment framework. The aim of monitoring is to track whether adaptations have been implemented, whether SFM objectives are being met under a changing climate, and whether residual vulnerability necessitates refinement of objectives or activities.

To be effective, monitoring should be part of a systematic process in which information gained by monitoring is used to improve decisions, refine practices, or change management objectives (e.g., adaptive management or continuous improvement). The monitoring results can help to identify areas where implementation is progressing and objectives are being met but also areas of concern. For each measure that raises a concern, adjustments to current practices (e.g., changes to operational practices, refinements to plans, enhanced research) should be identified and implemented. If SFM is not being satisfactorily achieved, the manager, agency, or organization responsible for forest management should determine a new course of action, such as modifying the adaptation, modifying relevant SFM objectives, or acknowledging (and ideally documenting) that the residual vulnerability to SFM is acceptable and that no further changes to current activities are needed (see the decision-analysis framework for adaptation to climate change, presented as Figure 4 in Williamson et al. [2012]).

All interested parties involved in or affected by the management and adaptation activities being evaluated should be included in, or at least informed about, the monitoring and evaluation of SFM and implementation of adaptations.

In an adaptive management context, there is a number of reasons for establishing a monitoring or tracking program, in addition to monitoring the performance of adaptations:

- to determine whether the context of your management objectives and vulnerabilities has changed
- to assess if any of the underlying research is out of date
- to track implementation progress
- to communicate accomplishments through regular reporting
- to support adaptive management
- to highlight areas requiring management attention
- to indicate where changes or revisions may be required to the adaptation plan.

6.4.2 The Practice

Where adaptations are mainstreamed into existing planning and practices, such as SFM plans, existing monitoring approaches should be reviewed to ensure they account for the adaptations. Additional monitoring should be considered to adequately track the success of adaptations and catch any concerns early in the adaptation process. As well, it may be necessary to refine existing indicators to integrate the new information from this process. A recent report by Steenberg et al. (2013) provides guidance on adjusting CCFM SFM indicators to reflect climate change adaptation (see "Case Study – Review of SFM indicators for climate change"). Williamson and Edwards (2014) have suggested that a national conversation may be required to address the potential impacts of climate change on the national CCFM criteria and indicators.

If existing planning and practices do not include monitoring and evaluation, the implementation of climate change adaptations may create an opportunity to integrate these important management phases into the organization's day-to-day operations,

again in support of mainstreaming. As a last resort, a separate monitoring and evaluation plan could be developed that outlines resource requirements, roles of contributing organizations, and individual responsibilities and milestones for monitoring SFM indicators and implementation of adaptation actions.

Case Study – Review of SFM indicators for climate change	Steenberg et al. (2013) have assessed the potential impacts of climate change on the existing CCFM criteria and indicators and made recommendations for maintaining, adjusting, or removing individual indicators. They also made recommendations for new indicators.

Use **Worksheet 6.4 (Evaluate adaptation performance)** to describe how you plan to evaluate adaptation performance.

A basic approach	Keep it simple. Your list of indicators should be kept to a realistic, practical number. When formulating your monitoring plan, consider the human and financial resources that are available for monitoring, and prioritize the list of indicators to those that are most meaningful for reporting on implementation progress and trends toward achieving SFM objectives.
A comprehensive approach	In the face of uncertainty, forest managers should take an approach that emphasizes ongoing learning, whereby management adaptations are treated to some extent as "experiments," and new information collected through monitoring is evaluated to determine next steps. Adaptive management recognizes the lack of knowledge about ecosystem function and climate change and integrates continual learning. Monitoring and evaluation should go hand in hand. Monitoring alone is useless if the information it generates is not analyzed in a formal evaluation process. By quantitatively or qualitatively describing status and trends over time, indicators provide the basis for before-and-after analyses.
Operational considerations	Regardless of how monitoring and evaluation are accomplished—by mainstreaming into existing activities, by adding these important steps to ongoing activities, or by creating separate implementation and monitoring/evaluation plans—the roles and responsibilities for these tasks must be clear, with defined reporting timelines. Including everyone who is involved in implementing adaptations in the monitoring and evaluation phase will expedite adaptation, promote continuous learning throughout partner organizations, and produce more realistic refinements to adaptations when needed.
Strategic considerations	Monitoring provides the information needed to improve plans and take timely corrective action. Success depends on a long-term commitment to integrate monitoring and evaluation into ongoing operations, both during implementation and over the lifespan of the adaptations. The selection of indicators for monitoring and the frequency of monitoring may evolve over time. You might also consider coordinating indicators and their measurement with other organizations and undertaking appropriate research initiatives to maximize the value of the information collected.

Chapter 6 Completion Check-In

Has the assessment team:

- ☐ Developed a list of prioritized adaptation options?
- ☐ Developed a list of recommended adaptation options for implementation?
- ☐ Integrated implementation planning into existing SFM processes, or created an implementation plan outlining the human resources, financial resources, business processes, and partnerships required for successful implementation of your adaptation priorities?
- ☐ Outlined a plan for continuous evaluation of the implementation of adaptation actions and for continuous monitoring of the SFM system?

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CHAPTER 7 THE WORKSHEETS

The worksheets in this chapter are provided as guidance for completing an assessment of SFM vulnerability to climate change and for identifying and implementing adaptation options, as defined in the assessment framework (Williamson et al. 2012). The worksheets represent one suggested approach to applying the assessment framework, and users of this guidebook are encouraged to adapt them as required. The worksheets are structured to stimulate and guide discussion within the assessment team and among interested parties; they can also serve as cues for the types of information that will be useful for the assessment. However, users should not be constrained by the tabular format of the worksheets and should record information in whatever format is deemed most suitable.

Although sequential completion of the worksheets is recommended, it is not essential, and users may find that an iterative process is required as the assessment project unfolds. In addition, some worksheets or parts thereof will not be useful for certain projects. Each assessment team must determine which worksheets will be most helpful for its own project and what will be the best method for completing the worksheets, given the resources available.

HINT

The Forestry Adaptation Community of Practice has been established as a go-to source of assistance for forestry resource professionals using this guidebook: http://ccadaptation.ca/facop. This online community contains forums to post questions, offer or access advice and experience, and network with other individuals interested in adapting forestry to climate change. Users of this guidebook are encouraged to use the community to share information about and lessons learned from their respective vulnerability assessments.

HINT

Review the theory and practice sections associated with each worksheet, as presented in the preceding chapters. These sections explain in more detail the purpose of each worksheet and each section (e.g., table column) within a worksheet. Keep in mind that the worksheets and tables represent a suggested approach to recording data and discussions as you work through the vulnerability assessment process. Some adaptation of the worksheets is expected to ensure that the outcomes of the process fit the context of your assessment.

7.1 Worksheets for Chapter 1

The following three worksheets will get you started on assessing vulnerability and mainstreaming adaptation into SFM. The worksheets are designed to facilitate project initiation and to define the scope and scale of the vulnerability assessment. Each worksheet consists of multiple tables.

Worksheet 1.1 **Define the problem or challenge**

- **Table 1.1** Factors prompting a vulnerability assessment for the SFM system of interest
- **Table 1.2** Anticipated benefits of conducting a vulnerability assessment and potential consequences of not doing so
- **Table 1.3** Statement of purpose for the vulnerability assessment
- **Table 1.4** Statement of one or more outcomes for the vulnerability assessment

Worksheet 1.2 **Describe the SFM system and define the scope of the vulnerability assessment**

- **Table 1.5** Description of the managed forest in the SFM system of interest
- **Table 1.6** Overview of organization or agency that is undertaking the vulnerability assessment
- **Table 1.7** Actors within the SFM system of interest
- **Table 1.8** Management objectives for the SFM system of interest
- **Table 1.9** Key nonclimatic factors currently affecting your SFM system

Worksheet 1.3 **Confirm the scope of the assessment**

- **Table 1.10** Resources available to carry out the vulnerability assessment
- **Table 1.11** Confirmation of the scope of the assessment

Worksheet 1.1. Define the problem or challenge

The goal of the tables in this worksheet is to address the question, "Is there a significant concern about the effects of climate change on SFM in the region of interest, and if so, why?" This worksheet also prompts you to articulate the purpose and expected outcomes of an SFM vulnerability assessment should any significant concerns be raised and the need to adapt be identified.

1.1-A. Factors prompting the assessment

Briefly describe factors in the categories listed in Table 1.1 that may have triggered your desire to initiate a vulnerability assessment: environmental or ecological (e.g., a recent extreme weather event; unprecedented forest disturbances), economic (e.g., demands from investors or insurance agencies to consider climate change), or social and cultural (e.g., market pressures to ensure sustainability under a changing climate). Examples of possible factors are provided in Appendix 2.

Table 1.1. Factors prompting a vulnerability assessment for the SFM system of interest

Possible trigger factor	Brief description
Environmental or ecological	
Economic	
Social and cultural	

1.1-B. Anticipated benefits of conducting a vulnerability assessment

List the anticipated benefits of conducting a vulnerability assessment for the SFM system of interest. You may also want to list the potential consequences of not doing so.

Table 1.2. Anticipated benefits of conducting a vulnerability assessment and potential consequences of not doing so

Anticipated benefits of a vulnerability assessment	Potential consequences of not conducting a vulnerability assessment

1.1-C. Purpose and outcome statements for the vulnerability assessment

For this part of the worksheet, consider the following questions: Why are you doing a vulnerability assessment? What are the desired or expected outcomes of completing a vulnerability assessment for the SFM system of interest? How will the results be used? Refer back to these purpose and outcome statements when defining the scale and scope of the assessment. Ensure that the scale is appropriate and the scope sufficient to achieve the intended and expected outcomes. Defining these aspects early in the assessment process will help you to focus the scope and participation level.

Table 1.3. Statement of purpose for the vulnerability assessment

Statement of purpose: Why are you undertaking the project?

Table 1.4. Statement of one or more outcomes for the vulnerability assessment

Outcome statements: What do you hope to achieve?

1.1-D. Factors causing significant concern

This step is intended to help identify and define significant concerns about the effects of climate change on SFM. Answering the following question can help participants maintain focus on the issues at hand.

Is there a significant concern about the effects of climate change on SFM in the region of interest, and if so, why?

_____

_____

_____

_____

_____

_____

_____

Worksheet 1.2. Describe the SFM system and define the scope of the vulnerability assessment

The following types of information, among others, are needed to describe the SFM system of interest:

- spatial and structural description of the managed forest system
- benefits and values derived from the forest, including industrial production values and nontimber values
- overview of the organization or agency that is proposing to undertake the assessment, including information about its responsibility and mandate for SFM
- description of how SFM is defined and implemented relative to the system of interest (i.e., SFM objectives).

The following sections of this worksheet provide guidance on describing the various aspects and elements of the SFM system of interest.

1.2-A. Description of the managed forest

Describe the spatial extent of the managed forest area selected for the vulnerability assessment. Provide details about factors relevant to forest management (e.g., types and distribution of ecosystems, species, age classes, timber volumes, disturbances), as well as the timber and nontimber benefits and values derived from the forest (e.g., wood values, recreational use, wildlife-related benefits, intrinsic forest values).

Table 1.5. Description of the managed forest in the SFM system of interest

Description of the managed forest

1.2-B. Overview of the organization or agency undertaking the vulnerability assessment

Prepare an overview of the organization or agency that is proposing to undertake the vulnerability assessment, including information about its responsibility and mandate for SFM. Defining the planning timeframes (e.g., detailed operations plans, timber supply plan horizons, SFM plans) at this stage of the process can help to determine the relevant timeframe for the assessment.

Table 1.6. Overview of organization or agency that is undertaking the vulnerability assessment

Organization or agency overview
Responsibility for SFM:
Mandate for SFM:
Implementation of SFM within the organization or agency (describe what, how, and who is involved in implementing SFM within the system of interest):
Planning timeframes for forest management:

1.2-C. Human elements of the SFM system (actors and their decision-making scope)

List the organizations and individuals involved in planning and operations in your SFM system and describe the role of each individual (e.g., prepares plans, approves plans, provides advice, supervises operations, monitors operations).

Decisions about managing forest resources will affect a wide range of other values that society derives from the forest. Therefore, you may also want to consider who will be affected by these decisions, so you can invite them to participate in the assessment or keep them informed of progress and outcomes. Having other interested parties (e.g., stakeholders) involved or kept informed from the outset can be of assistance if you wish to try new SFM options.

The human elements of an SFM system may include (but are not limited to) the following:

- agencies involved in overall land management or organizations that partner in the management of the area
- agencies involved in reviewing or approving plans for compliance and enforcement
- organizations holding land-use tenures
- any organization that can affect decisions for the area
- any organization or individuals that may be affected by decisions for the area

Table 1.7. Actors within the SFM system of interest

Organizations with a role in the SFM system	Individuals involved with the SFM system	Role of organization or individual

1.2-D. SFM criteria and objectives

A primary aspect of structured decision making is defining what you are trying to achieve by actively managing a system. In other words, what are the management objectives?

This worksheet is critical to the vulnerability assessment, as the objectives listed here are referenced throughout the rest of the guidebook (especially Worksheet 4.1 and beyond). The central focus of the CCFM vulnerability assessment approach is to determine what impacts climate change may have on your ability to achieve your management objectives. Also, adaptation options defined later in the assessment process should be linked to these objectives.

This guidebook focuses on the national SFM criteria, as defined by the CCFM (2003, 2006) and listed below (see Appendix 3 for a complete list of indicators for each CCFM criterion). The system of interest that you have defined may use the same structure, or it may have different categories of criteria. List the management goals or objectives in your area, using whatever structure is relevant for your system.

Criterion 1. Biological diversity: Maintaining biological diversity so that organisms and ecosystems can respond and adapt to environmental change.

Criterion 2. Ecosystem condition and productivity: Ensuring that forest ecosystems can cope with and recover from natural and human disturbances and maintain their ecological functions and processes.

Criterion 3. Soil and water: Modifying management techniques to minimize disturbance, erosion, and compaction.

Criterion 4. Role in global ecological cycles (specifically forest carbon management): Ensuring that forests are able to depend on and contribute to self-regulating processes responsible for carbon, water, nitrogen, and other life-sustaining elements.

Criterion 5. Economic and social benefits: Providing a broad range of forest goods and services over the long term, offering significant economic and social benefits.

Criterion 6. Society's responsibility: Reflecting social values in forest operations and recognizing that many rural communities depend on the forest for their economic, social, and cultural well-being.

Note: It may also be useful to reference any documentation on forest management planning, practices, procedures, and indicators that you use to achieve and track these management objectives. The assessment team may also want to explore any assumptions made in relation to the objectives (e.g., an objective that states "management practices will maintain forest cover strata as it exists today" likely assumes that climate will remain constant). Understanding these assumptions can aid during the vulnerability assessment steps in section 7.4.

Table 1.8. Management objectives for the SFM system of interest

Criterion	Management objective
Biological diversity	
Ecosystem condition and productivity	
Soil and water	
Role in global ecological cycles	
Economic and social benefits	
Society's responsibility	

1.2-E. Key nonclimatic factors currently affecting your SFM system

List any factors that are currently affecting your ability to achieve your SFM objectives (e.g., markets, shortage of workers, changes in land use, lack of data). These factors may affect your SFM system into the future and will need to be considered, along with any climate change impacts, during the vulnerability assessment. Identifying these factors now will help when developing future scenarios later in the process (section 7.3).

Table 1.9. Key nonclimatic factors currently affecting your SFM system

Factor	Effect on achieving SFM objectives	Additional effects of climate change on this factor in relation to achieving SFM objectives
Example: other land-use activities	Example: reduced productive forested area within forest management area	Example: potential for increased fire and forest pest outbreaks may further reduce timber supply, adding to the net loss of productive forest area

Worksheet 1.3. Confirm the scope of the assessment

The purpose of this worksheet is to identify the resources currently available to undertake an SFM vulnerability assessment at the scale and scope identified above, specifically whether the agency or organization is equipped to complete the vulnerability assessment.

1.3-A. Available resources

List all resources currently available within your organization that may be of use for conducting the vulnerability assessment as currently scoped. You may also wish to consider resources available through existing partnerships or collaborations.

Table 1.10. Resources available to carry out the vulnerability assessment

Resource	Description
Human resources (e.g., operational, coordination, administrative)	
Information resources (e.g., specialists, researchers, databases)	
Financial resources (direct money, in-kind)	
Existing initiatives, programs, and research projects, that may be of interest (describe nature of the work, how and where to link to the work, and potential collaboration)	

1.3-B. Summary of purpose and scope of the vulnerability assessment

This step is a recap of the worksheets completed so far. The point is to develop a short summary (e.g., two pages) of purpose and scope that can be used to garner support for the assessment from decision makers and other interested parties, if required.

1. Purpose and outcome statements for the vulnerability assessment (from Tables 1.3 and 1.4)

   _____

   _____

2. What are the main reasons (trigger factors) for conducting a vulnerability assessment?

   _____

   _____

3. Who are the main decision makers within the SFM system of interest?

   _____

   _____

4. What decisions, organizations, and individuals are likely to be affected by changes to SFM objectives and practices?

   _____

   _____

5. What is the best geographic scale for this assessment?

   _____

   _____

6. What planning timeframes should be assessed?

   Short = _____ years Medium = _____ years Long = _____ years

7. Have you established an assessment team? Consider including **terms of reference** and a **work plan** outlining the responsibilities of each member or organization and timelines for any deliverables.

   _____

   _____

8. Can you do it? Do you have the capacity to undertake the vulnerability assessment as you have defined it? See **Reality Check** on the next page (section 1.3-C).

   _____

   _____

1.3-C. Reality check

Consider each question in Table 1.11 and respond Yes or No, adding notes to explain your response.

Table 1.11. Confirmation of the scope of the assessment

Scope questions	Response		Notes
	Yes	No	
Does your organization have a particular need to complete a vulnerability assessment of SFM objectives and climate change?			
Are there regular planning processes (e.g., SFM plan, annual work plan?) into which climate change adaptation could be mainstreamed?			
If you need a person to champion this assessment to ensure it goes forward within your organization, has someone been identified or assigned to the task?			
Have you given thought to the human, financial, and information resources required to complete (or at least get a good start on) the vulnerability assessment?			
Is your organization willing to implement adaptation actions?			
Are groups and individuals that affect or are affected by your forest management decisions likely to support climate change adaptation?			
Are there other factors that should be considered?			

If most of the responses in Table 1.11 are "yes," then your team is likely ready to go forward with a vulnerability assessment and adaptation project at the scale and scope you have defined. Remember that the process is intended to be iterative and adaptive; you can always get started and come back to certain steps once new information or knowledge is gained.

If most of the responses in Table 1.11 are "no," then you probably need to do some additional preplanning to overcome some of the shortfalls. The following suggestions may help:

- If human, financial, and/or information resources are limited or unavailable, you might look to other initiatives, programs, databases, research projects, etc., for support. Partnering with a local college or university to compile information or do analyses may be effective.
- Review the worksheets for chapter 1 with colleagues and managers to boost their understanding of potential impacts, and identify a champion if one is needed.
- If interested groups or individuals are unlikely to support adaptation actions, consider having a respected champion speak to them, or review the worksheets for chapter 1 with them.
- Consider assessing a smaller geographic area or a selection of SFM activities for a better match with available expertise and resources.

1.3-D. Refine the scope of the assessment

Getting started with an assessment, even if it has not been perfectly defined, is often more beneficial than waiting until all the required resources can be gathered and the timing is "perfect." That said, starting a complex task such as vulnerability assessment without a clear scope and without knowing that the assessment is feasible and achievable can lead to failure (see Moser and Ekstrom 2010).

At this stage, you should have a clear and defined statement of purpose for the vulnerability assessment, along with its expected outcomes. You will also have defined the scope in terms of both geography and participants. Now is a good time to examine the goals and scope and ensure you have the ability to achieve them. If not, you may want to redefine the statement of purpose, narrow the scope, or find additional resources before proceeding.

7.2 Worksheets for Chapter 2

The following worksheets provide guidance on describing and documenting how climate has shaped current forest conditions and management practices in your SFM area. They also provide guidance for documenting any adaptations to changes in forest condition that you may have already implemented. The first three worksheets facilitate the gathering of climate information and the identification of relationships between climate and forests. The fourth worksheet is provided for listing and describing knowledge gaps and uncertainties that arise during the assessment.

Worksheet 2.1 **Describe the climatic conditions and trends**
Table 2.1 Climate data: normals and trends

Worksheet 2.2 **Describe the relationships among climate, forest conditions, and forest management practices**
Table 2.2 Relationships among current climate, forest conditions, and forest management practices

Worksheet 2.3 **Describe how recent climate trends or changes in forest conditions have led to changes in forest management practices**
Table 2.3 Recent changes to forest management plans or practices as a result of changes in forest conditions

Worksheet 2.4 **Identify uncertainties and knowledge gaps**
Table 2.4 Key uncertainties and knowledge gaps about climate, forest conditions, or future scenarios identified during the vulnerability assessment process

Worksheet 2.1. Describe climatic conditions and trends

2.1-A. Climate records

Gather information to describe recent climate trends and climate variability in your management area.

Climate and climate-related variables – The variables listed in this worksheet are suggestions of climate factors that might be used to describe the "exposure" of the SFM system of interest. The list includes information that is readily available for locations across Canada. You may delete or add variables to reflect local conditions and available information.

Historical trends – Trends refer to changes in climatic factors at a given location over a specified time period.

Climate normals – Average climate conditions are calculated from recorded climatic values for a given location over a specified period. A period of 30 consecutive years (e.g., 1971–2000) is the standard for calculating climate normals in Canada.

Table 2.1. Climate data: normals and trends

Location: ____________________

Climate and climate-related variables	Historical trend[a] (_____ to _____)	Climate normals (30-year averages) 1951–1980	1961–1990	1971–2000	1981–2010	Trend (e.g., change from 1961–1980 to 1981–2010)	Source(s)
Annual							
Mean temperature (°C)							
Total precipitation (mm)							
Season (months: __________ – __________)							
Mean temperature (°C)							
Maximum / minimum temperature (°C)[b]							
Total precipitation (mm)							
Rainfall (mm)							
Snowfall (cm)							
Season (months: __________ – __________)							
Mean temperature (°C)							
Maximum / minimum temperature (°C)[b]							
Total precipitation (mm)							
Rainfall (mm)							
Snowfall (cm)							
Season (months: __________ – __________)							
Mean temperature (°C)							
Maximum / minimum temperature (°C)[b]							
Total precipitation (mm)							
Rainfall (mm)							
Snowfall (cm)							
Season (months: __________ – __________)							
Mean temperature (°C)							
Maximum / minimum temperature (°C)[b]							
Total precipitation (mm)							
Rainfall (mm)							
Snowfall (cm)							

Table 2.1. Concluded

Climate and climate-related variables	Historical trend[a] (_____ to _____)	Climate normals (30-year averages) 1951–1980	1961–1990	1971–2000	1981–2010	Trend (e.g., change from 1961–1980 to 1981–2010)	Source(s)
Growing season (months: _____ – _____)							
No. of frost-free days							
No. of growing degree-days							
Other climate-related conditions and variables of interest to forest management planning and operations							
Drought (e.g., Climate Moisture Index[c])							
Extreme storms (e.g., wind, ice)							
Intense rainfall or rain-on-snow events (e.g., floods)							
Change in snowfall or snowpack							
Length or severity of fire season (e.g., Fire Weather Index[d])							
Change in timing of ice-in/ice-out (e.g., winter road season)							
Other							

[a]Define the timeframe for the trend (e.g., 1950–2010), and for each factor indicate the measure (e.g., change per decade or over the period).
[b]Seasonal maximum and minimum temperatures are the mean daily maximum and minimum temperatures, respectively, averaged over the months of the season.
[c]The Climate Moisture Index (CMI) was originally described by Hogg (1994, 1997) as a method for assessing differences in moisture regimes using simple climate data (temperature and precipitation).
[d]For information on the Fire Weather Index (FWI) see http://cwfis.cfs.nrcan.gc.ca/background/summary/fwi. Many Provincial and Territorial departments responsible for wildfires maintain FWI data records.

Information sources for climate data listed in Table 2.1.

Record your sources of climate data for easy reference.

Source: _____

_____

_____

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Source: _____

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Source: _____

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Source: _____

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Source: _____

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Source: _____

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Source: _____

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Worksheet 2.2. Describe the relationships among climate, forest conditions, and forest management practices

You will need to consider how climate (or weather) influences current forest management practices and plans.

Table 2.2. Relationships among current climate, forest conditions, and forest management practices

Forest conditions and processes	Relationship of climate to forest condition	Relationship of forest condition to forest management practices
Composition, productivity, disturbances, etc. (see Appendix 4 for more examples)	Example for disturbances: Wildfire is directly related to stand type and weather. Describe the role of fire and how fire shapes forest composition and productivity.	Example for wildfire: Describe how fire is managed in your area and how variability in climate and weather is incorporated into wildfire management.

Worksheet 2.3. Describe how recent climate trends or changes in forest conditions have led to changes in forest management practices

The aim of this worksheet is to highlight your organization's ability to adapt to new conditions. Climate change may already be influencing the forest ecosystem, and you may already be adapting policies and practices in response to these influences. If you have not yet noticed any changes to forest conditions in your area, there may be other factors unrelated to climate that have caused you to alter forest management plans or practices (e.g., changing markets).

Table 2.3. Recent changes to forest management plans or practices as a result of changes in forest conditions

Recent changes to forest conditions and processes	Description of change in forest condition	Description of changes in forest management
Example: Climate (or weather) has been drier and hotter for the past decade, leading to increases in fire severity and area burned.	Example: An increase in wildfire has led to greater mortality of trees (reduced timber supply), a reduction in conifer forest area (change in composition), and an increase in younger forests (altered age classes).	Example: Changes caused by wildfire have led to increased salvaging operations, increased fire-fighting capacities and capabilities, and changes in allowable annual cut.

Worksheet 2.4. Identify uncertainties and knowledge gaps

Record and describe key uncertainties or knowledge gaps that arise throughout the assessment process. The point is to record them here for use when working on later worksheets (e.g., addressing these knowledge gaps can be an adaptation option that increases adaptive capacity). Don't dwell on the uncertainties and gaps; at this stage, simply acknowledging that they exist can help move the assessment process forward.

Table 2.4. Key uncertainties and knowledge gaps about climate, forest conditions, or future scenarios identified during the vulnerability assessment process.

Uncertainty or knowledge gap	Description

7.3 Worksheets for Chapter 3

The following worksheets provide guidance on developing and describing future climate and forest impact scenarios. The worksheets are presented as tables, but it may also be useful to describe the climate and forest impact scenarios in narrative form.

Worksheet 3.1 **Develop and describe future climate scenarios**
Table 3.1 Description of future forest impact scenarios

Worksheet 3.2 **Develop and describe forest impact scenarios**
Table 3.2 Forest impact scenarios and overall forest impact ranking

Worksheet 3.1. Develop and describe future climate scenarios

Climate baseline – The baseline climate normals recorded in **Worksheet 2.1 (Describe climatic conditions and trends)** will be used as a point of reference. For many of the available climate projections, the baseline period is often taken as 1961–1990 or 1971–2000.

Climate scenarios – Once you have selected your climate scenarios, complete Table 3.1, below. This table presents a suggested list of climate and climate-related factors. You should adjust the list to include other factors that are relevant to your SFM system of interest.

Scenarios can be developed in a number of ways. For example, the overall timeframe for the scenarios may be 2014–2100 with scenarios 1–3 representing segments of time within this period (e.g., 2014–2040, 2041–2070, 2071–2100). Alternatively, you may wish to look at three or more scenarios of various degrees of climate change (e.g., low, medium, high) within a certain time frame (e.g., 2041–2070). Ideally, you should examine a range of scenarios spanning minimal to extensive climate change.

You may need to use multiple copies of these worksheets to develop a full range of scenarios, and you may also want to include detailed descriptions (e.g., narratives) of the scenarios in addition to completing the tabular worksheet.

A web application to generate various climate estimates for specific locations of interest anywhere in Canada or the United States is available at http://gmaps.nrcan.gc.ca/cl_p/climatepoints.php.

Table 3.1. Description of future climate scenarios

Location: ____

		Future climate scenarios (timeframe: _____ – _____) (measures = medians and ranges) (projection date)			
Climate factors	**Climate baseline years (______–______)**	**Scenario 1 Timeframe: ______–______ or low/med/high climate change**	**Scenario 2 Timeframe: ______–______ or low/med/high climate change**	**Scenario 3 Timeframe: ______–______ or low/med/high climate change**	**Data Sources Timeframe: ______–______ or low/med/high climate change**
Annual					
Mean temperature (°C)					
Total precipitation (mm)					
Season (months:______–______)					
Mean temperature (°C)					
Maximum / minimum temperatures (ºC)[a]					
Total precipitation (mm)					
Rainfall (mm)					
Snowfall (cm)					
Season (months:______–______)					
Mean temperature (°C)					
Maximum / minimum temperatures (ºC)[a]					
Total precipitation (mm)					
Rainfall (mm)					
Snowfall (cm)					
Season (months:______–______)					
Mean temperature (°C)					
Maximum / minimum temperatures (ºC)[a]					
Total precipitation (mm)					
Rainfall (mm)					
Snowfall (cm)					
Season (months:______–______)					
Mean temperature (°C)					
Maximum / minimum temperatures (ºC)[a]					
Total precipitation (mm)					
Rainfall (mm)					
Snowfall (cm)					

Table 3.1. Concluded

		Future climate scenarios (timeframe: _____ – _____) (measures = medians and ranges) (projection date)			
Climate factors	**Climate baseline years (_____–_____)**	**Scenario 1 Timeframe: _____–_____ or low/med/high climate change**	**Scenario 2 Timeframe: _____–_____ or low/med/high climate change**	**Scenario 3 Timeframe: _____–_____ or low/med/high climate change**	**Data Sources Timeframe: _____–_____ or low/med/high climate change**
Growing season (months:_____–_____)					
No. of frost-free days					
No. of growing degree-days					
Other climate-related conditions and variables of interest to forest management planning and operations					
Drought (e.g., Climate Moisture Index)					
Extreme storms (e.g., wind, ice)					
Intense rainfall or rain-on-snow events (e.g., floods)					
Change in snowfall or snowpack					
Length or severity of fire season (e.g., Fire Weather Index)					
Change in timing of ice-in/ice-out (e.g., winter road season)					
Other					

[a]Seasonal maximum and minimum temperatures are the mean daily maximum and minimum temperatures, respectively, averaged over the months of the season.

Information sources for climate data listed in Table 3.1.

Record your sources of climate data for easy reference.

Source: _____

_____

_____

_____

Source: _____

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_____

_____

Source: _____

_____

_____

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Source: _____

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Source: _____

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Source: _____

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_____

Source: _____

_____

_____

_____

Worksheet 3.2. Develop and describe forest impact scenarios

The term "impact" refers to the effects of climate change on natural and human systems. The effect may be direct (e.g., a change in tree growth in response to a change in the mean, range, or variability of temperature) or indirect (e.g., some influence on the frequency and severity of wildfires).

Forest impacts are based both on climate exposure, as described in **Worksheet 3.1 (Develop and describe future climate scenarios)**, and forest ecosystem sensitivity, the degree to which a system will respond to changes in climatic conditions and climate variability (e.g., extent of change in ecosystem composition, structure, and function).

In this worksheet, you can describe the range of impacts that the climate change scenarios developed in the Worksheet 3.1 may have on various aspects of the forest ecosystems within the SFM system of interest. The intent is to help you understand how these potential impacts may affect your ability to achieve SFM objectives (see section 7.4). Use the same list of forest conditions and processes that you developed in **Worksheet 2.2 (Describe the relationships among climate, forest conditions, and forest management practices)** as a starting point.

You may also want to assess an overall forest impact ranking for each scenario, using the following ranking system (see last row of Table 3.2).

Impact on forest ecosystems

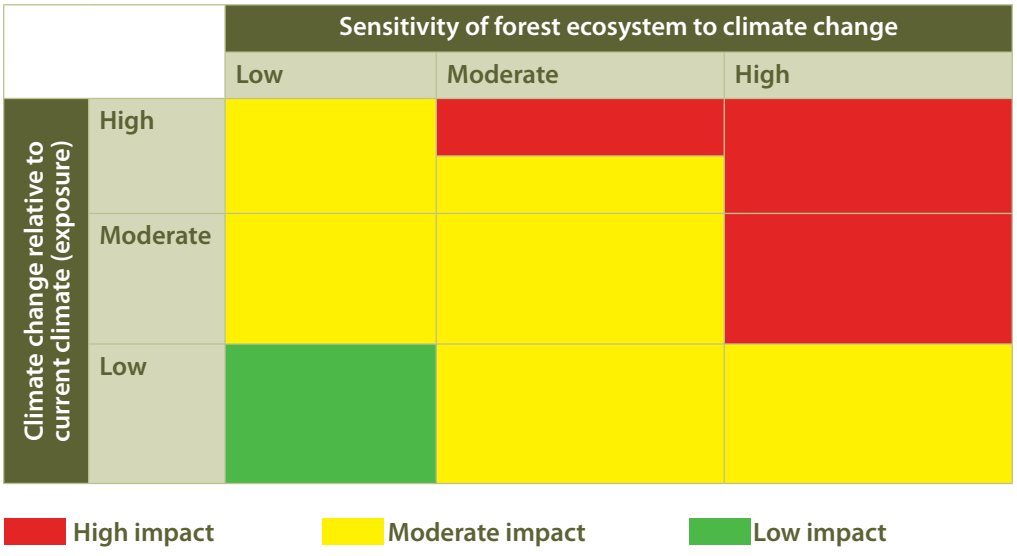

Table 3.2. Forest impact scenarios and overall forest impact ranking

Forest ecosystem condition	Forest impacts based on climate scenario 1	Forest impacts based on climate scenario 2	Forest impacts based on climate scenario 3
See Appendix 4 for examples			
Overall forest impact ranking (low, medium, high)			

7.4 Worksheets for Chapter 4

The following five worksheets provide guidance on evaluating and documenting vulnerability to current climate variability and the future forest impact scenarios developed in section 7.3.

Worksheet 4.1 **Assess current and future impacts of SFM**
- **Table 4.1** Current and potential future impacts on the SFM system of interest

Worksheet 4.2 **Evaluate adaptive capacity of the SFM system**
- **Table 4.2.1** Assessment of awareness and understanding of climate change and perceptions of risk related to climate change
- **Table 4.2.2** Assessment of knowledge capital
- **Table 4.2.3** Assessment of human capital
- **Table 4.2.4** Assessment of social capital
- **Table 4.2.5** Assessment of institutions
- **Table 4.2.6** Assessment of governance dynamics and institutional change as adaptation to climate change

Worksheet 4.3 **Assess current and future vulnerability**
- **Table 4.3** Assess the vulnerability of SFM objectives to current and potential future climate

Worksheet 4.4 **Assess overall SFM system vulnerability**
- **Table 4.4** Overall vulnerability of the SFM system

Worksheet 4.5 **Decision point: Is adaptation required?**
- **Table 4.5** Decision about adaptation

Worksheet 4.1. Assess current and future impacts on SFM

The ability to achieve SFM objectives in the future will be affected by expected impacts on the forest ecosystem from a changing climate and the sensitivity of the objectives to changes in forest ecosystems. Use the forest impacts scenarios and the overall impact rankings you created using **Worksheet 3.2 (Develop and describe forest impact scenarios)** as the basis for this worksheet. Populate these tables using the best available information (studies, expert judgments, datasets, model outputs, etc.). Note the source of information used to make each assessment. Given that the assessment of impacts on achieving SFM objectives under various future climates is somewhat subjective, the assessment team may not reach consensus on rankings. In that situation, noting the range of sensitivity (e.g., moderate to high) is an option.

To start, complete the column in Table 4.1 for impacts of current climate (and climate variability) on the ability to achieve SFM objectives. This should help you to become familiar with the process of describing how climate affects SFM objectives before introducing the added complexity of future climate change scenarios.

The following ranking system is one method of ranking the impacts of climate and climate change on each of the SFM objectives. The forest impact ranking was determined in **Worksheet 3.2 (Develop and describe forest impact scenarios)** and the sensitivity of the SFM objective is determined by the assessment team using the best available information and judgment.

SFM impact matrix

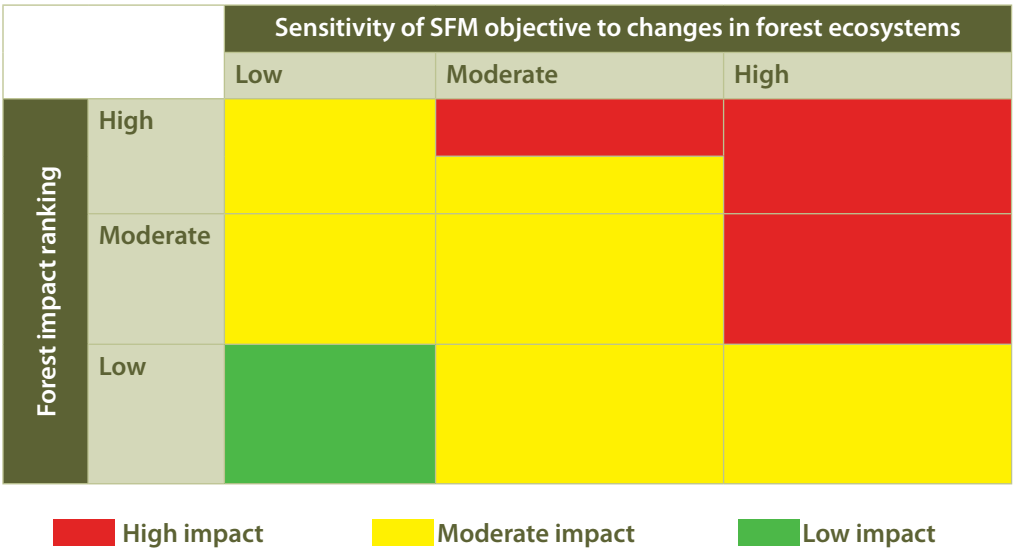

Table 4.1. Current and potential future impacts on the SFM system of interest

Combine Tables 2.2 and 3.2 to develop an idea of current impacts on SFM objectives and how those impacts may change under various forest impact scenarios. The management objectives to be listed in the first column were defined in **Worksheet 1.2-D** (Table 1.8).

SFM objectives (from Table 1.8)	Impacts of current climate on SFM objectives		Impacts on SFM objectives – scenario 1		Impacts on SFM objectives – scenario 2		Impacts on SFM objectives – scenario 3	
	Description	Ranking	Description	Ranking	Description	Ranking	Description	Ranking
CCFM criterion 1: Biological diversity								
CCFM criterion 2: Ecosystem condition and productivity								
CCFM criterion 3: Soil and water								
CCFM criterion 4: Role in global ecological cycles								
CCFM criterion 5: Economic and social benefits								
CCFM criterion 6: Society's responsibility								

Worksheet 4.2. Evaluate adaptive capacity of the SFM system

This worksheet provides a set of questions to guide the assessment of adaptive capacity as part of the broader vulnerability assessment approach described within this guidebook. The approach presented in this worksheet is relatively simple and direct. More intricate analysis of adaptive capacity can also be pursued but may require the participation of specialists. Williamson and Isaac (2013) provided a detailed overview of approaches for assessing adaptive capacity.

The capacity to adapt is the ability of individuals, organizations, or management systems to adjust to change, to take actions to moderate potential damages, to take advantage of opportunities, or to cope with the consequences of change. The means to adapt are a function of the assets and resources that contribute to adaptability (e.g., knowledge capital, human capital, social capital) and the factors that affect the ability to effectively mobilize or utilize adaptive capacity resources (e.g., awareness and perceptions of risk). Investment in adaptive capacity and the process of mobilizing adaptive capacity resources are also influenced by institutions. Sometimes, existing institutions pose barriers to adaptation (thereby reducing adaptive capacity). Thus, the ability to adapt may also depend on the ability to adjust, modify, or transform institutions. The ease with which institutions can be modified or transformed is in turn affected by the system of governance. The following are some of the key factors that contribute to the adaptive capacity of SFM organizations or systems: awareness and risk perceptions, knowledge capital, human capital, social capital (partnerships and networks), institutions, and resource governance. Questions related to each of these categories are presented in the Tables 4.2.1 – 4.2.6.

It should be noted that the capacity to adapt to climate change is not the same as a general capacity to adapt, although these concepts are related. SFM organizations and systems with a certain general capacity to adapt may in fact have a lower capacity to adapt to climate change. For example, a particular SFM organization or system might have significant human capital but lower human capital relevant to climate change impacts and adaptation. For the purposes of this assessment, both general adaptive capacity and adaptive capacity specific to climate change are of interest.

What is being assessed? The first step in assessing adaptive capacity is to identify and describe the organization or system that is being assessed. The adaptive capacity assessment should align as closely as possible with the organization or system defined in section 7.1, above.

How should the assessment be completed? The goal of this step is to assess the adaptive capacity or adaptability of the SFM organization or system, not to evaluate specific adaptations. Nonetheless, it may be helpful to think of adaptive capacity in terms of what would be needed to implement potential adaptations. For example, implementing a potential adaptation may require research, budget reallocation, increased funding, knowledge exchange, education, more knowledgeable staff, stronger networks, or changes in rules and policies. The question of adaptability pertains to the degree to which the resources that enable adaptation are available, the degree to which institutions are designed to permit adaptation where it is justified, and the flexibility of governance to allow for changes in institutions where they are needed and justified.

Tables 4.2.1 – 4.2.6 present a series of questions to guide you through an assessment of the adaptive capacity of your SFM system of interest. Many of the questions ask you to rank your response (e.g., high, medium, or low) and significant space is provided to record details of why a certain rank was chosen. It is likely members of the assessment team may have differing opinions on certain questions. It would be useful to record any discussions had on each question or difference of opinions presented within the assessment team.

4.2.1 Awareness and understanding of climate change and perceptions of risk related to climate change

Awareness and understanding of the potential effects of climate change and perceptions of risk by political leaders, senior policy makers, forest management practitioners, SFM stakeholders, and the general public will significantly influence preparedness and willingness to implement adaptation measures at various levels. Stakeholders includes those with a direct stake in forest resource management, including the forest industry, First Nations, nongovernmental organizations, other governments, grazing lease holders, trappers, outdoor recreation users, outfitters, professional foresters organizations, forest-based communities.

Table 4.2.1. Assessment of awareness and understanding of climate change and perceptions of risk related to climate change

What is the current level of awareness and understanding of **senior policy administrators or senior executives** regarding the **current and potential future impacts of climate change** on the SFM organization or system of interest?			
Ranking or response	High Medium Low	**Discussion**	
What is the current level of awareness and understanding of **forest management practitioners** responsible for forestry regarding the **current and potential future impacts of climate change** on the SFM organization or system of interest?			
Ranking or response	High Medium Low	**Discussion**	
What is the current level of awareness and understanding of **forestry stakeholders** regarding the **current and potential future impacts of climate change** on the SFM organization or system of interest?			
Ranking or response	High Medium Low	**Discussion**	
What is the current level of awareness and understanding of the **general public** regarding the **current and potential future impacts of climate change** on the SFM organization or system of interest?			
Ranking or response	High Medium Low	**Discussion**	
Is climate change perceived as a significant risk to achieving SFM objectives by senior policy administrators or senior executives who oversee the SFM organization or system of interest?			
Ranking or response	Yes No	**Discussion**	
Is climate change perceived as a significant risk to achieving SFM objectives by forest management practitioners within the SFM system of interest?			
Ranking or response	Yes No	**Discussion**	
Is climate change perceived as a significant risk to achieving SFM objectives by forestry stakeholders within the SFM system of interest?			
Ranking or response	Yes No	**Discussion**	
Is climate change perceived as a significant risk to achieving SFM objectives by the general public in the area of interest?			
Ranking or response	Yes No	**Discussion**	
Are actions needed to increase awareness and understanding of climate change risks for the SFM organization or system of interest? If so, what actions are suggested?			
Ranking or response	Yes No	**Discussion**	

4.2.2 Knowledge capital (science, information, knowledge exchange, and technology)

Knowledge capital is the stock of scientific and nonscientific information that supports forest management and the information management process to ensure access to and usability of the information. In the context of climate change, knowledge capital is the stock of relevant knowledge or information that supports impacts analysis and adaptation decision making for the SFM organization or system of interest. Knowledge capital related to climate change also includes the ability to develop, interpret, and utilize scientific knowledge and information about climate change and the ability to communicate and make accessible relevant knowledge and information. It includes the processes by which information is acquired, accessed, and communicated, as well as the capacity for knowledge exchange. Knowledge exchange and information management contribute to increased awareness of climate change and to more informed and effective decision making. Knowledge gaps can pose significant barriers to adaptation.

Table 4.2.2. Assessment of knowledge capital

What is the overall general state of knowledge capital for the SFM system of interest?			
Ranking or response	High Medium Low	**Discussion**	
What is the overall state of knowledge capital relevant to **climate change impacts and adaptation** (including knowledge related to potential impacts)?			
Ranking or response	High Medium Low	**Discussion**	
Are there significant knowledge gaps about **climate change** that are preventing forest managers from adapting forest management to climate change?			
Ranking or response	Yes No	**Discussion**	
Is there a need to strengthen knowledge exchange activities and science or management partnerships related to **climate change** impacts and adaptation?			
Ranking or response	Yes No	**Discussion**	
Does **climate change** necessitate increases in scientific research, information gathering, and knowledge exchange for the SFM organization or system of interest?			
Ranking or response	Yes No	**Discussion**	

4.2.3 Human capital

Human capital refers to the people involved in forest management for the SFM organization or system of interest, their educational attainment, training, and experience, and their skills, capabilities, competencies, and aptitudes.

Table 4.2.3. Assessment of human capital

What is the total number of forest management professionals (including forest management technicians) within the SFM organization or SFM system of interest?			
Ranking or response	High Medium Low	**Discussion**	
What is the total number of **climate change impacts and adaptation specialists** within the SFM organization or system of interest, and what are their specialties (e.g., climate scenario construction, forest response, social and economic impacts)?			
Ranking or response	High Medium Low	**Discussion**	
What is the level of knowledge, experience, education, training, and skill of forest managers, decision makers, and forestry stakeholders within the SFM organization or system of interest, and what are the key contributing factors (e.g., educational attainment, educational institutions, curriculum, training, professional standards)? Note, you may need to answer this question separately for each group (i.e., managers, decision makers, stakeholders)			
Ranking or response	High Medium Low	**Discussion**	
What is the level of knowledge, experience, education, training, and skill of forest managers, decision makers, and forestry stakeholders within the SFM organization or system of interest in areas pertaining to **climate change impacts and adaptation**, and what are the key contributing factors? Note, you may need to answer this question separately for each group (managers, decision makers, stakeholders).			
Ranking or response	High Medium Low	**Discussion**	
Is there a willingness among forest managers, decision makers, and forestry stakeholders to learn about **climate change impacts and adaptation**?			
Ranking or response	Yes No	**Discussion**	
Will **climate change** necessitate an enhancement of human capital for the SFM organization or system of interest? If so, exactly how?			
Ranking or response	Yes No	**Discussion**	

4.2.4 Social capital (partnerships and networks)

Social capital refers to human partnerships and networks. Such partnerships and networks can facilitate and contribute to innovative problem solving, improved access to information, collective actions, and access to resources that would not otherwise be available. Mutual respect and trust are important requirements for the effective functioning of partnerships and networks.

Table 4.2.4. Assessment of social capital

What key forestry-related groups, associations, organizations, and networks have a role in, contribute to, or have a stake in the delivery of SFM objectives for the SFM organization or system of interest? Specify the degree to which these groups work together in contributing to the implementation of SFM objectives.			
Ranking or response	Not applicable	**Discussion**	
What processes are in place to engage people at local to regional levels for the purposes of encouraging collaborative decision making? Will **climate change** require a change in the collaborative decision-making process?			
Ranking or response	Not applicable	**Discussion**	
What mechanisms (formal or informal) are in place to resolve differences (or conflicts)? Will **climate change** necessitate any changes in dispute settlement or conflict resolution?			
Ranking or response	Not applicable	**Discussion**	
How important are partnerships and networks to the ability of the SFM organization or system to adapt to change in general?			
Ranking or response	Very important Somewhat important Marginally important	**Discussion**	
Generally, the people in the forestry-related groups, associations, organizations, and networks that are involved in the SFM system of interest display mutual respect and trust for each other. There is a sense of community among individuals who are part of the SFM system.			
Ranking or response	Strongly agree Somewhat agree Disagree	**Discussion**	
To what extent do individuals, groups, and organizations cooperate and collaborate in addressing **climate change** issues?			
Ranking or response	Strongly Moderately Minimally	**Discussion**	
What additional arrangements are needed among groups and organizations for a collaborative and coordinated approach to SFM in a rapidly changing climate?			
Ranking or response		**Discussion**	

4.2.5 Institutions

Institutions are the laws, policies, customs, traditions, accepted practices, property rights, rules, norms, protocols, and standards that guide, direct, prescribe, or motivate forest management decisions and choices. Institutions can be formal (e.g., laws and policies) or informal (e.g., norms and customs).

Successful adaptation (i.e., adaptation that is rational, effective, and justified) requires that institutions allow for consideration of the current and potential future impacts of climate change on forests and on human values associated with forests. That is to say, institutions that effectively account for climate change provide the motivation, incentives, and authority for rational adaptation, along with disincentives or sanctions for failure to adapt (in cases where adaptation is warranted) or for maladaptation (i.e., inappropriate or unjustified adaptation). Institutions represent a key component of adaptive capacity, because those that fail to account for climate change will likely act as barriers to rational adaptation.

One of the major challenges to forestry institutions is to account for the increased levels of complexity and uncertainty associated with forest management policy, planning, and decision making under a changing climate. Institutional characteristics that are typically favoured by decision makers and stakeholders are lack of ambiguity, predictability, fairness, efficiency, stability, and consistency. However, under a changing climate, the following characteristics of forestry institutions are desirable: they explicitly recognize the potential impacts of climate change; they are forward-looking, while accounting for the significant uncertainties of future forest conditions and forest values under a changing climate; they are flexible; they are responsive; they accommodate or incorporate a diverse range of management options and forest conditions; they enable or permit adaptation to local impacts; they permit or enable, to some degree, an adaptive management approach; and they provide appropriate incentives for building adaptability or adaptive capacity.

The influence of institutions on the adaptive capacity of SFM systems can be assessed in various ways. The table below presents a number of questions related to general characteristics of forest management institutions, followed by an assessment of specific climate change adaptability considerations related to SFM policy, assessment and monitoring, forest management planning, and forest management practices (e.g., reforestation, harvesting).

Table 4.2.5. Assessment of institutions

4.2.5.1 General characteristics of forest management and SFM institutions			
Do **informal** forestry management and SFM institutions take account of current (or recent) and future climate change? (Questions related to formal institutions appear in section 4.2.5.2)			
Ranking or response	Yes No	**Discussion**	
Are current institutions (both formal and informal) sufficiently forward-looking while also accounting for the uncertainties of climate change?			
Ranking or response	Yes No	**Discussion**	
Are current institutions sufficiently flexible to deal with climate change?			
Ranking or response	Yes No	**Discussion**	
Are current institutions sufficiently responsive to climate change impacts as they occur?			
Ranking or response	Yes No	**Discussion**	
Do current institutions accommodate or incorporate a sufficiently diverse range of management options under changing forest conditions?			
Ranking or response	Yes No	**Discussion**	
Do SFM institutions enable or permit local adaptation to local impacts?			
Ranking or response	Yes No	**Discussion**	
Do SFM institutions allow or enable adaptive management?			
Ranking or response	Yes No	**Discussion**	
Do SFM institutions provide appropriate incentives for building adaptability or adaptive capacity (i.e., by enhancing adaptive capacity assets or improving the processes for mobilizing such assets)?			
Ranking or response	Yes No	**Discussion**	
4.2.5.2 Forestry legislation and SFM policy			
Do existing forestry legislation and SFM policy consider current (or recent) and future climate change?			
Ranking or response	Yes No	**Discussion**	
Is reducing the impacts of climate change a specific objective of the SFM organization or system of interest? If so, has it been incorporated in operating rules and guidelines, or is it considered in how guidelines are interpreted?			
Ranking or response	Yes No	**Discussion**	
Is there a need to amend or replace forestry legislation and SFM policy to enable adaptation to climate change and to provide the authority to adapt to climate change at appropriate levels? If so, how should this be done?			
Ranking or response	Yes No	**Discussion**	

Table 4.2.5. Continued

4.2.5.3 Forest tenure system			
Is current (or recent) and future climate change considered in existing forest tenure agreements?			
Ranking or response	Yes No	**Discussion**	
Are tenure agreements sufficiently flexible and of sufficient duration (i.e., long term), and do they provide sufficient incentives and motivation for tenure holders to adapt to the current and anticipated future impacts of climate change? For example, do tenures include the following features? • adaptive management • assessment and monitoring by tenure holders • long-term forest management plans prepared by tenure holders • timber management planning • reforestation and thinning • forest management to reduce disturbance impacts • road planning and development			
Ranking or response	Yes No	**Discussion**	
4.2.5.4 Assessment and monitoring			
Have the vulnerabilities, impacts, and risks associated with climate change been assessed (or are they assessed regularly)?			
Ranking or response	Yes No	**Discussion**	
Are the effects of climate change and other change factors monitored regularly?			
Ranking or response	Yes No	**Discussion**	
Is there a need to modify or enhance assessment and monitoring efforts under a changing climate? If so, how?			
Ranking or response	Yes No	**Discussion**	
4.2.5.5 Planning			
Is climate change considered in strategic planning for the SFM organization or system of interest?			
Ranking or response	Yes No	**Discussion**	
Is climate change included in long-range forest management planning? If so, how (e.g., through the use of scenarios)?			
Ranking or response	Yes No	**Discussion**	
Is there a need to modify planning approaches (either organizational strategic planning or long-term forest management planning) to account for climate change?			
Ranking or response	Yes No	**Discussion**	

Table 4.2.5. Concluded

4.2.5.6 Practices			
Do forest management practices, guidelines, and on-the-ground decisions consider climate change?			
Ranking or response	Yes Somewhat No	**Discussion**	
Is there a need to modify forest management practices to enable adaptation to climate change? If so, what should be done?			
Ranking or response	Yes No	**Discussion**	
4.2.5.7 Protection (from fire, insects, disease, drought)			
Is there a need to modify forest protection practices to enable adaptation to climate change? If so, what should be done?			
Ranking or response	Yes No	**Discussion**	

4.2.6 Resource governance dynamics and institutional change

Resource governance can be defined as the manner in which rules about resource management are established, implemented, and modified as deemed necessary and appropriate. Given the preponderance of provincially owned forest land in Canada, forest resource governance is largely the responsibility of provincial forest management agencies. Resource governance regimes in Canada are continuously evolving and adapting to new ecological, economic, cultural and social conditions. Modifying institutions in response to change is not a novel concept. However, climate change offers a new and somewhat unprecedented driver of change. It is not something that resource governance regimes have necessarily experienced in the past or for which they have precedents. The relative capacity of resource governance systems to make necessary changes to institutions to properly adapt to climate change, and the ease with which they do so, will vary from situation to situation. Thus, this section of the adaptive capacity assessment considers the ability of resource governance regimes to adapt their institutions in anticipation of climate change, considering both the mechanisms and the challenges of adapting institutions. A self-assessment approach is proposed.

Table 4.2.6. Assessment of governance dynamics and institutional change as adaptation to climate change

If there is a need to amend or replace forestry legislation or SFM policies to address climate change, what is the most appropriate process, what would be required, what are the challenges, and what is the expected timing?			
Ranking or response	Not applicable	**Discussion**	
If there is a need to amend or replace forestry tenure arrangements to address climate change, what would be required, and what are the challenges?			
Ranking or response	Not applicable	**Discussion**	
If there is a need to modify or enhance climate change assessment and monitor efforts, what is the most appropriate process, what would be required, what are the challenges, and what is the expected timing?			
Ranking or response	Not applicable	**Discussion**	
If there is a need to modify or enhance strategic and long-term forest management planning approaches in response to climate change, what is the most appropriate process, what would be required, what are the challenges, and what is the expected timing?			
Ranking or response	Not applicable	**Discussion**	
If there is a need to modify forest management practices (e.g., reforestation standards, harvesting practices, road construction) to enable adaptation to climate change, what is the most appropriate process, what would be required, what are the challenges, and what is the expected timing?			
Ranking or response	Not applicable	**Discussion**	
In general terms, is resource governance for the SFM system responsive to change and does it have the ability to bring in new rules or modify existing rules in a timely, effective, and efficient fashion?			
Ranking or response	Yes Somewhat No	**Discussion**	

Identify and discuss other factors that affect the adaptive capacity of the forest management organization or forest management system of interest.

Overall rating of the general adaptive capacity of the SFM system

Given your answers to the questions above, what is the general capacity of the SFM system to adapt to all drivers of change?

High _____ Medium _____ Low_____

Discussion: _____

_____

_____

_____

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_____

_____

Overall rating of capacity to adapt to climate change

Focusing on climate change as a driver and considering your answers to the questions in Tables 4.2.1–4.2.6, what is the capacity of the SFM system to adapt to climate change?

High _____ Medium _____ Low _____

Discussion: _____

_____

_____

_____

_____

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_____

_____

_____

_____

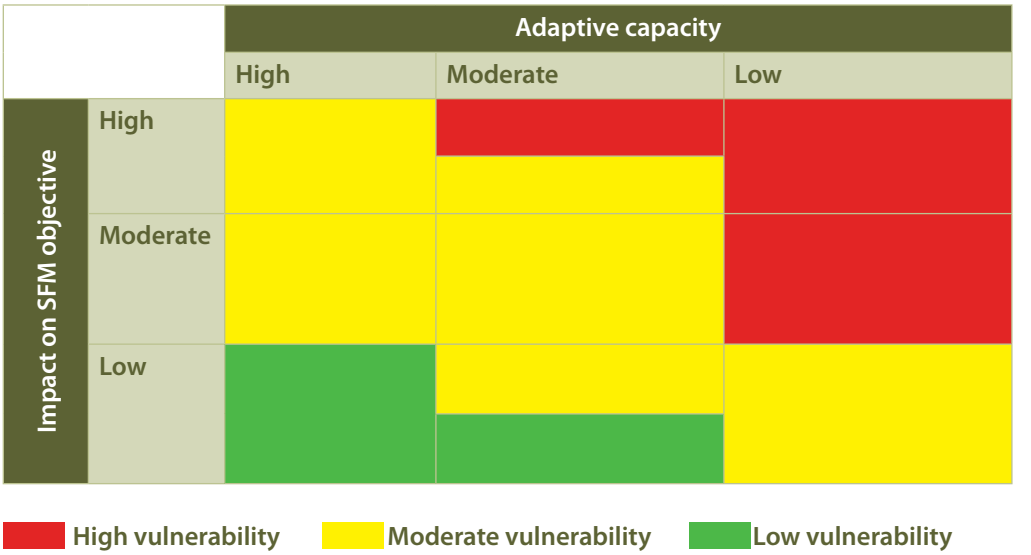
Worksheet 4.3. Assess current and future vulnerability

Use the results from the two preceding worksheets **(Worksheet 4.1** and **Worksheet 4.2)** to complete **Worksheet 4.3 (Assess current and future vulnerability)**.

Use the vulnerability matrix below to rank the current vulnerability of the SFM system in terms of the ability to achieve management objectives. Then rank the future vulnerability of achieving each SFM objective.

Instead of seeking consensus on a single ranking, you may wish to provide a range of rankings from various sources.

Vulnerability matrix for SFM objective or system



Intuitive scan: Once you have completed the rankings for each objective, scan the vulnerability rankings to intuitively check for internal consistency and logical results. Explore inconsistencies by returning to the earlier worksheets to understand the background information that led to the ranking.

Once you have scanned and, if necessary, adjusted the vulnerability rankings for each objective, conduct a scan across all the objectives. This is particularly important if different focus groups completed the assessments for different objectives. Again, check for internal consistency and logic, and adjust as needed.

Use the impacts on SFM objectives determined in **Worksheet 4.1 (Assess current and future impacts on SFM)** and the assessment of adaptive capacity to climate change from **Worksheet 4.2 (Evaluate adaptive capacity of the SFM system)** to determine the vulnerability of SFM objectives under current climate conditions and future climate scenarios.

Use current adaptive capacity to assess the vulnerability of the SFM objectives (as listed in Table 1.9 in **Worksheet 1.2-D**) in each scenario. Use additional pages if necessary to describe the potential vulnerabilities that you identify.

Table 4.3. Assess the vulnerability of SFM objectives to current and potential future climate

SFM objectives (Table 1.9) .	Current forest condition			Forest impact scenario 1		Forest impact scenario 2		Forest impact scenario 3	
	Impact on SFM objective	Adaptive capacity	Vulnerability	Impact on SFM objective	Vulnerability	Impact on SFM objective	Vulnerability	Impact on SFM objective	Vulnerability

Worksheet 4.4. Assess overall SFM system vulnerability

Bring all the analyses together to create a larger picture. Are you currently able to meet your SFM objectives? Are your SFM goals and objectives vulnerable to climate change? How is the system vulnerable? Given current climate and climate variability and expected future climate change impacts, what are the reasons that certain SFM goals and objectives may not be met?

Table 4.4. Overall vulnerability of the SFM system

	Vulnerability of the SFM system to climate change
Current Climate	
Scenario 1	
Scenario 2	
Scenario 3	
Other scenarios, as appropriate	

Worksheet 4.5. Decision point: Is adaptation required?

If the SFM system of interest is vulnerable to climate change impacts or if the system is expected to be vulnerable in any of the future climate scenarios, you will want to proceed with identifying and implementing adaptation options (as detailed in sections 7.5 and 7.6, below). If the vulnerability of the SFM system is low and the potential effects of climate change under the various scenarios are mild, you may wish to monitor the system and reassess vulnerability as you gain new knowledge, learning, or insights.

Table 4.5. Decision about adaptation

Is adaptation required?	Action
☐ Yes	Proceed to sections 7.5 and 7.6
☐ No	Continue to monitor the SFM system and reassess vulnerability if changes are noticed or if new knowledge is gained

7.5 Worksheets for Chapter 5

The following worksheets are designed to help you develop and assess adaptation options for SFM.

Worksheet 5.1 **Develop potential adaptation options for SFM objectives**
- **Table 5.1** Prioritize vulnerabilities of SFM objectives
- **Table 5.2** Potential adaptation options for SFM objectives and assessment of importance of implementation

Worksheet 5.2 **Develop potential adaptation options for the overall SFM system of interest**
- **Table 5.3** Potential adaptation options for the SFM system

Worksheet 5.1. Develop potential adaptation for SFM objectives

Prioritize the vulnerabilities of SFM objectives: On the basis of work done in Table 4.3, review the vulnerability (i.e., high, medium, or low) of the SFM objectives in your study area to current climate and future scenarios of climate change. You may want to sort the vulnerabilities from high to low, or start only with objectives that are ranked high or medium across all scenarios. Record the selected priority objectives in the table below and indicate how they are vulnerable to climate change. This step is optional, and you may instead decide to consider all vulnerabilities listed in Table 4.3.

Table 5.1. Prioritize vulnerabilities of SFM objectives

SFM objectives	Current vulnerability	Future vulnerability – scenario 1	Future vulnerability – scenario 2	Future vulnerability – scenario 3

Develop a list of potential adaptation options: All options can be considered at this stage, with prioritization and feasibility of implementation to be assessed later. You may first want to review the list of adaptation options in Appendix 5. These options, compiled from the literature, are suggested ways to adapt forest management policies and practices to achieve management objectives in a changing climate. In Table 5.2, list potential adaptation options for each SFM objective. You may also want to flag certain options as follows:

- Classify options as strategic, operational, or adaptive capacity options (doing so now may help to define an implementation plan later on).
- Indicate whether each adaptation option is useful for reducing a negative impact on the objective or increasing a potential opportunity to help achieve the objective.

Reviewing the knowledge gaps and uncertainties list you have created as you have worked through this guidebook may also be a good starting point for identifying options.

You may want to describe the adaptation options in more detail than the space in Table 5.2 allows; if so, use additional pages.

Table 5.2. Potential adaptation options for SFM objectives and assessment of importance of implementation

SFM objective (from Table 5.1)	SFM impact and vulnerability	Potential adaptation option	Strategic, operational, or adaptive capacity?	Reduce negative impact or increase potential opportunity?	Importance of implementation to achieve management objective in study area				Important options
					Current climate conditions	Scenario 1	Scenario 2	Scenario 3	

Assess the importance of implementing each adaptation option: Once you have identified the potential adaptation options, assess each option in terms of its importance for implementation to achieve management objectives in the SFM system of interest, considering the vulnerabilities noted in Table 5.1. Assess each option for "current climate conditions" and for each future climate scenario. The following scale could be used to rate these options: VI = very important, I = important, N= not important, ? = importance unknown.

Identify important or beneficial adaptation options: Determine which adaptation options are more generally important by identifying robust, no-regret, win–win, and must-do options.

Worksheet 5.2. Develop potential adaptation options for the overall SFM system of interest

In this worksheet you will develop options to reduce SFM system vulnerabilities or increase SFM system-wide adaptive capacity.

Refer back to **Worksheet 4.4 (Assess overall SFM system vulnerability)** and consider whether there are options that could be implemented to reduce SFM system vulnerabilities or increase SFM system-wide adaptive capacity. Such options would span many or all SFM objectives (e.g., increased partnerships and collaborations with governments, research institutes, and stakeholders or interested parties; new approach to decision making within your organization).

Assess these broader options according to a scale of the importance of implementation of each option for achieving SFM objectives. The following scale could be used to rate these options: VI = very important, I = important, N = not important, ? = importance unknown.

Identify adaptation options that are more generally important (e.g., those that are robust, no-regret, win–win, and must-do).

Table 5.3. Potential adaptation options for the SFM system

Potential SFM system adaptation option	Impact or vulnerability	Strategic, operational, or adaptive capacity?	Reduce negative impact or increase potential opportunity?	Importance of implementation to achieve SFM				Important options
				Current climate conditions	Scenario 1	Scenario 2	Scenario 3	

7.6 Worksheets for Chapter 6

The following worksheets provide guidance on mainstreaming adaptation for SFM.

Worksheet 6.1 **Prioritize adaptation options**
- **Table 6.1** Description of the process for prioritizing adaptation options
- **Table 6.2** Prioritized adaptation options

Worksheet 6.2 **Recommended priority adaptation options for implementation**
- **Table 6.3** Assessment and recommendation of priority adaptation options
- **Table 6.4** Expected achievement of SFM objectives

Worksheet 6.3 **Implement (mainstream) recommended adaptations**
- **Table 6.5** Implementation requirements for recommended adaptations (template to be completed for each adaptation)

Worksheet 6.4 **Evaluate adaptation performance**
- **Table 6.6** Description of evaluation of adaptation performance over time

Worksheet 6.1. Prioritize adaptation options

Prioritize adaptation options identified as important in **Worksheet 5.1 (Develop potential adaptation options for SFM objectives)** and **Worksheet 5.2 (Develop potential adaptation options for the overall SFM system of interest)**. Describe the prioritization process and list who was involved.

Table 6.1. Description of the process for prioritizing adaptation options

Description of the process for prioritizing adaptation options

Record the top adaptation options identified through the prioritization exercise and describe why they have priority. These options should be selected because of their potential to help in achieving SFM objectives, not because of their suitability or feasibility, which will be assessed using Worksheet 6.2. The first five columns of Table 6.2 are carried forward from Tables 5.2 and 5.3.

Table 6.2. Prioritized adaptation options

Prioritized adaptation option	SFM objective or overall SFM system	Impact or vulnerability	Strategic, operational, or adaptive capacity?	Reduce negative impact or increase potential opportunity?	Describe why this adaptation option is a priority

Worksheet 6.2. Recommend priority adaptation options for implementation

Use the list of top-priority adaptation options to complete Tables 6.3 and 6.4. For each option, assess the following:

- Is the option a modification of current practice? If so, note where it is referenced in an existing policy, plan, or operations guide.
- Is the adaptation ecologically suitable and socially acceptable?
- Is the implementation of the adaptation financially and technically feasible? In particular, is implementation feasible given institutional and organizational considerations?
- Does the option conflict with other management objectives or SFM values? If so, note them here. Are these conflicts resolvable?
- Given the suitability, feasibility, and potential conflicts, can the adaptation option be recommended for implementation?
- What is the timeframe for implementation (e.g., immediate, near future, distant future). Define the various timeframes in specific terms.
- With implementation of these adaptations, do you expect to be able to achieve SFM objectives in your study area? Indicate yes, no, or uncertain in Table 6.4, with a brief explanation.

Table 6.3. Assessment and recommendation of priority adaptation options

SFM objective or overall SFM system	Priority adaptation option	Currently practiced? (if yes, note reference)	Suitability and acceptability	Feasibility	Conflicts with other SFM objectives	Recommended for implementation?	Timeframe for implementation

Consider whether, once these adaptations have been implemented, you can expect to achieve SFM objectives in your study area. If not, you may need to consider additional adaptations or refine the identified adaptations.

Table 6.4. Expected achievement of SFM objectives

SFM objective (from Table 1.8)	Expected achievement (yes or no, with explanation)

Worksheet 6.3. Implement (mainstream) recommended adaptations

Using the template presented in Table 6.5, identify the implementation requirements associated with each priority adaptation option. You may want to group the options by SFM objective and overall SFM system adaptation options or by strategic, operational, or adaptive capacity categorization. For each recommended adaptation option, consider the following:

- Assess the jurisdiction within which the adaptation actions fall and the roles and responsibilities of various agencies and individuals in implementation.
- Identify the actions required to implement the adaptation (e.g., changes in planning, procedures, policies, regulations, legislation, investments, protocols, guidelines, training, and operational methods).
- Identify opportunities to mainstream the adaptation into regular business processes.
- Identify roles and responsibilities (i.e., the specific person or department that will lead implementation and other individuals or departments that should be involved). Set deadlines for implementation progress.
- Assess the internal support required for implementation to proceed (e.g., operational staff, specialists, senior management, political leaders).
- Assess the external support required for implementation to proceed (e.g., involvement or buy-in from other organizations).
- Identify the human resources required for implementation to proceed and assess whether these resources are available or if they must be secured.
- Assess information and/or training needs that may be required to implement the adaptation.
- Identify the financial resources required for implementation to proceed and assess whether these resources are available or if they must be secured.
- Describe what successful implementation would look like (e.g., all planning and operations staff are knowledgeable about climate change impacts and adaptation; silvicultural operations reflect changes in precipitation).
- Identify the overall schedule, the timing of specific events, and the milestones associated with implementation.
- Determine if there is a need to communicate with decision makers, other staff, or interested parties about the adaptation and its potential implications.
- Determine if there is an existing monitoring or tracking plan into which this adaptation should be incorporated.
- Consider whether the adaptation can help to achieve other non-SFM objectives or goals.

Table 6.5. Implementation requirements for recommended adaptations (template to be completed for each adaptation)

Recommended adaptation				
SFM objective(s)		**Strategic, operations, or adaptive capacity**		
Jurisdiction and decision-making responsibility				
Actions required for implementation				
Opportunities for mainstreaming				
Implementation roles and responsibilities (Who is doing what and by when?)				
Requirements for	**Internal support**			
	External support			
	Human resources			
	Information & training			
	Financial resources			
What does success look like?				
Milestones				
Communication needs				
Is there a monitoring or tracking plan into which this option should be incorporated?				
Does this adaptation help to achieve other non-SFM objectives or goals?				

Worksheet 6.4. Evaluate adaptation performance

Table 6.6. Description of evaluation of adaptation performance over time

Describe the process for evaluating adaptation effectiveness

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APPENDIXES

Appendix 1. 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).

Adaptation options

Potential actions or activities to address or reduce the vulnerabilities identified in a vulnerability assessment.

Adaptation recommendations

A subset of adaptation options, consisting of those options that will benefit sustainable forest management objectives and for which implementation is acceptable and feasible.

Adaptive capacity

"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" (Parry et al. 2007). In this report, adaptive capacity refers to the human (as opposed to the biological) components of the sustainable forest management system.

Adaptive capacity assessment

Assessment of (1) the human and institutional resources and capacities (for example, human capital, social capital) available to identify adaptation requirements and to implement adaptation actions; (2) the structural attributes, properties, and characteristics that affect the ability of a system to adapt (for example, flexibility, rigidity, diversity, liquidity, substitutability); and (3) the factors that impair optimal choices related to adaptation and adaptive capacity requirements (for example, inefficient institutions, critical knowledge gaps, lack of awareness, biased perceptions of risk).

Adaptive management

"A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices" (MEA 2005).

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).

Climate change impacts

"The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts." Potential impacts are "all impacts that may occur given a projected change in climate, without considering adaptation." Residual impacts are "the impacts of climate change that would occur after adaptation" (Parry et al. 2007). In vulnerability assessment, impacts are the result of exposure to climate change and the sensitivity of the sustainable forest management system to a particular level of exposure.

Climate variability

"Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. The term is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) from the long-term statistics relating to the corresponding calendar period. In this sense, climate variability is measured by those deviations, which are usually termed anomalies. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability)" (WMO n.d.).

Driver

Any natural or human-induced factor that directly or indirectly causes a change in a system, such as an ecosystem, managed forest, or human community (MEA 2005). Examples include changes in atmospheric concentrations of greenhouse gases driving changes in planetary mean temperature or changes in societal values driving changes in forest use.

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).

Ecosystem services

"Ecological services or functions having monetary or non-monetary value to individuals or society at large. There are (i) supporting services such as productivity or biodiversity maintenance, (ii) provisioning services such as good, fibre, or fish, (iii) regulating services such as climate regulation or carbon sequestration, and (iv) cultural services such as tourism or spiritual and aesthetic appreciation" (Parry et al. 2007).

Ecozone

"A broad, ecologically distinctive area delineated at a 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; these are subdivided into 53 ecoprovinces, the ecoprovinces into 194 ecoregions, and the ecoregions into 1020 ecodistricts" (CCFM 2006).

Exposure

The degree of climate change imposed upon a particular unit of analysis. Exposure may be represented as long-term changes in climate conditions, as well as by changes in climate variability, including the magnitude and frequency of extreme events (McCarthy et al. 2001).

Forest impact scenarios

A range of possible future forest conditions that could result under a given climate scenario. Forest impact scenarios include descriptions of changes in (1) processes such as physiological processes, phenological processes, and regeneration; (2) the frequency and intensity of biotic disturbances, such as insect outbreaks and diseases, and abiotic disturbances, such as severe weather, drought, and wildfire; (3) ecosystem health and productivity; (4) forest inventory; and (5) forest composition and age-class over the landscape.

Mainstreaming adaptation

Inclusion of climate change considerations in day-to-day decision making and management on a continuous and ongoing basis.

Resilience

"The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" (Parry et al. 2007).

Scenarios

"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).

Sensitivity assessment

Assessment of the sensitivity or magnitude of a system's potential response to a particular rate and magnitude of change in local climate (including change in mean values and changes in variability and extremes). Sensitivity can be reduced or modified by adaptation.

Sustainable forest management (SFM)

"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.

Sustainable forest management system

A coupled human–environmental system that obtains goods and services from forests and works toward the management of forests in a manner consistent with sustainable forest management (SFM) principles and objectives. SFM systems vary with spatial, operational, and organizational contexts. An SFM system can exist at any scale, including provincial forests, community forests, protected areas, industrial lease areas, and small private woodlots.

Vulnerability

"The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Parry et al. 2007).

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Appendix 2. Examples of Factors Triggering a Sustainable Forest Management Vulnerability Assessment

Users of this guidebook are encouraged to identify their own factors in addition to any relevant examples from this list.

Environmental and Ecological

- Past extreme event (e.g., insect infestation, fire, intense precipitation)
- Past slow changes in climate and/or ecosystems, including forests (e.g., species die-off)
- Anticipated future extreme events
- Anticipated future slow changes in climate and/or ecosystems
- Identified vulnerability (e.g., results of a scientific study or anecdotal evidence)

Economic

- Desire to realize concurrent benefits (e.g., job creation, community sustainability)
- Demands from investors or insurance agencies that climate considerations be built into plans
- Funding opportunities for climate change adaptation activities

Social or cultural

- Desire to adopt "best management practices" or to be an "early adopter"
- Pressure from interest groups or the public
- Professional ethics
- Risk perceptions and concerns of managers, practitioners, and/or the public

Appendix 3. Criteria and Indicators of Sustainable Forest Management of 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 for 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. <http://www.ccfm.org/pdf/CI_Booklet_e.pdf> (accessed April 28, 2014).

Appendix 4. Examples of Ecological, Economic, Social, and Cultural Factors to be Considered

These examples can be used in Tables 2.2, 2.3, and 3.2.

Forest conditions and processes

- Forest cover type and age-class distribution
- Forest growth, mortality, and/or productivity
- Frequency, intensity, severity, or magnitude of forest fires
- Frequency, intensity, severity, or magnitude of pest outbreaks
- Phenology (timing of spring budburst, flowering, etc.)
- Regeneration success
- Treeline change (elevation or latitude)
- Abundance and ranges of invasive species
- Abundance, movement, and ranges of wildlife species

Land and water conditions

- Access (length of winter road season)
- Roads (including bridges and culverts)
- Drainage structures
- Length of season when ground and water bodies are frozen
- Timing and peak levels of stream flows
- Stability of terrain
- Abundance, movement, and ranges of fish and other aquatic species

Socioeconomic conditions (including cultural factors)

- Timber supply
- Timber values
- Operating costs
- Markets
- Availability of nontimber forest products
- Land values and land-use options
- Economic opportunities
- Livelihood (employment and income)
- Cultural activities
- Forest recreation activities and facilities

Appendix 5. Inventory of Potential Adaptation Options

The following inventory (compiled from Ogden and Innes [2007] and Innes et al. [2009]) lists examples of strategic and operational adaptation options gleaned from the literature. The Canadian Council of Forest Ministers (CCFM) does not endorse any particular adaptation options listed here, nor does it intend this list to be used as a prescription for adapting sustainable forest management (SFM) to climate change. Users of this guidebook are encouraged to develop their own adaptation options through the processes described and to consult Ogden and Innes (2007), Innes et al. (2009), and the original cited references for more detail on each option before implementing any option listed in this table.

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Biological diversity	Alteration of plant and animal distribution	Strategic	Minimize fragmentation of habitat and maintain connectivity	Peters 1990; Noss 2001
			Maintain representative forest types across environmental gradients in reserves	Holling 2001; Noss 2001
			Protect primary forests (i.e., forests largely undisturbed by human activities)	Noss 2001
			Protect climate refugia at multiple scales	Noss 2001
			Identify and protect functional groups and keystone species	Holling 2001; Noss 2001
			Provide buffer zones for adjustment of reserve boundaries	Noss 2001
			Protect most highly threatened species *ex situ*	Noss 2001
			Develop a gene management program to maintain diverse gene pools	Parker et al. 2000; Noss 2001
			Strategically increase size and number of protected areas, especially in "high-value" areas	Innes et al. 2009
			Ensure that conservation corridors extend across environmental gradients	Innes et al. 2009
			Ensure that infrastructure investments do not interrupt conservation or riparian corridors	Innes et al. 2009
			Increase regional cooperation in management of both species and protected areas	Innes et al. 2009
			Create artificial reserves or arboreta to preserve rare species	Parker et al. 2000
		Operational	Practice low-intensity forestry and prevent conversion to plantations	Noss 2001
			Assist changes in the distribution of species by introducing them to new areas	Parker et al. 2000
			Establish neo-native forests	Innes et al. 2009
			Increase colonization capacity in areas between existing habitat and potential new habitat	Innes et al. 2009

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Biological Diversity	Alteration of plant and animal distribution	Operational	Design tree plantations to have a diverse understory	Innes et al. 2009
			For planted forests, establish indigenous, mixed-species stands, maximize natural genetic diversity, mimic the structural properties of the surrounding forests, and avoid direct replacement of native ecosystems	Innes et al. 2009
	Invasion of habitat by non-native species	Strategic	Adopt policy to maintain the integrity of ecosystems by avoiding disruption by non-native species	Noss 2001; Kellomaki et al. 2005
		Operational	Control invasive species	Noss 2001; Kellomaki et al. 2005
	Increased frequency and severity of forest disturbance	Strategic	Maintain natural fire regimes	Noss 2001
			Reduce the rate of deforestation and forest degradation	Innes et al. 2009
			Maintain under- and above-ground seed sources (seed banks or trees)	Innes et al. 2009
		Operational	Allow forests to regenerate naturally following disturbance; prefer natural regeneration wherever appropriate	Kellomaki et al. 2005
			Reduce fire hazard by implementing reduced-impact logging, especially through reduction in the size of felling gaps and fuel loads	Innes et al. 2009
Ecosystem condition and productivity	Decreased forest growth	Strategic	Adapt silvicultural rules and policies to ensure that growth rates of trees are maintained or enhanced	Watson et al. 2000
		Operational	Practice high-intensity forestry in areas managed for timber production (to promote growth of commercial tree species) and where the forested land base is allocated using a triad approach to landscape zonation	Innes and Nitschke 2005
			Include climate variables in growth-and-yield models to generate more specific predictions about the future development of forests	Kellomaki et al. 2005
			Enhance forest growth through fertilization	Watson et al. 2000
			Employ vegetation control techniques to offset drought	Parker et al. 2000
			Perform precommercial thinning or selectively remove suppressed, damaged, or poor-quality trees to increase resource availability for the remaining trees	Smith et al. 1997; Papadopol 2000; Kellomaki et al. 2005
			Plant genetically modified species	Gitay et al. 2001; Lemmen and Warren 2004; Kellomaki et al. 2005

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Ecosystem condition and productivity	Decreased forest growth	Operational	Identify more suitable genotypes	Gitay et al. 2001; Lemmen and Warren 2004; Kellomaki et al. 2005
			Match provenances of trees to new site conditions	Innes et al. 2009
			Adjust the annual cut to maintain forest processes in a state as close to equilibrium as possible	Innes et al. 2009
	Decreased health and vitality of forest ecosystems because of cumulative impacts of multiple stressors	Strategic	Reduce nonclimatic stresses by managing tourism, recreation, and grazing impacts, to enhance the ability of ecosystems to respond to climate change	Biringer 2003
			Reduce nonclimatic stresses by regulating atmospheric pollutants, to enhance the ability of ecosystems to respond to climate change	Biringer 2003
			Reduce nonclimatic stresses by restoring degraded areas to maintain genetic diversity and promote ecosystem health and thereby to enhance the ability of ecosystems to respond to climate change	Biringer 2003
			Monitor all forests (not just production forests) at subnational and national scales through improved national, regional, and operational forest health monitoring networks, through harmonization of inventory, through reporting protocols for such networks, and through expansion and linkage of invasive species networks	Innes et al. 2009
			Pursue better and more cost-efficient methods for multiscale monitoring systems for early detection of change in forest status and health	Innes et al. 2009
		Operational	Develop, test, and improve risk assessment methods	Innes et al. 2009
			In natural forests, ensure large juvenile populations to promote high genetic variation	Innes et al. 2009
			Work with others to ensure that stressors outside the control of forest managers (e.g., atmospheric pollution) are minimized	Ogden and Innes 2007
			Adopt a holistic management approach that balances timber and nontimber goods and services	Ogden and Innes 2007
			Maximize forest area by quickly regenerating any degraded areas	Wheaton 2001; Biringer 2003
	Forest management plans and policies lack the flexibility that is required to respond to climate change	Strategic	Relax rules governing the movement of seed stocks from one area to another	Kellomaki et al. 2005

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Ecosystem condition and productivity	Increased frequency and severity of forest disturbance	Strategic	Allocate forest land base using a triad approach to landscape zonation to identify areas that may be managed for timber production and where high-intensity plantation forestry may be practiced	Innes and Nitschke 2005
		Operational	Assist in tree regeneration	Lemmen and Warren 2004
			Apply silvicultural techniques that maintain or increase species and structural diversity	Biringer 2003
			Actively manage forest pests	Biringer 2003
			In drought-prone areas, increase the use of precommercial and commercial thinning to enhance the tolerance of remaining trees, and introduce drought-resistant species where appropriate	Innes et al. 2009
			Preferentially use coastal provenances of species in areas likely to be affected by windstorms	Innes et al. 2009
	Increased frequency and severity of insect and disease disturbance	Strategic	Adjust harvest schedules to harvest stands most vulnerable to insect outbreaks	Lemmen and Warren 2004
			Establish landscape-level targets for structural or age class measures, for landscape connectivity for species movement, and for passive or active measures to minimize the potential impacts of fire, insects, and diseases	Innes et al. 2009
		Operational	Plant genotypes that are tolerant of drought, insects, and/or disease	Namkoong 1984; Farnum 1992; Kellomaki et al. 2005
			Reduce disease losses through sanitation cuts to remove infected trees	Smith et al. 1997
			Breed for pest resistance and for a wider tolerance to a range of climate stressors and extremes in specific genotypes	Namkoong 1984; Wang et al. 1995; Kellomaki et al. 2005
			Use prescribed burning to reduce fire risk and reduce forest vulnerability to insect outbreaks	Lemmen and Warren 2004
			Employ silvicultural techniques to promote forest productivity and increase stand vigor (e.g., partial cutting or thinning) and thus reduce susceptibility to insect attack	Wargo and Harrington 1991; Gottschalk 1995; Dale et al. 2001; Biringer 2003
			Shorten the rotation length to decrease the period when stands are vulnerable to damaging insects and diseases and to facilitate change to more suitable species	Lindner et al. 2000
			Increase the genetic diversity of trees used in plantations	Innes et al. 2009

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Ecosystem condition and productivity	Increased mortality due to climate stresses	Strategic	Avoid planting new forests in areas likely to be subject to natural disturbances (e.g., floods)	Innes et al. 2009
		Operational	Minimize amount of edge created by human disturbances	Innes et al. 2009
	Increased nitrogen losses	Operational	Use nitrogen fertilization or encourage nitrogen-fixing species in the understory	Innes et al. 2009
	Invasions by non-native species	Strategic	Adopt policies to ensure that disruption of ecosystems by non-native species is avoided	Ogden and Innes 2007
		Operational	Control undesirable plant species that will become more competitive in a changed climate	Parker et al. 2000; Kellomaki et al. 2005
	Species are no longer suited to site conditions	Strategic	Adapt silvicultural rules and practices to maintain optimum species–site relationships	Spittlehouse and Stewart 2003; Kellomaki et al. 2005; BCMOFR 2006
		Operational	Where current advanced regeneration is unacceptable as a source for the future forest, underplant with other species or genotypes	Spittlehouse and Stewart 2003
			Design and establish a long-term, multi-species or seedlot trial to test improved genotypes across a diverse array of climatic and latitudinal environments	BCMOFR 2006
			Reduce the rotation age and follow with planting to speed the establishment of better-adapted forest types	Lindner et al. 2000; Parker et al. 2000; Kellomaki et al. 2005
			Relax rules governing the movement of seed stocks from one area to another; examine options for modifying seed transfer limits and systems	Kellomaki et al. 2005; BCMOFR 2006
			Use germplasm mixtures with high levels of genetic variation when planting	Innes et al. 2009
			In plantations, avoid the use of clonal material selected purely on the basis of past growth rates	Innes et al. 2009

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Soil and water	Changes in the salinity of coastal forest ecosystems	Strategic	Avoid low river flows, especially those caused by upstream obstruction	Innes et al. 2009
	Increased soil erosion due to increased precipitation and melting of permafrost	Strategic	Adopt policies to minimize the risk of sediment generation associated with roads and harvesting activities	Spittlehouse and Stewart 2003
		Operational	Maintain, decommission, and rehabilitate roads to minimize sediment runoff due to increased precipitation and melting of permafrost	Spittlehouse and Stewart 2003
			Minimize soil disturbance through low-impact harvesting activities	Watson et al. 2000
			Minimize density of permanent road network, and decommission and rehabilitate roads to maximize productive forest area	BCMOFR 2006
			Limit harvesting operations to the winter, to minimize road construction and soil disturbance	Ogden and Innes 2007
	Increased instability of the terrain due to extreme precipitation events or melting of permafrost	Strategic	Reassess maps of terrain stability in light of changing ground conditions associated with climate change	BCMOFR 2006
		Operational	Avoid constructing roads in landslide-prone terrain, where increased precipitation and melting of permafrost may increase the risk of slope failure	BCMOFR 2006
	More and earlier snow melt resulting in changes in the timing of peak flow and volume in streams	Strategic	Reassess river and stream peak flows, and link this information to design standards for bridges and roads	Mote et al. 2003; Spittlehouse and Stewart 2003
		Operational	Examine the suitability of current road construction standards and stream crossings to ensure they adequately mitigate potential impacts on infrastructure, fish, and potable water of changes in timing and volume of peak flows	Mote et al. 2003; Spittlehouse and Stewart 2003

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Role in global ecological cycles	Decrease in forest CO_2 sinks and increased CO_2 emissions from forested ecosystems because of declining forest growth and productivity	Strategic	Adopt policy to mitigate climate change through forest carbon management (e.g., to minimize the risk of a forest ecosystem becoming a net source of carbon)	Watson et al. 2000
		Operational	Enhance forest growth and carbon sequestration through fertilization	Watson et al. 2000
			Modify thinning practices (timing, intensity) and rotation length to increase growth and carbon turnover	Kellomaki et al. 2005
			Minimize density of permanent road network to maximize forest sinks	Spittlehouse and Stewart 2003
			Decommission and rehabilitate roads to maximize forest sinks	Spittlehouse and Stewart 2003
	Decrease in forest CO_2 sinks and increased CO_2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance	Strategic	Identify forested areas that can be managed to enhance carbon uptake	Parker et al. 2000; White and Kurz 2003
			Identify areas that may be suitable for afforestation	Watson et al. 2000
			Identify areas where deforestation may be avoided	Watson et al. 2000
			Identify areas where forests have been degraded and can be rehabilitated	Watson et al. 2000
		Operational	Reduce forest degradation and avoid deforestation	Watson et al. 2000
			Decrease impact of natural disturbances on carbon stocks by managing fire and forest pests	Watson et al. 2000; Lemmen and Warren 2004; BCMOFR 2006
			Minimize soil disturbance through low-impact harvesting activities	Watson et al. 2000
			Enhance forest recovery after disturbance	Wheaton 2001
			Offset the use of fossil fuels by increasing the use of forests for biomass energy	Spittlehouse and Stewart 2003
			Practice low-intensity forestry and prevent conversion to plantations	Noss 2001
	Forest management policies and incentives do not encourage adaptation to climate change	Strategic	Provide incentives and remove barriers to enhancing carbon sinks and reducing greenhouse gas emissions	BCMOFR 2006
		Operational	Provide incentives for forest management activities to be included in carbon trading systems (e.g., as outlined in article 3.4 of the Kyoto Protocol)	Ogden and Innes 2007

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Economic and social benefits	Decreased socioeconomic resilience	Strategic	Diversify forest economy (e.g., develop markets for dead wood products, value-added products, nontimber forest products)	Ogden and Innes 2007
			Diversify regional economy (i.e., lessen dependence on the forest)	Ogden and Innes 2007
			Expand tourism and recreational services to three- or four-season operations	Innes et al. 2009
		Operational	Develop technology to use wood of altered quality and to use different tree species; modify wood-processing technology	Kellomaki et al. 2005; Spittlehouse 2005
	Forest management plans and policies lack the flexibility that is required to respond to climate change	Strategic	Provide long-term tenures to encourage incorporation of long-term considerations within short-term decisions	Ogden and Innes 2007
	Increased frequency and severity of forest disturbance	Strategic	Include risk management in management rules and forest plans, and develop an enhanced capacity for risk management	Kellomaki et al. 2005; Ohlson et al. 2005; Spittlehouse 2005; Johnston et al. 2006; Venevsky 2006
		Operational	Increase awareness about the potential impact of climate change on the fire regime, and encourage proactive measures with regard to fuels management and community protection	BCMOFR 2006
			Encourage appropriate capital investments, retraining of the workforce, and mobility of the population	Innes et al. 2009
			Protect higher-value areas from fire through FireSmart techniques	Lemmen and Warren 2004
			Increase the amount of timber from salvage logging of fire- or insect-disturbed stands	Spittlehouse and Stewart 2003

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Society's responsibility	Decreased socioeconomic resilience	Strategic	Anticipate variability and change, and conduct vulnerability assessments at a regional scale	Spittlehouse and Stewart 2003; Chapin et al. 2004; BCMOFR 2006; Venevsky 2006
			Enhance capacity to undertake integrated assessments of system vulnerabilities at various scales	Spittlehouse 2005; Johnston et al. 2006
			Establish objectives for the future forest under climate change	Kellomaki et al. 2005
			Review forest policies, forest planning, forest management approaches, and forest management institutions to assess the ability to achieve social objectives under climate change (e.g., conservation objectives)	Spittlehouse 2005; Johnston et al. 2006
		Operational	Foster learning and innovation, and conduct research to determine when and where to implement adaptive responses	Spittlehouse and Stewart 2003; Chapin et al. 2004; BCMOFR 2006
			Encourage societal adaptation (e.g., encourage changes in expectations)	Spittlehouse 2005; Johnston et al. 2006
			Make informed choices about preferred tree species composition for the future	Kellomaki et al. 2005; Spittlehouse 2005
			Enhance dialogue among stakeholder groups to establish priorities for action on climate change adaptation in the forest sector	Lemmen and Warren 2004
			Conduct assessments in local communities to determine priorities and preferences	Innes et al. 2009
			Strengthen local organizational and planning skills	Innes et al. 2009
			Compile local and community knowledge about past and current changes	Innes et al. 2009

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Society's responsibility	Erosion of local forest-related knowledge in forest-dependent societies	Strategic	Support indigenous and local community efforts to document and preserve local forest-related knowledge and practices for coping with climatic variability and associated changes in forest structure and function	Innes et al. 2009
			Incorporate study of local forest-related knowledge into forestry and environmental education	Innes et al. 2009
			Promote research to examine the underlying ecological bases of traditional forest management practices	Innes et al. 2009
			Encourage multidisciplinary, participatory research and dialogue between forest scientists and holders or users of local forest knowledge aimed at increasing the adaptive capacity of both local ("informal") and formal, science-based approaches to sustainable forest management	Innes et al. 2009
	Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change	Strategic	Develop forest management plans that reduce the vulnerability of forests and forest-dependent communities to climate change	Spittlehouse and Stewart 2003; Chapin et al. 2004; BCMOFR 2006
			Support knowledge exchange, technology transfer, capacity building, and information sharing on climate change; maintain or improve capacity for communications and networking	Chapin et al. 2004; Lemmen and Warren 2004; Johnston et al. 2006
			Support research on climate change, climate impacts, and climate change adaptations; increase resources for basic climate change impacts and adaptation science	Spittlehouse and Stewart 2003; Lemmen and Warren 2004; Johnston et al. 2006
		Operational	Incorporate new knowledge about the future climate and forest vulnerability into forest management plans and policies	Spittlehouse 2005
			Involve the public in an assessment of forest management adaptation options	Lemmen and Warren 2004
			Gather information about natural and cultural heritage values and ensure that this knowledge is used in the decision-making process established to manage the forest for climate change impacts	Innes et al. 2009

CCFM SFM criterion	Climate change impact or vulnerability	Forest management planning level	Adaptation options	References
Society's responsibility	Forest management plans and policies lack the flexibility that is required to respond to climate change	Strategic	Evaluate the adequacy of existing environmental and biological monitoring networks for tracking the impacts of climate change on forest ecosystems, identify inadequacies and gaps in these networks, and identify options to address them	BCMOFR 2006
			Practice adaptive management, which rigorously combines management, research, monitoring, and means of changing practices so that credible information is gained and management activities are modified by experience	Spittlehouse and Stewart 2003
			Develop flexible forest management plans and policies that are capable of responding to climate change	Ogden and Innes 2007
		Operational	Measure, monitor, and report on indicators of climate change and sustainable forest management to determine the state of the forest and to identify when critical thresholds are reached	Spittlehouse 2005
	Forest management policies and incentives do not encourage adaptation to climate change	Strategic	Remove barriers and develop incentives to adapt to climate change	Ogden and Innes 2007

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