Canadian Council of Forest Ministers
Conseil canadien des ministres des forêts

Adapting Sustainable Forest Management to Climate Change:

Scenarios for Vulnerability Assessment

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

Copies of this report in both official languages can be found online at ccfm.org or by contacting the Canadian Council of Forest Ministers.

Canadian Council of Forest Ministers

Canadian Forest Service
580 Booth Street, 8th floor
Ottawa, Ontario
K1A 0E6

T (613) 947–9099
F (613) 947–9033

Cette publication est également disponible en français sous le titre *Adapter l'aménagement forestier durable aux changement climatiques : emploi de scénarios dans l'évaluation de la vulnérabilité.*

Cover photos: Natural Resources Canada

Library and Archives Canada Cataloguing in Publication

Price, David Thomas, 1954-

Adapting sustainable forest management to climate change : scenarios for vulnerability assessment / David Price, and Kendra Isaac.

Issued also in French under title: Adapter l'aménagement forestier durable aux changements climatiques : emploi de scénarios dans l'évaluation de la vulnérabilité.

"This report is a product of the Climate Change Task Force of the Canadian Council of Forest Ministers"--P. [2] of cover.

Available also on the Internet.

ISBN 978-1-100-20687-5
Cat. no.: Fo79-4/2012E

1. Forest management--Environmental aspects--Canada--Forecasting.
2. Sustainable forestry--Canada--Forecasting.
3. Climatic changes--Environmental aspects--Canada--Forecasting.
I. Isaac, Kendra
II. Canadian Council of Forest Ministers
III. Canadian Council of Forest Ministers. Climate Change Task Force
IV. Title.

SD387 E58 P74 2012 333.75'160971 C2012-980115-1

PRINTED IN CANADA IMPRIMÉ AU CANADA

Recycled paper

Adapting Sustainable Forest Management to Climate Change:
Scenarios for Vulnerability Assessment

D.T. Price[1] and K.J. Isaac[2]

Canadian Council of Forest Ministers
Climate Change Task Force

[1]Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, 5320–122 Street, Edmonton, AB T6H 3S5.
[2]Formerly Canadian Council of Forest Ministers Secretariat. Present address: Alberta Environment and Sustainable Resource Development, 12th Floor Baker Centre, 10025-106 Street, Edmonton, Alberta T5J 1G4.

Canadian Council of Forest Ministers

Climate Change Task Force

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

A vision for Canada's forests: 2008 and beyond

(CCFM 2008)

Photo: Natural Resources Canada

CANADIAN COUNCIL OF FOREST MINISTERS

CLIMATE CHANGE TASK FORCE

Alberta Ministry of Environment and Sustainable Resource Development – Stan Kavalinas, Daryl Price, Evelynne Wrangler

British Columbia Ministry of Forests, Lands, and Natural Resource Operations – Kathy Hopkins, Dave Peterson (Co-Chair), Jim Snetsinger (Co-Chair)

Manitoba Department of Conservation and Water Stewardship – Greg Carlson, Ryan Klos

New Brunswick Department of Natural Resources – Mike Bartlett, Tom Ng, Chirs Norfolk

Newfoundland and Labrador Department of Natural Resources – Wayne Kelly

Northwest Territories Department of Environment and Natural Resources – Tom Lakusta

Nova Scotia Department of Natural Resources – Jorg Beyeler, Jonathan Kierstead

Ontario Ministry of Natural Resources – Paul Gray

Prince Edward Island Department of Agriculture and Forestry – Dan McAskill

Quebec Ministry of Natural Resources and Wildlife – Michel Campagna

Saskatchewan Ministry of Environment – Dwayne Dye

Yukon Department of Energy, Mines, and Resources – Aynslie Ogden, Robin Sharples

Natural Resources Canada – Kelvin Hirsch, Tim Sheldan (Co-Chair), Tim Williamson

Canadian Council of Forest Ministers Secretariat – Marie-Eve Bonneau, Kumiko Onoda

TECHNICAL ANALYSIS GROUP

Ontario Ministry of Natural Resources – Paul Gray

Quebec Ministry of Natural Resources and Wildlife – Michel Campagna

Saskatchewan Research Council – Mark Johnston

Yukon Department of Energy, Mines, and Resources – Aynslie Ogden

Natural Resources Canada – Jason Edwards, Kelvin Hirsch (Lead), David Price, Catherine Ste-Marie, Tim Williamson

Canadian Council of Forest Ministers Secretariat – Marie-Eve Bonneau, Kendra Isaac, Kumiko Onoda


Photo: Kelvin Hirsch

FOREWORD

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

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

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

TIM SHELDAN
Co-Chair, CCFM Climate Change Task Force
Natural Resources Canada
Canadian Forest Service
Edmonton, Alberta

JIM SNETSINGER and DAVE PETERSON
Co-Chairs, CCFM Climate Change Task Force
British Columbia Ministry of Forests, Lands, and Natural Resource Operations
Victoria, British Columbia

Price, D.T.; Isaac K.J. 2012. *Adapting sustainable forest management to climate change: scenarios for vulnerability assessment*. Can. Counc. For. Minist., Ottawa, ON.

ABSTRACT

Maintaining sustainable forest management practices in Canada during the 21st century and beyond will be a major challenge, given the uncertainties of global socioeconomic development and multiple interacting consequences of global environmental change. Scenarios represent an important tool for decision makers to use in exploring the causes and effects of possible changes in future environmental conditions and the implications of those changes for forests and the social, environmental, and economic benefits that forests provide. Scenario analysis allows managers and other stakeholders to evaluate the consequences of plausible alternative futures for forest management and to develop robust adaptation strategies. This report addresses the origins of the scenarios that will be needed to assess the impacts of climate change and other stressors on managed forest systems. It examines how scenarios can be constructed for application at local scales (such as a forest management unit), using both top–down (downscaling from global and regional projections) and bottom–up (accounting for local trends and projections) approaches. Practical examples of using scenarios for impact assessment in forestry are briefly reviewed in four case studies from across Canada.

Key words: climate change, socioeconomic development, sustainable forest management, adaptation, vulnerability, sensitivity, exposure, impacts, adaptive capacity, scenarios, uncertainty

RÉSUMÉ

Maintenir des pratiques d'aménagement forestier durable au Canada au cours du 21e siècle et au-delà constituera un défi de taille, étant donné les incertitudes qui planent au niveau du développement socioéconomique mondial et des conséquences multiples et interdépendantes des changements environnementaux planétaires. L'utilisation de scénarios représente un outil important pour les décideurs quand il s'agit d'examiner les causes et les effets des changements à venir dans les conditions environnementales et les conséquences de ces changements sur les forêts, notamment les avantages que les forêts apportent sur le plan économique, environnemental et social. L'analyse de scénarios permet aux gestionnaires et aux autres intervenants d'évaluer les conséquences des diverses avenues d'aménagement forestier que nous pourrions mettre en place à l'avenir et de mettre au point de solides stratégies adaptées à ces changements. Ce rapport présente les scénarios devant servir à l’évaluation des impacts des changements climatiques et des autres sources de stress sur les systèmes d'aménagement forestier. Il explique comment les scénarios peuvent être conçus pour une application à l’échelle locale (p. ex., une unité d’aménagement forestier), suivant une approche descendante (par réduction des projections réalisées à l'échelle mondiale ou régionale) ou ascendante (les projections sont fondées sur les tendances locales). À l'aide de quatre cas d'espèce provenant de diverses localités canadiennes, on y décrit l'emploi des scénarios pour en évaluer les impacts en foresterie.

Mots clés : changements climatiques, développement socioéconomique, aménagement forestier durable, adaptation, vulnérabilité, sensibilité, exposition au risque, impacts, capacité d'adaptation, scénarios, incertitudes

CONTENTS

INTRODUCTION

Sustainable forest management (SFM) is a widely adopted objective in the Canadian forest sector. However, reaching this goal has become much more challenging in a rapidly changing climate. Changes in climate pose a serious threat to Canadian forests, not only in terms of their role as providers of raw materials and environmental services, such as biodiversity, habitat, clean water, and carbon storage, but also in terms of their wider economic and social benefits, including jobs, spiritual values, and recreation. SFM practitioners will need to respond to major environmental changes in coming decades if SFM is to continue to provide "opportunities for present and future generations."

Even if global emissions of greenhouse gases (GHGs) were to decrease appreciably from today's levels, further changes in climate are a near-certainty in the coming decades. Yet the impacts of climate change on Canadian forests remain uncertain. How serious could these impacts be? Which regions of Canada could be most affected? This report explores ways to assess uncertainty through scenarios: plausible alternative "stories" or "thought experiments" about what the future may be like.

What is sustainable forest management?

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

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

Scenarios are also a key tool in vulnerability assessment. Vulnerability assessment is a relatively new approach that evaluates the extent to which a system (in this case, a forest managed with sustainability objectives, an SFM system) is susceptible to, and may be unable to cope with, the adverse effects of climate change. Vulnerability assessment helps forest managers to identify what might be appropriate adaptations, and where and when to implement them. Scenarios provide crucial information to address how, given an uncertain future for Canadian forests, forest managers and others can ensure that adaptations will be effective in a range of possible future outcomes.

Scenarios therefore offer a way to explore future uncertainty, assess the range of possibilities, and develop flexible adaptation plans for the continued sustainability of Canada's forest systems.

This report is a summary of a comprehensive information report about using scenarios in vulnerability assessments by Price and Issac (n.d.). The information report contains additional details on accessing and developing scenarios relevant to climate change and SFM and provides additional resources and a thorough list of references.


Photo: Kelvin Hirsch

EXPLORING UNCERTAINTY

Scenarios are a tool that forest managers can use when planning for an uncertain future. One particular challenge in projecting climate change is that it depends on human behavior, which is largely unpredictable. For example, we cannot say what will happen to the global economy, and we do not know how much GHG emissions will rise. Further, although scientists are constantly learning more about how the Earth reacts to rising GHG emissions, our knowledge has large gaps—another source of uncertainty. Finally, we do not yet know whether human adaptations to climate change will be effective in coping with or reducing its negative impacts.

Expert climate scientists around the world have been developing and using global climate models (GCMs) for several decades to simulate what may happen to the climate in the future. For the past, these models can reproduce the important trends in observed climate. For the future, the models tend to diverge, but they generally agree in projecting global warming trends related to rising GHG concentrations. There is strong agreement among scientists that these trends are substantially correct. However, the models differ in the many details of how they represent processes in the atmosphere, oceans, ice caps, glaciers, and land-based ecosystems, all of which contribute to climate. As a result, GCM projections of temperature, rainfall, and other climate variables also differ both in terms of the rate of change and among geographic regions. To improve the projections, the GCMs are continually being refined. For example, some of these models now account for the effects of climate warming on forest fires and melting of permafrost, both of which trigger further increases in global emissions of GHGs and hence contribute to additional changes in climate. Although this improvement makes the GCMs more representative of reality, it also makes the range of their projections wider. As a consequence, although the GCMs have steadily been improved, much uncertainty remains in their estimates of future change.

It is this uncertainty, stemming from human behavior, knowledge gaps, and differences among scientific models, that scenarios can help to address.

Looking forward: terms for future weather and climate

Weather | The short-term conditions outdoors, at a particular time and place, which can change dramatically over periods of hours or even minutes.

Climate | The long-term average of daily and seasonal weather, typically compiled as statistical data for periods of 30 years or longer.

Scientists also draw important distinctions among terms used to express views of the future climate:

Projection | A description of how the future may unfold. A climate projection generally refers to a single simulation performed with a climate model for a given scenario of future greenhouse gas emissions and other factors.

Prediction or Forecast | A statement, based on what is already known, that something is likely to happen in the future. For example, weather forecasts are typically based on multiple model projections, which are in turn based on current weather conditions. Expert forecasters use these projections to decide which weather outcome is most likely to occur.

DEFINING SCENARIOS AND SCENARIO ANALYSIS

Scenarios are plausible alternative futures, none of which is considered more likely than any other. A scenario therefore differs from a prediction or forecast, which provides a single view of the future that experts consider most likely to happen (see "Looking forward: terms for future weather and climate," above). In climate change impacts research, scenarios can be considered "thought experiments" to explore how the future climate may differ from today's, and what effects the changed climate might have on forests and other systems.

Scenarios may be based on projections of the future drawn from models, and they may, in turn, form the basis for new projections when used as data to inform other models.

It is important to recognize that scenarios are based on simplifying assumptions and may reflect the biases of the individuals who develop them. Making incorrect assumptions or omitting important factors will lead to invalid conclusions. Therefore, it is essential to have open discussions about the assumptions underpinning each scenario and to evaluate several scenarios reflecting the range of opinions about what might happen.

Scenario analysis is a formal process to compare the outcomes from a range of alternative scenarios. It has been used since the 1960s, first in military strategy and later in business management, as a systematic approach to decision-making in the face of uncertainty. The expressions "best-case scenario" and "worst-case scenario," which are familiar to many people, come from scenario analysis.

In an SFM context, scenarios can constitute an important element in planning and decision-making about the impact of climate change and other factors on achieving and maintaining SFM objectives, including biodiversity, the quality and quantity of water resources, and carbon storage. Scenarios can help forest managers to explore how SFM may have to change to cope with the new reality or to take advantage of opportunities that it offers.

Such scenarios also have social and economic dimensions, allowing exploration of how employment, wealth, or recreation may change. Scenarios can also be key inputs into vulnerability assessments (see "Using scenarios for adaptation," below), as they offer alternative, credible views of how the environment may change.

Scenarios are useful at a variety of scales, including the community, the region, and the country. Local scenarios for SFM will usually be applicable at the scale at which most forests are managed (1000 km^2 to 10 000 km^2). This is the scale at which we can also explore the effects of climate change on communities, including safety (for example, risks of wildfire or flooding), and economic, social, and cultural life (for example, outdoor recreation or employment in forestry).

Local scenarios of impacts on SFM can be informed by global analyses of population, economic growth, and associated changes in GHG emissions. Global climate change scenarios may form the basis of local climate projections (see "Creating local scenarios," below). Furthermore, local scenarios for ecological and socioeconomic effects of climate change depend on current conditions and on drivers of change, including global trends in socioeconomic development and land use.

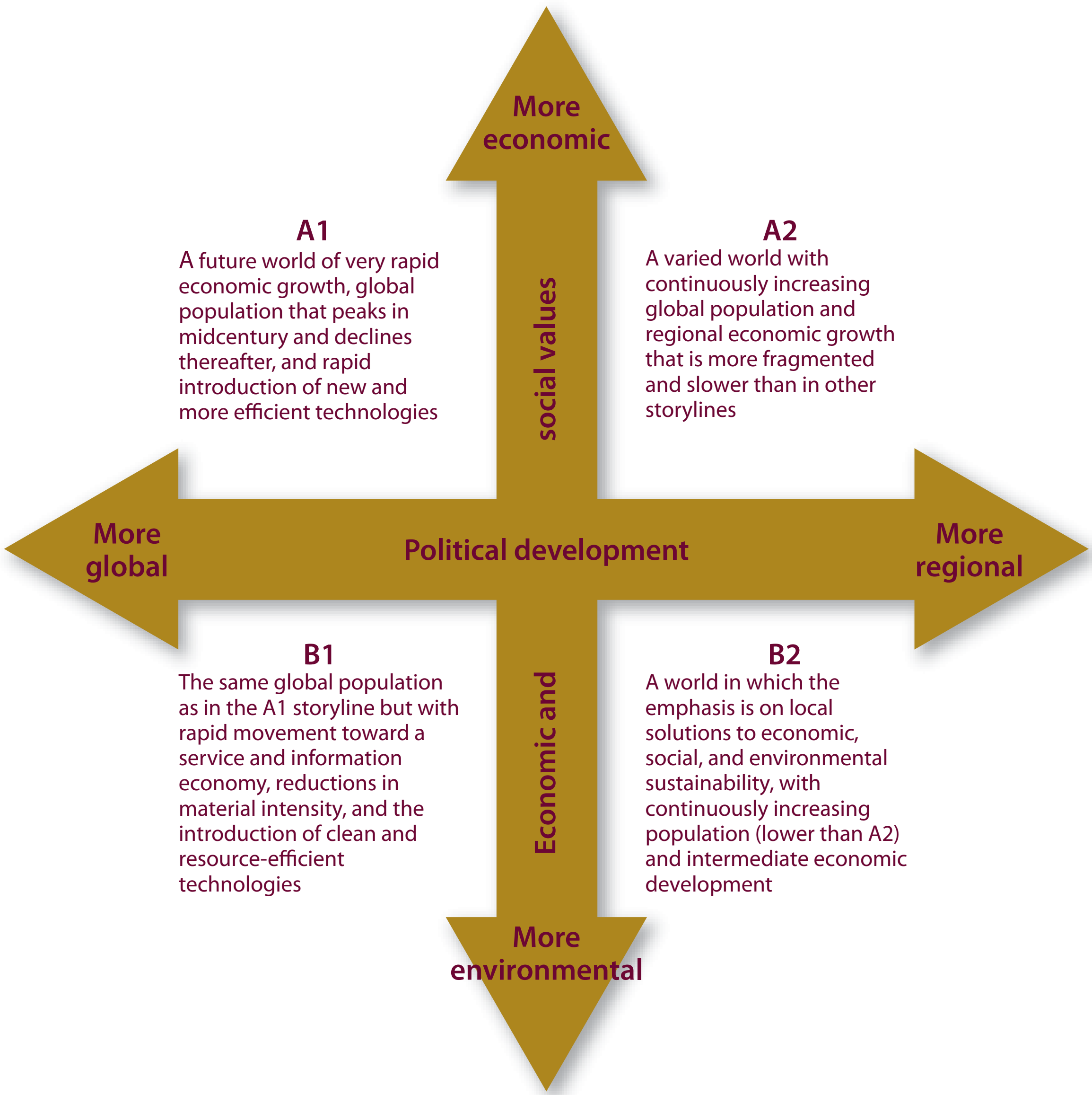
LINKING STORYLINES AND SCENARIOS

The foundation of any scenario is a storyline, a narrative that highlights the main characteristics and dynamics of the system of interest and the relationships among key driving forces. Storylines are often developed by groups of interested parties (including local stakeholders or invited experts or both) convened to discuss the trends (in environment, society, and the economy) that will have a bearing on how the future unfolds. The directions that these trends may take inform the storylines. As precursors to scenarios, storylines define and constrain them. An example will serve to illustrate the relationship between storylines and scenarios.

The Intergovernmental Panel on Climate Change has developed storylines of global development leading to differing projections of future GHG emissions. The storylines are represented on two axes, representing a range of possible futures, a method called the "scenario-axis approach" (see diagram on next page). On the horizontal axis is a range of possible political developments, from a more regionalized political future to a more globalized one. On the vertical axis are potential trends in economic and social values, ranging from one in which economic values dominate to one in which environmental values are paramount.

The resulting four sectors, formed by the intersection of the two axes, each contain a different combination of these trends, representing four different storylines. Each of these storylines informs several scenarios (known as a "family" of scenarios).

Photo: Natural Resources Canada



The "scenario-axis approach" using IPCC storylines (adapted from Nakićenović, N.; Alcamo, J.; Davis, G.; de Vries, B.; Fenhann, J.; Gaffin, S.; Gregory, K.; Grübler, A.; Jung, T.Y.; Kram, T.; La Rovere, E.L.; Michaelis, L.; Mori, S.; Morita, T.; Pepper, W.; Pitcher, H.; Price, L.; Raihi, K.; Roehrl, A.; Rogner, H.-H.; Sankovski, A.; Schlesinger, M.; Shukla, P.; Smith, S.; Swart, R.; van Rooijen, S.; Victor, N.; Dadi, Z. 2000. Special report on emissions scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK, and New York, NY. 599 p.).

CREATING LOCAL SCENARIOS: *from the top down or from the bottom up*

While global storylines may be useful, their scope is often too broad and their scale too large to be applied locally. It is generally local scenarios that are needed to inform decision-making for SFM. Local scenarios can be created in two distinct but complementary ways.

The first approach involves working from the top down, through a process that is also referred to as "downscaling," that is, extracting information from data covering large regions so that it can be meaningfully applied at the local scale. Such large-scale data might include, for example, the climate projections obtained from GCMs and statistical projections of population and economic trends for Canada. Downscaling covers a range of methods, from relatively simple interpretation procedures to statistical methods correlating local economic projections with national- or regional-scale projections, and from application of large-scale data to specific locations to dynamic computer models that link global effects and local responses.

The second approach, sometimes referred to as working from the bottom up, begins with local sources of information and data, which help to identify the vulnerability of the local forest system, including human communities and infrastructure. This approach can be used by communities and organizations concerned with SFM in a particular region and is typically based on conversations between local and outside experts. For example, in participatory scenario development, local players and professional researchers come together as partners to broaden the local knowledge contributing to the storylines. Local players offer their knowledge and concerns, whereas the researchers comment on whether any assumptions are reasonable and fill gaps in local knowledge.

A bottom-up approach generally requires defining the purpose of the analysis and the key factors to be considered in the local storylines. With this approach, the scenario-axis method can help to outline alternative possible futures, but the contrasting social, environmental, or economic drivers represented by the axes can be based on local concerns. The cultural, economic, and political viewpoints of the key players developing these local scenarios are often critical, so it is important to state clearly any assumptions underlying the storylines used. In the final stage of creating local scenarios, the implications of the various scenarios are used to assess impacts. The approach may be quantitative, using models of ecological and economic responses, or subjective, ranking responses in importance and considering their possible effects.

Whether the approach used is top-down or bottom-up, several scenarios of future climate should be applied to explore the range of uncertainty. Scenarios of climate change are available from several sources, including previously downscaled data and various online or desktop-computer-based tools designed for this purpose.

USING LOCAL SCENARIOS

Communities and organizations have used local scenarios in a variety of ways. To date, many approaches have been used, falling into four distinct groups.

Quantitative models represent how climate change may affect the system, using equations based on observed effects to represent responses to climatic variations. These models are generally computer programs used to simulate well-known processes, such as ecological impacts, and to isolate the effects of different types of change on the system. For example, in the cumulative impacts study performed by Millar Western Forest Products Ltd. (see "Case studies," below), several computer models were used to generate local scenarios. Climate data were generated by combining projected changes in temperature and precipitation, as simulated by a GCM using past climate data for the local area. A stand-based forest model was then used to simulate growth in timber volume and changes in species composition. An additional model was constructed to project changes in land use from forestry to other activities. Another example is the study of "climate prosperity" (see "Case studies," below), in which the National Round Table on the Environment and the Economy used several approaches, including a model of economic effects of climate change that projected sea-level rise, amount of warming, and resulting economic and noneconomic damage under projections of high and low GHG emissions.

The second group of approaches to using local scenarios is empirical analogies, which are based on observations of how recent changes in the environment have affected local conditions (such as the health of forests). Various sources of information, such as the following, are available:

- observations by residents in remote regions;
- formal monitoring programs, such as permanent sample plots in forests, used to track stand growth and development;
- field experiments to improve understanding and provide information; and
- volunteer programs such as the PlantWatch project (http://www.naturewatch.ca/english/plantwatch/).

For example, in a study of the biophysical impacts of climate change in the Vanderhoof forest–based community in British Columbia (see "Case studies," below), temperature data were confirmed by local residents' personal observations of more abrupt and severe storms, shorter winter logging seasons, increased stream flows in spring, and shallower snowpacks in the valley.

Expert judgment is the opinion of players from various fields, including natural and social sciences, who are knowledgeable about specific drivers of change or impacts on a system. Panels of experts are often convened specifically to discuss and develop scenarios. In the Forest Futures Project (see "Case studies," below), experts were involved in a participatory process that identified 13 drivers in the forest sector. The project then commissioned 13 reports from experts to address each of these drivers.

Finally, participatory processes involve key players, communities, and researchers working together to develop scenarios that are both locally relevant and scientifically believable. Local experts have knowledge of past climate and extreme climatic events such as storms, floods, and droughts, as well as recent climate impacts (such as large fires or insect attacks). Local experts also have valuable insights into what could be important in the future. Participatory processes represent a collective learning approach, to build consensus, foster local empowerment, and increase community capacity. The Forest Futures Project (see "Case studies," below) used a participatory process to identify drivers of change in the forest sector and to generate scenarios. These processes include discussions of the local implications of the scenarios and possible adaptation responses. National workshops involved academics, members of the Sustainable Forest Management Network, and First Nations representatives, and regional workshops involved a variety of players with an interest or involvement in forests. Through these workshops, participants expressed reactions, shared views, and reached consensus on the need for more flexible forest management in the future.

The approach adopted to develop scenarios depends on both the intended type of scenario and the available resources (including funding and expertise). Quantitative methods require technical expertise and a high level of knowledge of the systems to be modeled. By contrast, participatory methods are useful for collective learning and planning involving communities. In practice, most projects use a combination of these approaches.

USING SCENARIOS FOR ADAPTATION

Vulnerability assessment is a relatively new approach to understanding the potential effects of climate change. Vulnerability describes the extent to which an ecological and human system is susceptible to, and unable to cope with, the adverse effects of climate change. Vulnerability is considered to be determined by three factors: exposure, sensitivity, and adaptive capacity. In the context of SFM, exposure refers to the amount of change in climate that the forest is projected to experience, including changes in variability and the occurrence of extreme events. Sensitivity is how much the forest system responds to a given change in climate. Adaptive capacity refers to the ability of the whole system (ecological and human) to adjust to climate change, that is, to moderate damage, take advantage of opportunities, and cope with the consequences.

Scenarios provide key inputs for vulnerability assessments. Typically, an assessment begins with an examination of how the system of interest is affected by current climate, followed by an exploration, through scenarios, of how exposure to future climate will change the system and what this will mean for forests and for SFM. Finally, this information is used to examine adaptation options, develop a strategy, and integrate the strategy into SFM.

In Canada, progress in achieving SFM is often measured through the use of national and provincial or territorial criteria and indicators. Some of these measures may form a good basis for assessing the sensitivity of a given forest management system to climate change. That is, a measurable change in an indicator in response to an observed change in climate could be used as a measure of its climate sensitivity. Examples of possible indicators include timber productivity, carbon storage, measures of biodiversity, and cultural values.

Developing adaptation strategies requires not only scenarios and vulnerability assessment, but also a vision to guide adaptation in the short and long term. SFM practitioners need to be aware of the wider consequences of any planned adaptation and ready to take them into account. As such, the conversation between practitioners and researchers may begin with scenario development, but it also needs to gauge the implications of adaptations for the future, both locally and globally.

The uncertainties of global societal and economic trends—changes in land use, population growth, emergence of new technologies, and economic shocks—may also need to be integrated into local adaptation and planning for the future. However, this task is complex, as the driving forces are not easy to predict. Expert input may help in local-scale analysis, and a participatory process, such as that described above, is often the most likely to succeed in capturing these aspects.

Scenario analysis has some limitations, because it may not capture the effects of future adaptations to SFM. Adaptation strategies can have feedback effects that may need to be taken into account. As a hypothetical example, consider an area of Canada where traditional conifer wood supplies are projected to decline because of increased fires or insect attacks. Forest managers may decide to establish intensively managed plantations of fast-growing broad-leaved trees to boost fiber production. However, major changes in forest composition would likely have other consequences, such as changes in wildlife and possible effects on water supplies and carbon storage. These effects would not have been captured in the original scenarios leading to this adaptation strategy. Vulnerability assessment, which looks at moderating impacts through adaptation, can be used in conjunction with scenario analysis to take account of these feedback effects.

Ultimately, the discussions that take place around scenarios—particularly discussions about the potential impacts of climate change and possible adaptation strategies—may prove more important than the creation and use of the scenarios themselves. The involvement of local key players, which is crucial in developing scenarios, is also valuable in thinking about the possibilities and in taking ownership of the scenarios that emerge. These conversations can open up possibilities for the future and lead to more robust decision-making, not only for scenarios, but also for future adaptation options. Scenarios are therefore a vital part of the decision-making process for all those involved in SFM, including the forestry industry, researchers, First Nations, and governments.

Photo: Natural Resources Canada

CASE STUDIES: CREATING LOCAL SCENARIOS

The following case studies provide examples of how scenarios have been developed and used to explore the implications of climate change in various SFM contexts in Canada. Each case uses a unique approach and method to suit their individual purpose. Website links are provided where available so that readers can access more information about initiatives that interest them.

Millar Western Forest Products Ltd. cumulative impacts study

In an example of mainstreaming adaptation to climate change into management planning, Millar Western Forest Products Ltd. conducted a study of the effects of climate change, forest fires, increasing population, and oil and gas development in a defined forest area near Whitecourt, Alberta, over a 200-year projection period. The methods used for this study were mainly quantitative models.

Because climate change was only one of several factors considered, the study authors used a single climate projection with an extreme emissions scenario to assess the sensitivity of future harvest levels to the effects of severe climate change, relative to other factors. Changes in climate from the GCM projection were combined with daily data over 30 years to create a scenario approximating climate at the end of the 21st century.

A stand-level forest model was used to simulate growth in volume of trees and changes in species composition. The effects of climate change and increasing carbon dioxide concentration on productivity were simulated with additional climate-sensitive submodels.

To project fire occurrence, the future climate scenario was used to estimate daily fire weather indices and hence the number of fires per year. To take into account the effects of human population growth on fires (because fires caused by humans are a significant hazard), a scenario derived from national population growth projections was used. Areas burned were then simulated using two models of fire occurrence and spread.

Loss of forest land to oil and gas development was estimated from simulations of seismic line exploration, increases in the number of wells established, and growth in the network of pipelines.

These analyses were integrated in a model developed to simulate the landscape-scale changes in harvestable timber volume in the defined forest area. Scenarios looked at the allowable annual cut, harvestable area, and volume production (including salvage) but also effects on ecosystem diversity due to changes in stand ages and fragmentation. In total, nine scenarios were examined, with various combinations of climate change, fire occurrence, population increase, and oil and gas development.

The analysis revealed that climate change would have a major impact on fire occurrence. However, this impact would be greatly mitigated by two factors. First, as a result of oil and gas developments and managed harvesting, the land base would become more fragmented, which would reduce the opportunities for fires to spread and increase access for suppression efforts. Second, the losses due to fire would be offset by general increases in productivity due to the beneficial effects of longer growing seasons and increased carbon dioxide concentrations.

These results were integrated into a novel forest management plan that considers the cumulative impact of these changes in SFM.

For more information: http://www.srd.alberta.ca/LandsForests/ForestManagement/ForestManagementPlans/documents/MillarWesternForestProducts/Appendix19_MWFP.pdf

National Round Table on the Environment and the Economy: Climate Prosperity

The National Round Table on the Environment and the Economy estimated the future economic costs of climate change to forestry in Canada using both top-down and bottom-up analyses.

The top-down analysis identified two driving forces: climate change (resulting from low and high estimates of future GHG emissions) and Canadian economic and population growth (resulting from slow and rapid rates of global socioeconomic development). These driving forces formed the axes for generation of four scenarios for Canada.

A global economic model was used to estimate sea-level rise and amount of warming, along with the economic consequences of these impacts for traditional sectors, the non-economic costs to health and ecosystems, the costs resulting from sea-level rise, and the costs resulting from catastrophic damage. For each scenario, the costs of climate change were estimated for three different time horizons.

The bottom-up analysis looked at climate change impacts on timber supply, including the effects of forest fires, changes in productivity, and pest-related disturbances. Timber production in six regions of Canada was examined through a model that used Statistics Canada data for production inputs and outputs. Models were then used to estimate future regional economic baselines for each region under the slow and rapid economic development scenarios. Climate projections from four GCMs driven by the two emissions scenarios were used to generate regional climate warming scenarios. Forest sector outputs were adjusted on the basis of regional estimates of changes in timber supply due to climate change effects.

By comparing changes in selected economic indicators with and without climate change, the economic impacts of climate change were estimated. Results indicated net losses to timber supply, increasing over time, in all regions. This effect was more pronounced in western regions than in the east. Economic losses in forestry due to climate change were estimated at $2.4 billion to $17.4 billion by 2050 and $25 billion to $176 billion by 2080.

The bottom-up analysis also considered the costs and benefits of three adaptations: greater prevention, control, and suppression of forest fires; greater prevention and control of pests; and planting of tree species suitable to future conditions. The benefits of these adaptations outweighed the costs in every region under every scenario.

For more information: http://nrtee-trnee.ca/wp-content/uploads/2011/09/paying-the-price.pdf

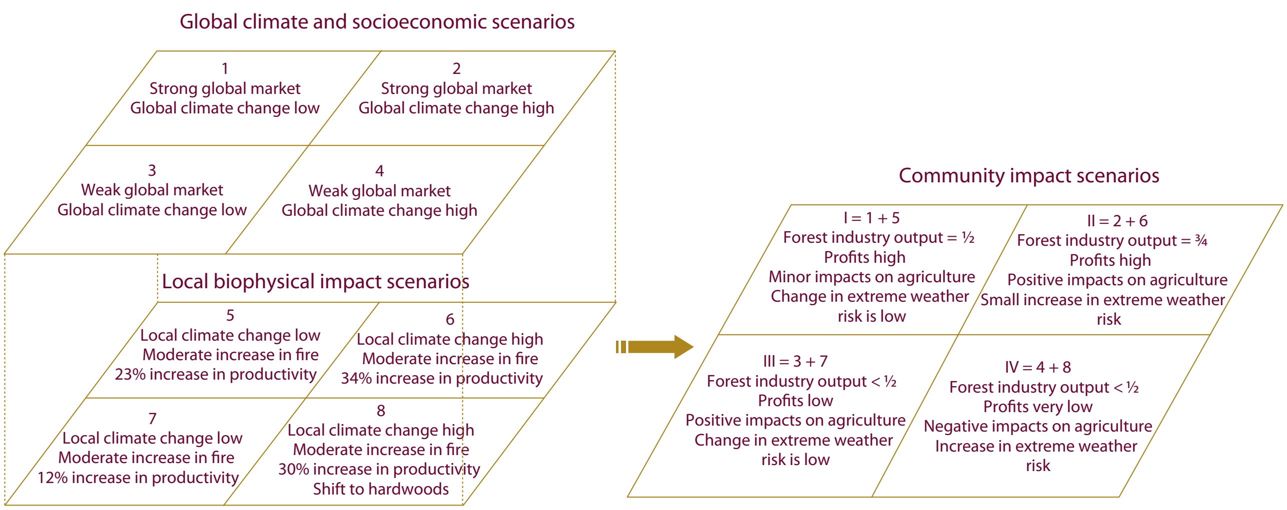
Vanderhoof forest-based community, British Columbia

The Vanderhoof project assessed the potential impacts of climate change on local forest resources and on the community, as well as the economic implications for agriculture, water resources, fisheries, outdoor recreation, and tourism. Four scenarios were generated, mainly through quantitative models, integrating ecology, community, and economics.

Vanderhoof, a town in the central interior of British Columbia about 90 km west of Prince George, is home to 4 400 people, with a further 12 000 people living in the surrounding area. Forestry, the largest economic sector in the region, was recently dealt a serious blow by the mountain pine beetle outbreak, which led to major losses of mature timber.

Researchers used models from several scientific and economic areas to make a range of projections. For climate, they used three GCMs with two emissions scenarios to create six scenarios of future climate. Three climate scenarios, dubbed "warm and dry," "cool and dry," and "hot and wet," were selected for the Vanderhoof region. A mechanistic vegetation model was used to project the response of forest vegetation to key environmental variables. Combined with the climate scenarios, the vegetation model generated three projections for changes in forest composition but did not account for surprises such as intense storms, fires, and insect outbreaks. A separate landscape-scale model was used to project susceptibility to fire under four scenarios of flammability and climate change.

The future economic impacts of climate change on the local economy were evaluated. In particular, an economic model was applied to project changes in forest sector exports. Four scenarios of socioeconomic development were created, using the scenario-axis approach, which took into account possible changes in climate and in global market conditions. From these, changes in timber supply, supply and costs of labour, and household income were analyzed.



Example framework, using the Vanderhoof case study, for integrating global climate, socioeconomic, and local biophysical impact scenarios for the purposes of developing community impact scenarios. The top level of the box on the left provides four scenarios with different combinations of global climate change and global market change. The bottom level of the box on the left provides four scenarios of local biophysical impacts under different assumptions regarding local climate change and sensitivity. The chart on the right compresses the two layers and summarizes community-level impacts. For example, quadrant I on the right is based on the assumed conditions and impact scenarios associated with quadrants 1 and 5 on the left. Diagram reproduced from Williamson, T.B.; Price, D.T.; Beverly, J.L.; Bothwell, P.M.; Frenkel, B.; Park, J.; Patriquin, M.N. 2008. Assessing potential biophysical and socioeconomic impacts of climate change on forest-based communities: a methodological case study. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-415E. Reprinted with permission from the publisher. Available from: http://cfs.nrcan.gc.ca/publications?id=29156

All of these analyses were brought together to create four integrated impacts scenarios, along axes for moderate to significant climate change and strong to weak socioeconomic development (see diagram above). These scenarios will assist forest managers and community leaders in planning to 2050, the time horizon of the scenarios. The long-term outlook is greater uncertainty and economic volatility as the climate becomes more extreme.

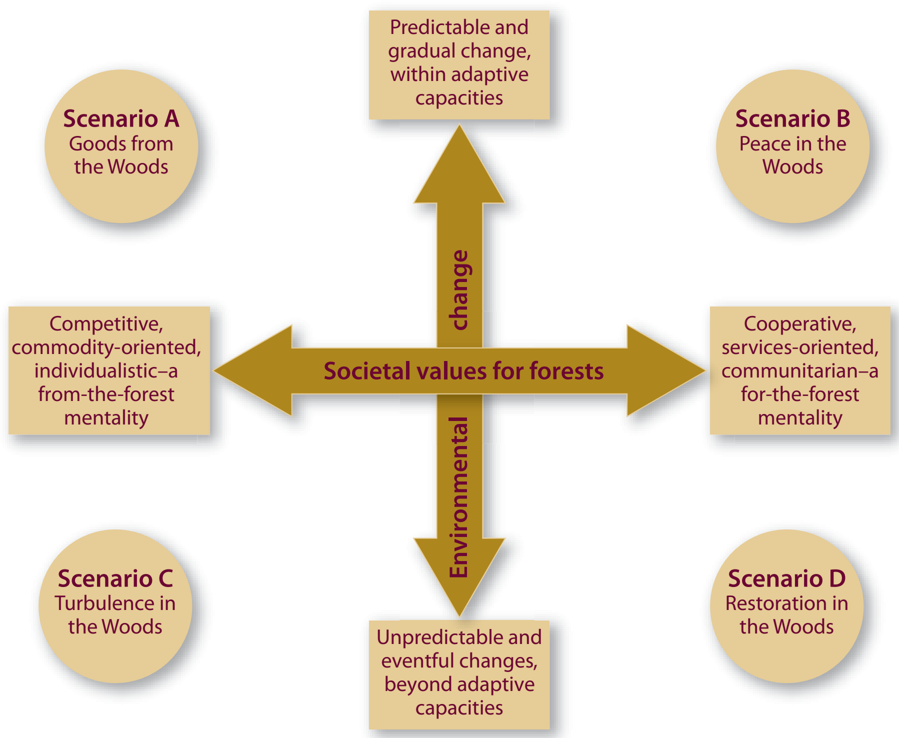
For more information: https://cfs.nrcan.gc.ca/publications?id=29156.

Forest Futures Project

The Forest Futures Project developed and tested scenarios for the future of Canadian forests and sustainable forest management (SFM) through a participatory process. Carried out for the Sustainable Forest Management Network, a former pan-Canadian Network of Centres of Excellence, the project's aim was to inform forest policy and planning.

Workshops were held across the country. Four national workshops engaged members of the Network, First Nations representatives, and academics, and 13 regional workshops involved key players with an interest or involvement in forests or the forest sector. Earlier workshops focused on developing scenarios, whereas later ones concentrated on assessing whether the scenarios were believable and discussing their implications.

Through the process, 13 drivers of change were identified (including global climate change), and expert reports on each driver's influence on the forest sector and future trends were commissioned. Two drivers (environmental change and societal values for forests) were considered very influential but uncertain. These were chosen as the axes for a matrix approach to scenarios (see diagram below). For each quadrant formed by the intersecting axes, a representative scenario was developed and assigned an appropriate name. Scenarios had a common structure: a description of a specific future and responses of the other 11 drivers.



Matrix approach with axes and representative scenarios in each quadrant, from the Forest Futures Project. Reproduced from Duinker, P. 2008. Scenarios of the forest futures project: why and how we created them, and how to use them. http://www.sfmn.ales.ualberta.ca/Research/ForestFutures/~/media/sfmn/Research/ForestFutures/Documents/ScenariosFFP_WhatWhyHow_02_04_2008.ashx. Accessed 1 May 2012.

Each workshop to discuss these scenarios involved 10 to 60 participants, led by a facilitator. Through presentations and small-group discussions, the workshop participants explored the scenarios. Participants identified themes, differing in perspectives as well as areas of consensus, the role of policy, and the need for cooperation to manage future challenges.

For more information: http://www.sfmn.ales.ualberta.ca/Research/ForestFutures/ForestFuturesDocuments.aspx

ACKNOWLEDGMENTS

Special thanks are expressed to the members of the CCFM Climate Change Task Force (CCTF): Stan Kavalinas, Daryl Price, Evelynne Wrangler (all from Alberta Ministry of Environment and Sustainable Resource Development), Jim Snetsinger, Kathy Hopkins, Dave Peterson (all from British Columbia Ministry of Forests, Lands, and Natural Resource Operations), Greg Carlson, Ryan Klos (both from Manitoba Department of Conservation and Water Stewardship), Mike Bartlett, Tom Ng, Chris Norfolk (all from New Brunswick Department of Natural Resources), Wayne Kelly (Newfoundland and Labrador Department of Natural Resources), Tom Lakusta (Northwest Territories Department of Environment and Natural Resources), Jonathan Kierstead, Jorg Beyeler (both from Nova Scotia Department of Natural Resources), Paul Gray (Ontario Ministry of Natural Resources), Dan McAskill (Prince Edward Island Department of Agriculture and Forestry), Michel Campagna (Quebec Ministry of Natural Resources and Wildlife), Dwayne Dye (Saskatchewan Ministry of Environment), Aynslie Ogden, Robin Sharples (both from Yukon Department of Energy, Mines, and Resources), Tim Sheldan, Tim Williamson (both from Natural Resources Canada), Marie-Eve Bonneau and Kumiko Onoda (both from Canadian Council of Forest Ministers Secretariat).

We express sincere thanks to the CCTF's Technical Analysis Group (TAG) members: Paul Gray (Ontario Ministry of Natural Resources), Michel Campagna (Quebec Ministry of Natural Resources and Wildlife), Mark Johnston (Saskatchewan Research Council), Aynslie Ogden (Yukon Department of Energy, Mines, and Resources), Jason Edwards, Kelvin Hirsch, Catherine Ste-Marie, Tim Williamson (all from Natural Resources Canada), Marie-Eve Bonneau and Kumiko Onoda (both from Canadian Council of Forest Ministers Secretariat) for providing valuable input, feedback, and assistance on the various drafts of this report.

We also greatly appreciate the contributions of Peter Fuglem (British Columbia Ministry of Forests, Lands, and Natural Resource Operations - retired) and Jeff Young (Natural Resources Canada) as well as the outstanding work of our editors Brenda Laishley (Natural Resources Canada) and Peggy Robinson (independent editorial consultant), and graphic designer Sue Mayer (Natural Resources Canada), independent technical writer Carolyn Brown, French translator Hélène D'Avignon, and French editor Denis Rochon (independent French editorial consultant).

LITERATURE CITED

[CCFM] Canadian Council of Forest Ministers. 2006. Criteria and indicators of sustainable forest management in Canada: national status 2005. Ottawa, ON. 154 p.

[CCFM] Canadian Council of Forest Ministers. 2008. A vision for Canada's forests: 2008 and beyond. Ottawa, ON. 15 p. Also available at: <http://www.ccfm.org/pdf/Vision_EN.pdf>

Duinker, P. 2008. Scenarios of the forest futures project: why and how we created them, and how to use them. http://www.sfmn.ales.ualberta.ca/Research/ForestFutures/~/media/sfmn/Research/ForestFutures/Documents/ScenariosFFP_WhatWhyHow_02_04_2008.ashx. Accessed 1 May 2012.

Nakićenović, N.; Alcamo, J.; Davis, G.; de Vries, B.; Fenhann, J.; Gaffin, S.; Gregory, K.; Grübler, A.; Jung, T.Y.; Kram, T.; La Rovere, E.L.; Michaelis, L.; Mori, S.; Morita, T.; Pepper, W.; Pitcher, H.; Price, L.; Raihi, K.; Roehrl, A.; Rogner, H.-H.; Sankovski, A.; Schlesinger, M.; Shukla, P.; Smith, S.; Swart, R.; van Rooijen, S.; Victor, N.; Dadi, Z. 2000. Special report on emissions scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK, and New York, NY. 599 p.

Williamson, T.B.; Price, D.T.; Beverly, J.L.; Bothwell, P.M.; Frenkel, B.; Park, J.; Patriquin, M.N. 2008. Assessing potential biophysical and socioeconomic impacts of climate change on forest-based communities: a methodological case study. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-415E.

Photo: Natural Resources Canada

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.

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).

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).

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).

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).

GCM | General circulation models. These are also referred to as global climate models.

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

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).

Storyline | A narrative description of a scenario (or family of scenarios) that identifies the key drivers of future change, the relationships among them, and the underlying assumptions used to frame the scenarios. Storylines allow the range of future uncertainty to be explored and provide greater transparency to users of the scenarios (Nakićenović 2000; Metzger et al. 2010).

Sustainable forest management | "Management that maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social, and cultural opportunities for present and future generations" (CCFM 2008).

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).

Literature Cited

[CCFM] Canadian Council of Forest Ministers. 2008. A vision for Canada's forests: 2008 and beyond. Ottawa, ON. <http://www.ccfm.org/pdf/Vision_EN.pdf>. Accessed 11 April 2012.

[MEA] Millennium Ecosystem Assessment, Responses Working Group. 2005. Appendix A: colour maps and figures. Pages 585–623 *in* K. Chopra, R. Leemans, P. Kumar, H. Simons, Eds. Ecosystems and human well-being: policy responses, volume 3 [on-line]. Island Press, Washington, DC. <http://www.maweb.org/documents/document.776.aspx.pdf>. Accessed 11 April 2012.

McCarthy, J.J.; Canziani, O.F.; Leary, N.A.; Dokken, D.J.; White, K.S., Eds. 2001. Climate change 2001: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK.

Metzger, M.J.; Rounsevell, M.D.A.; Van den Heiligenberg, H.A.R.M.; Pérez-Soba, M.; Hardiman, P.S. 2010. How personal judgment influences scenario development: an example for future rural development in Europe. Ecol. Soc. 15(2):5.

Nakićenović, N.; Alcamo, J.; Davis, G.; de Vries, B.; Fenhann, J.; Gaffin, S.; Gregory, K.; Grübler, A.; Jung, T.Y.; Kram, T.; La Rovere, E.L.; Michaelis, L.; Mori, S.; Morita, T.; Pepper, W.; Pitcher, H.; Price, L.; Raihi, K.; Roehrl, A.; Rogner, H.-H.; Sankovski, A.; Schlesinger, M.; Shukla, P.; Smith, S.; Swart, R.; van Rooijen, S.; Victor, N.; Dadi, Z. 2000. Special report on emissions scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK, and New York, NY. 599 p.

Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; van der Linden, P.J.; Hanson, C.E., Eds. 2007. Appendix I: Glossary. *In* Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK, and New York, NY.

For other CCFM Climate Change Task Force reports contact:

Canadian Council of Forest Ministers
c/o Canadian Forest Service
Natural Resources Canada
580 Booth Street
Ottawa, Ontario
K1A 0E6

www.ccfm.org